NATIONAL SEMINAR

ON

DEVELOPMENTS IN SOIL SCIENCE – 2016

# ABSTRACTS

81st Annual Convention
Indian Society of Soil Science
20-23 October 2016

# 81st ANNUAL CONVENTION

**October 20-23, 2016**
**held at the**
**R.V.S.K.V.V., Gwalior**

# Abstracts


## Indian Society of Soil Science

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ABSTRACTS: NATIONAL SEMINAR ON DEVELOPMENTS IN SOIL SCIENCE – 2016

May 2017



*Edited by*
D.R. Biswas
K.K. Bandyopadhyay



*Published on behalf of the Indian Society of Soil Science by:*

**Dr D.R. Biswas**
Secretary, Indian Society of Soil Science
Ist Floor, National Societies Block
National Agricultural Science Centre Complex
Dev Prakash Sastri Marg, Pusa, New Delhi -110 012
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**A.K. Mandal, Ranbir Singh, P.K. Joshi and D.K. Sharma**
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Waterlogged salt affected soils in Hisar district were characterized and mapped based on the image interpretation, soil profile studies and laboratory characterization of soil samples. IRS LISS III (March and October 2009-10) imageries showed prominent water absorption and higher spectral reflectance from salty surface. Ground truth and soil profile studies revealed waterlogging and soil salinization in the canal irrigated areas, showing no or imperfect internal soil drainage. Four representative soil profiles (Pedon) were characterized to suggest suitable reclamation and management options. The pedon 1 is a moderately saline soil showing high ECe (9.8 to 16.9 dS $m^{-1}$) and the dominance of $Cl^-$, $SO_4^{2-}$, $Na^+$, $Ca^{2+}$ and $Mg^{2+}$ ions. The water table depth (1.5 m) was high. The higher contents of $CaCO_3$ (0.4 to 8.96%) at sub-surface layers and sandy clay loam texture showed increasing stratification with depth. Pedon 2 was a saline-alkaline soil (pHs 8.1 to 9.2 and ECe 2.4 to 12.7 dS $m^{-1}$) and salt composition indicated the dominance of $Ca^{2+}$, $Mg^{2+}$ and $SO_4^{2-}$. Higher silt and clay contents at sub-surface depths indicated impermeable strata and caused high water tabled depth (1.5m). Pedon 3 is a moderately sodic calcareous soil showing high pHs 8.8 to 9.2 and significant contents of calcium carbonate (0.4 to 24.0%). The increasing clay contents at lower depths (sandy loam to sandy clay loam) favored waterlogging. Pedon 4 is a complex sodic soil with high pHs (8.7 to 10.1), high sodium content and high salt content (ECe 7.2 to 25.7 dS $m^{-1}$) showing chloride and sulfate dominated salts. P1 and P2 require interventions with sub-surface drainage, P3 and P4 needs treatment by gypsum with appropriate dosage. About 23% of the total area is affected by waterlogging and soil salinity / alkalinity

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# Fertility Maps of Bidanagere Micro-watershed, Tumkur District, Karnataka using Interpolation Techniques in GIS Platform

**T.C. Chikramappa, Prabhudev Dhumgond, Y. Shruti, H.M. Vinod Kumar and V.R. Ramakrishna Parama**

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A study was conducted in Bidanagere micro-watershed (77°4'47.99'' to 77°6'35.94" E longitude and 13°8'45.6" to 13°10'40.8" North latitude) Tumkur district, Karnataka to prepare soil fertility maps using geospatial techniques. The cadastral map indicating parcel boundaries served as the base map. A grid of 250 $m^2$ spacing was overlaid on the cadastral map for the study. 103 grids in the microwatershed covering an area of 649 ha from which soil samples were collected. The soil samples were processed and analysed for various soil chemical properties using standard procedures. The pH of the soil ranged from 6.0 to 7.35, Electrical conductivity was normal and organic carbon ranged from 0.24 to 0.72 per cent. The status of N (230.0 to 404.5 kg $ha^{-1}$) and K (124.0 to 383.4 kg $ha^{-1}$) was medium. While, P content was low (11.45 to 22.21 kg $ha^{-1}$). The content of S was medium to high (12.75 to 30.25 ppm) in majority of the area. The soils were sufficient in Ca, Mg , Fe, Mn and Cu content, Zn was deficient in majority of soils. The fertility maps indicating soil reaction, salinity, organic carbon, major, secondary and micronutrient content were prepared using Kriging technique in ArcGIS platform. The maps indicated the fertility status of microwatershed. Based on which fertilizer recommendation for crops are made leading to economy of fertilizer and balanced application.

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# Mapping Extent and Type of Degraded Lands in a Part of IGP using MODIS NDVI Time Series Data

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Assessment of extent and type of degraded lands is very important to improve land productivity for sustained growth, as the room for extensive expansion has almost disappeared in Indian agriculture. Various approaches employing remote sensing have been made to estimate degraded lands in the country and elsewhere: visual interpretation and supervised or unsupervised classifications of moderate resolution satellite data of one or more seasons and proxy assessment of degradation by time series NDVI data of low resolution sensors. The area under degradation and their types varied widely depending on method employed for study. The present study attempts the proxy approach using 12-years MODIS NDVI time series (250 m) data for identification of degraded lands and their types in a part of Indo-Gangetic Plains (IGP).

The degraded lands were identified based on the hypothesis that these constantly have lower biomass productivity reflected in terms of constant lower NDVI. The area has mainly gullied, eroded and salt affected soils as major types of degraded lands. These were separated with the help of Digital Elevation Model (DEM), Landsat, and legacy data. The results were compared with the land degradation datasets on 1:50,000 scale provided by National Remote Sensing Centre (NRSC), Hyderabad, based on visual interpretation and on-screen digitization of 3 season IRS LISS-III data (23.5 m). The MODIS time series NDVI data supported by DEM and legacy data proved sufficient for identifying extent and types of degraded lands. The results were in good agreement with data on land degradation provided by NRSC. The approach is found to be a reliable tool for quick identification and mapping of degraded lands.

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# Genesis, Classification and Evaluation of Some Sugarcane-growing Black Soils in Semi Arid Tropical Region of Telangana

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The morphological, physical and physicochemical characteristics of some sugarcane growing black soils of Medak district of Telangana State have been studied for proper appraisal of their productivity potential and their rational use. The soils were formed at nearly level and plain topography on granitic gneiss parent material mixed with calcareous murram. The soils are deep to very deep. The textural class of fine earth fraction was clay loam and clayey and had angular blocky structure. The colour varied from very dark grayish brown (10 YR3/2) to dark yellowish brown (10YR 4/4) under dry condition. The clay content ranged from 38.7 to 71.4 per cent in surface and 37.2 to 76.2 per cent in subsurface horizons. The silt clay ratio was found to be less than 0.5 indicating the moderate weathering. The soil pH was neutral to strongly alkaline in range (6.5 to 9.2) and non saline in nature. The organic carbon content was medium to high (4.3 to 8.4 g $kg^{-1}$) in surface horizons. The soils are moderately calcareous with $CaCO_3$ ranges from 1.3 to 7.8 per cent with high in cation exchange capacity. The exchangeable bases were in the order of $Ca^{+2} > Mg^{+2} > Na^{+} > K^{+}$ on the exchange complex. The CEC/clay ratios of black soils were high (0.58 to 0.86) which indicates the presence of smectitic type of clay minerals. The soils have been classified as Typic Haplusterts and Vertic Haplustepts based on the morphological, physical, physico-chemical, and chemical properties. The black soils of sugarcane cane growing area fall under land capability sub class 'III swef' with limitations of drainage, texture, erosion and soil fertility. The soils were moderately suitable to highly suitable for cultivation of sugarcane.

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# Pedogenic Characterization and Land Use Planning of Krishi Vigyan Kendra Farm, (Fatehabad), Haryana

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A detailed soil survey of Krishi Vigyan Kendra farm (Fatehabad) was carried out which is situated at about 7 km from Fatehabad bus stand and lies between 29°31.004′ to 29°31.998′ N latitude and 75°29.37′ to 75°29.49′ E longitude. It extends over an area of 24 acres and 7 canals which is accessible by road. Geologically, the area constitutes part ofIndo- gangatic alluvial plains and belongs to the Pleistocene age. The physiographic units found in the study area are old and recent flood plains of Ghaggar river. The area has a plain topography and gentle slopes with existence of micro-relief variation. The climate of the area is semi arid and monsoonal type. The average annual rainfall is around 350 mm, about seventy percent of which is received during July to September.

The objective of the study was to characterize the soils of research farm and classify them as per Soil Taxonomy and group them according to their capability classes for optimum micro level planning. For this, entire area of the farm was traversed on foot and with the help of post-hole auger, the soils were examined at an interval of 100-150 meters depending upon the variation in the soils. Two profiles were exposed, one in each physiographic unit having similar soil, to study detailed morphological characteristics. Soil samples from different horizons of the profiles and surface samples from fields were also collected for their physico-chemical analysis in the laboratory as per the standard procedures. The pH and EC ranged from 7.34-8.20 and 0.07-0.21 dS $m^{-1}$. The organic carbon in the farm soil was found low to medium (0.24-0.45%). The available nitrogen and potassium was found low (104-236 kg $ha^{-1}$) and (72-186 kg $ha^{-1}$), respectively whereas phosphorus was found low to medium ( 6.54-12.24 kg $ha^{-1}$) in the study area. Among the micronutrients none of the samples falls under deficient category for Zn, Fe, Mn and Cu micronutrients. The soils were classified as: Fine loamy, mixed, hyperthermic, Typic/Natric Haplustepts. The soils of the farm were good cultivable land and hence they were placed in land capability classification as class IIs. These soils have less limitation for sustained use under irrigation thus is placed in class A. The soil suitability classification is determined by matching the soil characteristics and land use requirements of different crops. It was found that these soils were moderately suitable for wheat, cotton mustard, berseem, sorghum and forestry plantation and marginally suitable for bajra and horticultural plantation..

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# Effect of Long-term Zero Tillage in Wheat on Physical Properties of Soils under Rice-Wheat Cropping System

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The rice–wheat cropping system is one of the most prevalent cropping systems in the Indo-Gangetic Plains of India. Intensive cultivation resulted in slowdown in productivity of rice-wheat crops due to deterioration of the soil physical conditions. Keeping in view the importance of the system for food security of the country, experiments were carried out at farmers' field during 2015-16 to investigate the effect of zero tillage on physical properties of texturally different soils under rice-wheat cropping system of Haryana State. The long-term zero tillage (ZT) resulted in decrease in bulk density at 15-30 cm soil depth as compared to conventional tillage (CT). The adoption of ZT increased saturated hydraulic conductivity and soil organic carbon (SOC) content over the conventional tillage. The continuous zero tillage for 20 years in wheat resulted in increase in SOC stock in 0-30 cm soil depth by 35.2, 27.6 and 17.6 per cent in sandy loam, loam and clay loam soils, respectively. The results revealed that ZT had potential to reduce soil penetration resistance of sub-surface soil as compared to the CT practice. The zero tillage significantly increased aeration porosity of surface soil layer. The higher values of soil moisture at field capacity in zero tillage indicated a higher volume of medium-sized water-holding pores due to favourable conditions for enhanced aggregate formation. The effect was, however, more pronounced in clay loam followed by loam and sandy loam soils. The ZT resulted in higher least limiting water range in 0-15 cm and 15-30 cm soil depths in sandy loam, loam and clay loam soils. The practice of long-term zero tillage was found effective in increasing yield of wheat in fine textured soils as compared to coarse textured.

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# Effect of Tillage, Crop Residue Mulching and Nitrogen Management on Soil Physical Health, Soil Organic Carbon Pools, Productivity and Input Use Efficiency of Maize in an Inceptisol

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A field experiment was conducted on a Typic Haplustept at the Indian Agricultural Research Institute, New Delhi during *kharif* seasons of 2014 and 2015 in a split-split plot design with two levels of tillage viz., conventional tillage (CT) and no tillage (NT)), under two levels of mulching (with or without wheat straw mulch @ 5 t $ha^{-1}$) and three nitrogen (N) doses (75, 150 and 225 kg N $ha^{-1}$, which represent 50, 100 and 150% of the recommended dose of N, respectively) to study the effect of tillage, crop residue mulching and N interactions on soil physical health, soil organic carbon pools, yield and water and N use efficiency of maize crop (cv HQPM1) in maize-wheat system. It was observed that there was significant increase in the soil moisture storage due to application of crop residue mulch. There was increase in bulk density (3%) and decrease in the total porosity (5.3%) and air filled porosity (18.5%) under NT than that of CT in the surface 0-15 cm soil layer. However, there was decrease in BD (2.2%) and increase in total porosity (3.8%) and air filled porosity (10.4%) due to crop residue mulch than that of no-mulch treatment in the surface layer. The mean weight diameter and percentage of water stable aggregates under NT and crop residue mulching was higher than that of CT and no-mulch treatment at 0-5, 5-15 and 15-30 cm soil depth. Similarly there was improvement in the carbon management index under NT and crop residue mulching than that of CT and no-mulch treatment at 0-5, 5-15 and 15-30 cm soil depth. The pooled grain yield of maize under conventional tillage was statistically at par with no-tillage though there was reduction in grain yield of maize under NT than that of CT. Application of wheat residue mulch @ 5 t $ha^{-1}$ significantly increased the grain yield of maize by 15.3 per cent than that of no-mulch treatment. Application of 225 kg N $ha^{-1}$ significantly increased the grain yield of maize by 24.4 and 81.8 per cent than that of 150 and 75 kg N $ha^{-1}$, respectively. Similarly application of 150 kg N $ha^{-1}$ significantly increased the grain yield of maize by 46.2 per cent than that of 75 kg N $ha^{-1}$. The water use efficiency (WUE) of maize was not influenced significantly due to tillage practices but crop residue mulching significantly improved the pooled WUE of maize by 27.6 per cent than no-mulch treatment. Application of 150 and 225 kg N $ha^{-1}$ significantly increased the WUE of maize by 51.8 and 71.5 per cent than that of 75 kg N $ha^{-1}$ but there was no significant difference between 150 and 225 kg N $ha^{-1}$ with respect to WUE of maize. The partial factor productivity of N (PFPN) under CT was statistically at par with that of NT. Application of crop residue mulch significantly increased the PFPN by 15.2 per cent than that of no-mulch treatment. The PFPN of maize with 150 and 225 kg N $ha^{-1}$ decreased significantly 36.8 and 65.1% than that of 75 kg N $ha^{-1}$. Thus from this study it may be concluded that maize may be grown under no-tillage with wheat straw mulch @ 5 t $ha^{-1}$ and 150 kg N $ha^{-1}$ to attain better soil physical health, soil organic carbon pools and achieve higher water and N use efficiency without any significant reduction in crop yield than that of conventional tillage in Inceptisols of Delhi region.

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# Soil Physical Properties as Influenced by Various Tillage Practices

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Tillage systems influence physical, chemical, and biological properties of soil and have a major impact on soil productivity and sustainability. Zero tillage aims to conserve soil moisture and reduce soil erosion by leaving more than one-third of the soil surface covered by crop residues and becoming popular amongst farmers of Haryana for wheat in rice-wheat cropping system. Studies conducted under a wide range of climatic conditions, soil types, and crop rotation systems have shown that no-tillage and reduced tillage have significantly influence of soil physical properties as compared to conventionally tilled soils. Keeping these views in mind, an experiment was conducted to study the effect of various tillage practices on physicochemical properties and yield of wheat in sandy loam soil of semi-arid region. Soil core samples at harvest of wheat were taken for 0-5, 5-10, 10-15, 15-20, 20-25 and 25-30 cm depth for estimation of various physical properties from an ongoing experiment on "Phosphorus management in wheat under different tillage practices in sequence with sorghum" initiated in 2011 at Soil Research Farm, CCS HAU, Hisar. The experiment was laid out in a split plot design with four replications. Three tillage treatments in main plots [(Zero tillage-ZT; conventional tillage-CT (two cultivator + two tractor drawn harrowing followed by planking); and minimum tillage-MT (one cultivator + one tractor drawn harrowing followed by planking)] and four P treatments in sub-plots (0, 45, 60 and 75 kg $ha^{-1}$) applied in wheat. On these plots, sorghum was raised for fodder in *kharif* as per other package of practices. The results revealed that mean weight diameter of soil aggregates in 0-5 cm soil depth under ZT, MT and CT practices was significantly higher under ZT as compared to MT and CT. Amongst all the tillage systems, bulk density increased with depth. Highest value of 1.65 Mg $m^{-3}$ was observed for soil depth below 25 cm. Lowest bulk density value was observed in the surface layer under ZT which was significantly lower than MT (1.57 Mg $m^{-3}$) and CT (1.58 Mg $m^{-3}$). The Hydraulic conductivity (Ks) value was highest in the surface layer and then decreased with depth under all tillage treatments. The Ks value in the surface 5 cm depth was significantly better under ZT as compared to other practices. The moisture content values at field capacity for different soil depths under ZT, MT and CT showed significantly higher moisture content (16.6%) under ZT as compared to MT (16.1%) and CT (16.0%) in surface 5 cm soil depth. At lower depths, the values though increased with depth but there were no significant differences under different tillage practices. The values of moisture content at permanent wilting point for different soil depths under ZT, MT and CT revealed that tillage practices did not influence the moisture content at permanent wilting point (PWP). The data on infiltration rate of water in ZT, MT and CT systems showed that under CT and MT practices, water intake rate was almost similar *i.e.* 3.73 and 3.75 cm $h^{-1}$, respectively, which were significantly lower than the value of infiltration under ZT (3.83 cm $h^{-1}$) practice. The short term zero tillage practice in wheat under sorghum-wheat cropping system thus increased the infiltration rate by only about 3 per cent over CT practice. It was concluded that after three years of tillage treatments, almost no improvement in soil physical properties was observed under ZT and MT as compared to CT.

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# Soil Physical Properties and Soil Organic Carbon as Influenced by Cropping Systems in Vertisols

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Cropping systems imply a specific pattern of crop succession, component crops, and frequency with which all these interact and influence soil system favourably. Cropping systems are thought to alter the soil physical, chemical and biological parameters. Therefore, a better understanding of the impact of continuous cropping systems on soil properties is essential for the quantification of soil quality impacts and thereby enhancing the cropping system sustainability. Thus, present investigation was conducted to characterize the effects different cropping systems and nitrogen levels on soil physical properties and organic carbon (SOC) of vertisol of central India. Soil samples were collected after 5 year of experimentation from two cropping systems *viz* maize-wheat, and maize-chickpea and four nutrient managements *viz.,* N 150% (N1), N 100% (N2), N 50% (N3), N 0% (N4). We hypothesized that cropping systems with different nutrient management may improve the soil physical attributes and SOC under the vertisol and can be better options towards sustainable agriculture. Results showed slight improvement in soil physical environment for maize–wheat cropping systems compared to maize-chickpea systems under all the nitrogen levels. This was translated in decreased bulk density and soil strength, increased soil organic carbon and total porosity, and higher aggregate stability and macro-aggregate distribution and associated carbon especially at surface soil. It is evident that cropping and soil nutrient management that accumulate higher plant residues can improve soil physical environment.

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# Quantifying Impact of Soil Impedance on Root System Architecture of Wheat

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Compaction of agricultural soils is an increasingly challenging worldwide problem for crop production and environment and an important issue in the field of soil management. Soil compaction may restrict deep root growth and adversely affect plant access to sub-soil layer. Therefore, it is important to study rooting behaviour of crops to soil compaction that are imparted on it naturally or artificially. Thus, the present investigation was taken up to determine the effect of soil compaction levels by varying the soil bulk density (BD) on root system architecture to understand the dynamics of rooting behaviour of two cultivars *viz.,* Sujata and Malwa shakti of wheat. Compaction level treatments, *i.e.* BDs were (i) 1.2, (ii) 1.4, (iii) 1.5 and (iv) 1.6 Mg $m^{-3}$.The root systems of wheat cvs Sujata and Malwa Shakti showed a great response to soil compaction levels. There was significant difference in the root architecture of both the cultivars with increase in BD from 1.2 Mg $m^{-3}$ to 1.6 Mg $m^{-3}$. Between the two cultivras of wheat, the main axis length was greater in Malwa Shakti than Sujata at 1.2 and 1.4 Mg $m^{-3}$, whereas, there was not much differences in main axis length at 1.5 and 1.6 Mg $m^{-3}$ BD levels. However, the main axis length of the both the cultivars decreased significantly with increase in soil compaction levels. Increased in BD, decreased the number of primary axis significantly in both the cultivars and higher number of primary roots were observed in Malwa Shakti than Sujata. On an average, there was 30 and 36 per cent reduction in number of primary root in Malwa Shakti and Sujata with increase in BD from 1.2 Mg $m^{-3}$ to 1.6 Mg $m^{-3}$, respectively. At the same increment in BD reduced the number of nodes by 35 and 36 per cent in Malwa Shakti and Sujata, respectively.

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# Residue Mulch Effects on Soil Hydrothermal Conditions of Bt Cotton under Irrigation and Nitrogen Regimes

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In north-western India, large-scale adoption of rice based cropping system resulted in over-use of ground water. Depleting water and increasing fertilizer N cost necessitate efficient use of resources and demands a major shift from high water to low water requirement crops and Bt cotton has emerged as a viable option to save water and energy. Bt cotton is sown immediately after wheat harvest with wide row-and plant-spacing, experiences high temperature during early part of growing season leads to high rate of evaporation losses and demands frequent irrigations. Mulching with crop residues provides favourable soil hydrothermal conditions that may enhance yield and economize irrigation and n use. This study examined the combined effects of crop residue mulch, irrigation and N regimes on soil hydrothermal regimes of Bt cotton in sandy loam soil in a sub tropical environment of north-west India. The treatments included combination of three irrigation regimes-IW: CPE ration of 0.2, 0.3 and 0.4 and two crop residue mulch rates (0 and 6 t $ha^{-1}$ ) in main plots and four nitrogen rates (0.50, 100 and 150 kg $ha^{-1}$) in subplots. Bt cotton crop was sown in the first week of May with recommended doses of $P_2O_5$and $K_2O$. Residue mulching affects hydrothermal regime of soils by moderating soil temperature and reducing soil water evaporation. The mulched plots retained higher moisture content in the soil profile, which ranged from 0.5 to 1.7%, 0.2 to 3.5% and 0.2 to 1.2% at 35, 80 and 110 day after sowing (DAS), respectively over no-mulch treatment. However, there was no such significant different in moisture content at harvest. In general, soil moisture content increased with increasing soil depth. At 35 DAS depth wise volumetric soil moisture content was higher in $I_{0.3}$ followed by $I_{0.4}$ and $I_{0.2}$ irrigation regimes across the mulch and nitrogen regimes. At later stages, there was no consistent effect of irrigation regimes on moisture content, which appears due to the sufficient rainfall and reduction in evaporation due to crop canopy cover in advance stage of crop growth. Minimum soil temperature recorded ranged from 24.7 to 31.$^0$C in mulched plots and 24.3 to 33.5 °C in no mulch plots. Maximum soil temperature recorded ranged from 30.4 to 36 $^o$C in mulched plots and 32.5 to 48.5 $^o$C in no mulch plots. Crop residue mulch lowered down the maximum and minimum soil temperature at 5cm depth by 2.1 to 12.5 $^o$C , respectively. This study has shown that residue mulching modify moisture and thermal regimes in soil and provide favorable conditions for the crop growth.

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# Effects of Organic Nutrient Sources on Soil Organic Carbon, Water Stable Aggregates and Microbial Attributes in Rice-Potato-Lady's Finger Cropping System under an Irrigated Ecosystem

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A field experiment on organic nutrient management in rice-potato-lady's finger cropping system was initiated during 2006-07 at Bhubaneswar, Odisha under irrigated conditions in a sandy loam soil with 6.2 g $kg^{-1}$ organic carbon contents. Eight treatments comprising of five organic, two integrated and one inorganic approach of nutrient management were tested in randomized block design (RBD) with three replications. These treatments were 100% NPK (NPK), 50% recommended NPK through mineral fertilizers+50% N as FYM (NPK+FYM), FYM+vermicompost (VC)+neem cake (NC) each equivalent to 1/3rdof recommended N (FYM+VC+NC), 50% N as FYM + biofertilizer for N + bone meal to substitute phosphorus requirement of crops + phosphate solublizing bacteria (FYM+BFN+BM+PSB), FYM + vermicompost +neem cake each equivalent to 1/3rd of recommended N+PSB (FYM+VC+NC+PSB). Soil attributes such as organic carbon (OC), bulk density (BD), water stable aggregate (WSA), microbial biomass carbon (MBC), soil basal respiration and microbial population were estimated after 9th cropping cycle. The organic treatments increased the OC (+36.1 to 44.3%), macro-aggregates (+19.3 to 31.6%), MBC (+69.8 to 92.2%), basal respiration (+ 19.7 to 30.3%), bacteria (+20.1 to 28.7%), fungi (+21.1 to 33.9%) and actinomycetes (+26.1 to 37.4%) over the inorganic treatment after 9th cropping cycle. Soils treated with organic sources also exhibited lower BD (-2.0 to 4.8%), micro-aggregate (-12.7 to 18.0%) and $qCO_2$ (-29.3 to -32.9%) as compared to soils applied with inorganic fertilizers only. The elevated SOC contributed significantly in enriching macro-aggregates (r = 0.93**), MBC (r = 0.92**), basal respiration (r = 0.91**), bacteria (r = 0.90**), fungi (r = 0.76**) and actinomycetes (r = 0.89**).

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# Studies on Physicochemical Properties of Rubber Soils of North-East India with Special Reference to Potassium Fixation

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Potassium (K) fixation capacity under rubber growing soils of north-east India, namely Assam, Meghalaya and Tripura were carried out and their relationship with various soil properties was evaluated. Altogether 328 composite soil samples at the depths of 0-30 and 30-60 cm were collected from mature rubber plantation (10-30 years). They were analyzed for various soil properties. Analysis of data revealed that rubber soils were acidic in reaction with soil pH ranging from 4.02-5.87 in surface soil and 4.07-5.68 in sub-surface soil. Organic carbon varied from 3.3-25.7 g $kg^{-1}$ in surface soil and 2.1-17.8 g $kg^{-1}$ in sub-surface soil. Ninety-five per cent of theses soils showed low values for available phosphorus (P). Available K ranged from 91.8-533.1 kg $ha^{-1}$ in surface soil and 62.7-526.4 kg $ha^{-1}$ in sub-surface soil and 44, 28 and 10-percent of these soils from Tripura, Assam and Meghalaya showed low K-fertility status. Majority of these soils were sandy loam to sandy clay loam in texture; however relative proportion of finer fractions of soil were high under rubber soils of Meghalaya. Bulk density (BD) of surface soils varied from 1.28-1.48 Mg $m^{-3}$ and lower BD under rubber soils of Meghalaya soils could be due to its higher content of OM. Higher exchange acidity (2.13 cmol($p^+$)$kg^{-1}$) was recorded under rubber soils of Meghalaya indicating presence of higher proportion of exchangeable Al and Fe which could fix a substantial amount of P. Mean K-fixation capacity of the said three state locations ranged from 28.7-51.34% with higher fixation was observed for Meghalaya soil. It was observed that rubber soils accumulated higher proportion of sand in the surface layer. Significant negative correlation was between K-fixation capacity of soils and sand in all the three state locations whereas both clay and silt showed positive and significant relationship with K-fixation. The result indicates that a major amount of added K to these soils will be leached our or percolated down the profile.

81st Annual Convention: October 20-23, 2016
National Seminar on Developments in Soil Science: 2016

# Agroforestry Impacts on Soil Organic Carbon and Aggregate Stability in Different Textured Soils in Shiwalik Regions of Northwest India

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Land use changes have resulted in severe soil erosion, soil organic carbon (SOC) losses, lowered soil aggregate stability and deteriorated the soil physical environment in rainfed region of Shiwalik Himalaya. Aggregates resulting from physicochemical and biological interaction in soil ecosystem can physically protect the organic carbon in inter-aggregates from decomposers. Organic carbon budget in a soil is a function of carbon input as plant litter ever year and soil texture also plays a crucial role in SOC storage. The study was conducted in a mixed watershed situated in the foothills of Himalayas comprising of three different textures *viz*. loamy sand, sandy loam and clay loam under two cropping systems maize-wheat and agro-forestry. The bulk soil samples and natural undisturbed soil aggregates were collected from three sites for each texture and two cropping systems. The size of large macro-aggregates is greater than 2 mm, small macro-aggregates from 2-0.25 mm and micro-aggregates less than 0.25 mm. The mean SOC content was significantly higher (0.69%) in fine textured soils followed by medium (0.63%) and was lowest (0.42%) in coarse textured soils. In sub-surface layer (15-30 cm) the SOC concentration decreased by 61.3 per cent with change in soil texture from coarse to fine in soil under maize-wheat and in soils under agro-forestry, the SOC content decreased by 26.9 per cent. The coarse textured soils under maize-wheat had stored lower SOC (14.5 Mg $ha^{-1}$) compared to 23.3 Mg $ha^{-1}$ in soils under agro-forestry system. The medium and fine textured soils under maize-wheat stored higher SOC than the coarse textured soils. The mean macro-aggregates were highest (64%) in coarse textured soils and decreased by 10.6 and 39 per cent in medium and fine textured soils, respectively. The cropping system and soil texture interacted significantly to affect water stable aggregates (WSA) > 0.25 mm. The macro-aggregates were 48.1 percent higher in agro-forestry than in soils under maize-wheat with coarse texture. However, in medium textured soils, the soils under agro-forestry had 45.7 per cent lower aggregates than under maize-wheat, whereas in fine textured soils, these were statistically similar. In sub-surface soils, the mean WSA > 0.25 mm were highest in coarse textured soils and decreased by 30.5 and 37.6 per cent in medium and fine textured soils, respectively. The mean stability index (SI) was highest (0.186 J $kg^{-1}$) in fine textured soils followed by medium (0.139 J $kg^{-1}$) textured soils and was lowest in coarse textured soils (0.115 J $kg^{-1}$). The SI decreased by 25.3 per cent and 38.2 per cent in medium and coarse textured soils from that in fine textured soils. The soils under agroforestry system with fine texture had higher SOC sequestration capacity and aggregate stability.

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# Water Balance and Water Use Efficiency in Wheat (*Triticum aestivum* L.) as Influenced by Management Interventions: Field and Simulation Study

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A field experiment on the effect of three sowing dates, two cultivars and two irrigation regimes in wheat was conducted during 2014–15 at Punjab Agricultural University, Ludhiana. This study focuses on (i) computing water balance components and wheat yield under different management interventions under field conditions and (ii) simulating water balance components for different soil series in Ludhiana district employing past meteorological data. Field results showed that the yield of November 5 ($D_2$) sown wheat was higher than sown at October 20 ($D_1$) and November 20 ($D_3$). Mean potential yield of PBW 550 was more (9%) than that of PBW 621. Averaged over the cultivar and irrigation regime, ET was 85 mm more in $D_1$ than $D_2$ and $D_3$ but the drainage was more in $D_3$ compared to $D_1$ and $D_2$. Water balance components in both cultivars were comparable except drainage, which was higher in PBW 550 due to its shorter crop period. WUE in $D_2$ was more by 40 and 61 per cent than $D_1$ and $D_3$, respectively. Simulation with CERES–Wheat model point out that grain yield, biomass accumulation and ET under different dates of sowing, cultivars and irrigation regimes had trends similar to measured responses, though there were differences in their magnitude. The wheat grain yield, transpiration and ET increased with fineness of soil texture. Similar to the observed results, the yield was higher in $D_2$ followed by $D_1$ and $D_3$ during 1983–2013. Wheat yield was 22 per cent higher in loam soils than loamy sand. ET was 32 per cent higher in loam than loamy sand soils. Though yield and ET were higher in finer textured soil but WUE was higher in coarse textured soils than fine textured soils. However, the drainage decreased with fineness of soil texture. It was 33 per cent less in loam soils than loamy sand soils.

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# Influence of Irrigation Water Quality and Mulching on Fruit Yield and Soil Properties in Okra

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A field experiment was conducted for 6 years from 2010-2015 at Punjab Agricultural University Regional Research Station, Bathinda to study the effect of quality of irrigation water and mulching on fruit yield and soil properties of okra (*Abelmoschus esculentus*) in light textured soil prevalent in semi arid conditions of Punjab. The experiment was conducted with nine treatments consisting of three qualities of irrigation *viz*. canal water alone (CW), poor quality tubewell water alone (TW) and cyclic use of CW and TW (CW/TW) under three mulch conditions *viz.*, no mulch ($M_0$), rice straw mulch @ 6 t $ha^{-1}$ ($M_1$) and plastic mulch, black 50 *micron* ($M_2$). The experimental soil is alkaline in reaction, low in organic carbon, medium in available phosphorus and high in available potassium. The residual sodium carbonate and electrical conductivity of the tubewell water (categorized as saline-sodic) was 6.4 meq $L^{-1}$ and 2200 µmhos $cm^{-1}$, respectively. The corresponding values for canal water were 0.5 meq $L^{-1}$ and 450 µmhos $cm^{-1}$, respectively. The pooled research data of 5 years revealed that alternating the application of tubewell water (saline sodic) with canal water significantly enhanced the green okra yield to the tune of 47.0 per cent than only tube well water application. Alternate use of CW and TW under straw mulch and plastic mulch increased the green okra yield by 14.1 and 19.5 per cent over no mulch. Mulching resulted in significantly higher green okra yield than non mulching conditions, irrespective of type of mulch. The application of straw and polythene mulch improved the green fruit yield by 14.8 and 21.2 per cent respectively, over no mulch regardless of quality of water. However, polythene mulch proved to be superior over straw mulch by 5.5 per cent. Mulch application decreases pH and ESP of the surface layer of the soil under TW and CW/TW treatments. Organic carbon status of the soil improved with the application of straw mulch. The water expense efficiency was higher under straw and plastic mulch application than without mulch. Cyclic use of saline sodic water and canal water with or without mulch is recommended to obtain higher green okra yield and to maintain soil health.

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# Effect of Tillage and Residue Retention Practice on Soil Temperature and Wheat Yields

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Conservation tillage plays an important role in sustaining the productivity of rice wheat cropping system. Residue retention on soil surface and minimum/zero tillage are the agronomic practices which modify soil moisture and thermal regimes and thus affect crop growth and yield. In a field study conducted at research farm of Department of Soil Science, Punjab Agricultural University, Ludhiana during *rabi* 2014-15; the effect of tillage and residue retention practices on soil temperature and performance of wheat was evaluated in a sandy loam soil; with four treatments i.e. combinations of conventional (CT) and zero tillage (ZT), with and without rice straw mulch (RSM). The site is located in the Indo-Gangetic alluvial tract at 30°56′ N 75°52′E and at an altitude of 274 m above mean sea level. During the crop growth period, weekly mean soil temperatures at 5 cm depth for CT, ZT, CT+RSM and ZT+RSM treatments respectively, ranged from 10.2-27.4, 10.0-27.1, 10.7-26.1 and 10.7-26.7 °C for morning hours and from 12.9-36.9, 13.1-36.7, 12.7- 30.6 and 12.7- 30.8 °C for afternoon hours. In morning hours, mulch increased the soil temperature from sowing to week 11 and the effect was reversed at week 12 till maturity of the crop. However, for afternoon hours, mulch lowered the soil temperature throughout the growing season and the decrease was comparatively higher during week 12 to 17. For vegetative (26-88 DAS), reproductive (89-123 DAS) and maturity (124-166 DAS) stage of wheat; there was cooling due to rice straw mulch, irrespective of soil depth and tillage, for afternoon hours. However, for morning hours the soil temperatures were lower under no mulch conditions, for vegetative and reproductive growth stage of wheat. Similarly, soil temperatures under ZT were slightly higher than CT, with few exceptions, for surface layer in vegetative and reproductive growth stages only. Surface temperatures were in general higher than subsurface, with exceptions for vegetative and reproductive growth stage of wheat, when subsurface was warmer instead; under no mulch conditions in morning hours. Plant height, ear length, grains per ear and thousand grain weight did not vary significantly, but effective tillers were significantly higher in CT (6.2%) than ZT and in mulch (3.4%) than no mulch. The grain yield (t $ha^{-1}$) under CT was 14.2 per cent higher than under ZT and it was 8.9 per cent higher with rice straw mulch than without rice straw mulch. Rice straw mulch improved soil temperature and wheat yield, under both conventional and zero tillage.

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# Soil Clay-to-Carbon Saturation: A Useful Indicator for Strength and Structural Stability of Soil

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There are a few 'functional' soil structure indices proposed to link soil structure to various soil interface processes. These indices could define the thresholds where soil structure is either improved, maintained (structure resilience) or destroyed. We tested the 'soil clay-to-saturation' concept as a measure of soil strength and structural stability under two long-term experiments. The manifestation of the effect of soil organic matter was scale-dependant, and different at micro (soil aggregate) and macro (bulk soil) levels. Small changes in SOC is reflected at bulk soil through deformation characteristics, but is not recorded at aggregate level. Soil friability, an important soil parameter, is not linearly related to SOC increase, but reaches to a level of saturation. Soil strength and friability was different in long-term experiments and although higher soil organic carbon content is proven beneficial, the effect largely varies over kind of organic inputs and the tillage practices. Clay/OC ratio could be a useful index, and is closely linked to clay dispersibility. Further studies should identify a critical threshold level of organic C essential to maintain soil functional structure; and a fraction rather than the total organic C, should be responsible for improving the soil physical environment.

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# Detection of Some Soil Properties Using Hyperspectral Remote Sensing of Semi Arid Region of Tamil Nadu

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Remote sensing with hyperspectral sensors can provide the fine resolution required for site specific farming. The spatial distribution of some soil properties was found by using multiple linear regressions to select the best combinations of wave bands, taken from a full set of 512 narrow bands in the wavelength range of 350 to 1050 nm. The resulting regression equations made it possible to calculate the value of the soil property with a spatial resolution of 3.0 nm FWHM (Full Width Half Maximum). Both surface and subsurface samples of soil profile were taken from the three research stations. The soil samples were tested in a laboratory for 20 different properties. The percent sand in surface samples was found to be detectable with a reasonable degree of accuracy with $R^2$ = 0.851 for a three parameter model; the best combination of wavelengths was 426.81, 730.47 and 1037.7 nm. For silt, clay, field capacity, wilting point, available water content, pH, electrical conductivity and $CaCO_3$, the results were varied with a degree of accuracy from 0.609 to 0.826 ($R^2$). The $R^2$ values varied from 0.759 to 0.906 for soil exchangeable properties such as Ca, Mg, Na, CEC and chemical composition such as $SiO_2$ and $Fe_2O_3$, the poorest fit was found with organic carbon ($R^2$ = 0.220) followed by $Al_2O_3$ ($R^2$ = 0.313). Available micronutrients (Fe and Mn) had $R^2$=0.491 and 0.490 respectively. For all the properties except organic carbon and $Al_2O_3$, the correlation was statistically significant. The main findings of some soil properties can be accurately detected using hyperspectral remote sensing.

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# Effect of Biochar on Nitrogen and Phosphorus Transformations in Two Texturally Different Soils

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Limited and inconsistent information is available on the effect of biochar on nutrient transformations in agricultural soils. Present incubation study was conducted to evaluate the effects of rice straw biochar (RSB) and acacia wood biochar (ACB) applied at three rates (0, 5 and 10 g $kg^{-1}$) on N and P transformations in two soils of divergent in texture. The concentration of $NH_4^+$-N decreased progressively with the increase in incubation period but the depletion of $NH_4^+$-N content in both the soils was faster in soils amended with both biochars. The differences between 5 and 10 g $kg^{-1}$ rates of biochar on $NH_4^+$-N content on different sampling dates were generally non-significant. The concentration of $NH_4^+$-N in 100 mg N $kg^{-1}$ treatment reduced to a level < 0.5 mg $kg^{-1}$ with both the biochars at 15 and 30 days after incubation in loamy sand and clay loam soil, respectively. Biochar type showed no significant effect on the $NH_4^+$-N content in the both soils. RSB showed significantly greater increase in $NO_3^-$-N content compared to ACB on all sampling dates in both soils. Application of RSB at 10 g $kg^{-1}$ resulted in significant increase in $NO_3^-$-N content compared to 5 g $kg^{-1}$ RSB on all sampling dates. Contents of $NO_3^-$-N on all the sampling dates increased significantly with the application of biochar and fertilizer N in both soils. The $NO_3^-$-N contents increased with increased rate of biochar in clay loam soil until 15 days after incubation but the contents were lower at 10 g $kg^{-1}$ biochar compared to that at 5 g $kg^{-1}$ biochar treatment at 30 and 60 days after incubation in loamy sand soil. Addition of RSB applied at 5 and 10 g $kg^{-1}$ caused greater increase in rate of nitrification compared to ACB in both the soils. In case of ACB, the net increase in accumulation of $NO_3^-$-N contents with 10 g $kg^{-1}$ compared to that at 5 g $kg^{-1}$ continued until 60 days in clay loam and 30 days in loamy sand soil. Application of biochar at 5 g $kg^{-1}$ significantly increased per cent nitrification compared to no biochar in both soils. Olsen-P remained consistently higher in both the soils (64-69% on clay loam and 56-58% on loamy sand) amended with for RSB and ACB to the end of the 60-day incubation period. The Olsen-P increased significantly with biochar applied at the rate of 10 g $kg^{-1}$, irrespective of type of biochar. The increase in contents of Olsen-P in soil was more in loamy sand compared to clay loam soil.

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# Determination of Threshold Levels for Potassium Release in Vertisols of Different Agro-ecological Regions of India

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An attempt has been made to find out threshold K levels in soil below which release of non-labile K is initiated. In this method the soil release threshold level (RTL) was equilibrated with 0.01*M* $CaCl_2$ solution having series of soil: solution ratio, after which the remaining amount of exchangeable K was extracted with *N* $NH_4OAc$ (pH 7). Total amount of K extracted ($K_T$ = K desorbed in $CaCl_2$ solution plus K extracted with 1 *N* $NH_4OAc$) remained more or less constant with decreasing K level up to a certain value (say threshold value) below which $K_T$ increased sharply indicating K release from non-labile form. The threshold value in terms of K concentrations (release threshold concentration) of Panjari, Nagpur, Maharashtra (Typic Haplusterts, sub-humid dry), Teligi, Bellary, Karnataka (sodic Haplusterts, semi-arid dry) and Kheri, Jabalpur, Madhya Pradesh (Typic Haplusterts, sub-humid moist) soil were 0.044-0.049, 0.034-0.062 and 0.043-0.11 mM, respectively. The relationships between release threshold level and exchangeable potassium, non-exchangeable potassium determined by 1 *N* $HNO_3$ and sodium tetraphenylborate ($NaBPh_4$) have been discussed.

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# Effect of Long-term Manuring and Fertilization to Rice-Wheat Sequence on Nitrogen Fractions and Rooting Behavior of Wheat in Vertisol of Chhattisgarh

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The effect of long-term manuring and fertilization on nitrogen (N) fractions and rooting behavior under rice-wheat cropping sequence in Vertisols was studied under the long-term fertilizer experiment (AICRP's) at IGKV, Raipur (CG). The treatments comprised of control, 50% NPK, 100% NPK, 150% NPK, 100% NPK+ Zn @ 10 kg $ha^{-1}$, 100% NP, 100% N,100% NPK + FYM @ 5 t $ha^{-1}$, 50% NPK + BGA, 50% NPK + GM laid out in split plot design. The results of the present study revealed that the nitrate–N, ammonium –N and inorganic –N status was improved with the application of 100% NPK + FYM. The organic–N components *viz*., hydrolysable $NH_4^+$-N, amino acid–N, amino sugar-N and unidentified hydrolysable–N increased significantly with the application of 100% NPK + FYM. The application of NPK + FYM significantly increased the root length (489 cm), root volume (0.103 $cm^3$), root diameter (0.197 mm) and root surface area (30.14 $cm^2$) of wheat. The root oxidizing activity and CEC was influenced significantly with the application of NPK + FYM. The grain (35.4 q $ha^{-1}$) and straw yield (46.7 q $ha^{-1}$) of wheat increased significantly with the combined application of manures and fertilizers. The root phosphatase activity under P starvation condition influenced significantly with the application of 100% N alone (289.2 µm PNPP $g^{-1}$ FW) and control (289.6 µm PNPP $g^{-1}$ FW) treatment.

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# Effect of Different Levels of Potassium on Yield, Nutrient Status and Potassium Fractions under Wheat Grown on Farmer's Field in Vertisols

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The experiment was conducted on farmer's field to study the effect of different levels of potassium (K) on yield of wheat and nutrient status in swell-shrink soil of Vidarbha region. The treatments comprised of different levels of K *viz.*, 0, 30, 60 and 90 kg $K_2O$ $ha^{-1}$ along with 120:60 kg N and $P_2O_5$ kg $ha^{-1}$ laid out in randomized block design replicated fives times serving one replication as one farmer. The results of the present study revealed that the highest grain yield (25.5 q $ha^{-1}$) was obtained with the application of 120:60:90 kg NPK $ha^{-1}$ followed by 120:60:60 kg NPK $ha^{-1}$. In respect of straw yield, the treatment of 120:60:90 kg NPK $ha^{-1}$ recorded significantly higher straw yields (40.4 q $ha^{-1}$) followed by 120:60:60 kg NPK $ha^{-1}$ which was found to be on par with each other. The lowest straw yield was observed under control treatment (19.6 q $ha^{-1}$). The soil chemical properties as influenced by different levels of K was found to be non significant except available K, which was influenced significantly with the application of 120:60:90 kg NPK $ha^{-1}$ (407 kg $ha^{-1}$) followed by 120:60:60 kg NPK $ha^{-1}$ (398 kg $ha^{-1}$). The increasing levels of potassium significantly influenced the all forms of K *i.e.* WS-K, Ex-K, non-Ex-K, total K and lattice K. The significantly highest values of various forms of K were observed with the application of 90 kg K $ha^{-1}$ followed by 60 kg K $ha^{-1}$.

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# Soil Organic Carbon and Pools of Carbon as Affected by Land-uses in Indogangetic Soils

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Soil organic matter content, composition and soil structure are known to vary with land use. Different land-uses have different potentials for carbon sequestration due to differential soil organic carbon (SOC) and aggregation dynamics. The mass distribution of SOC within different sized aggregates varies with time and space in interaction with land-use system and soil management. Land-use strongly influences soil properties and unsuitable practices lead to degradation of soil and environmental quality. Keeping this in mind, the present study was conducted to evaluate the impact of agricultural land-uses on status of organic carbon and C pools in soils of Indo-Gangetic plains. We studied the impact of four land-uses *viz.*, cropland, forestry, horticulture and uncultivated on SOC, hot water soluble carbon (HWC), potassium permanganate-oxidizable carbon ($KMnO_4$-C), mineralizable carbon (MC), aggregate associated carbon (AAC), particulate organic carbon (POC) and mineral associated organic carbon (MinOC) in central alluvial plains of Punjab. Forestry soils had approximately 60, 32 and 66 per cent higher SOC concentration than the cropland, horticulture and uncultivated soils respectively. Forestry soils could store approximately 28-67 per cent higher SOC stock against rest of the three land-uses in 90 cm soil profile. Aggregate associated C was higher in forestry by 45.5, 28.3 and 36.2 per cent than the cropland, horticulture and uncultivated soils, respectively. Uncultivated soils had the highest amount of total POC. Forestry affected labile C pools *viz.*, HWC and MC to the maximum extent whereas $KMnO_4$-C, IC, POC and MinOC were higher in uncultivated soils.

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# Release of Soil Zinc by Organic Ligands and Bio-availability to Wheat (*Triticum aestivum*)

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Most of the Indian soils are low in plant available zinc (Zn) in spite of high content of total Zn in soil due to which frequent application of fertilizer Zn is required. Release kinetics of soil Zn in presence of different organic ligands was studied in an incubation study to find out the feasibility of mobilization of native soil Zn and the bio-availability of Zn under the influence of most promising treatments in a greenhouse experiment using wheat as test crop. The treatments for the incubation study were various combination of Zn deficient soil (Inceptisol and Mollisol), Zn (0 and 2.5 mg Zn $kg^{-1}$ soil as $ZnSO_4$), oxalic acid (@10 and 20 mg $kg^{-1}$ soil), citric acid (@10 and 20 mg $kg^{-1}$ soil), farmyard manure (@ 0 and 2.5 g $kg^{-1}$ soil) and Zn solubilising microorganism. Released Zn at 1, 10, 20, 30, 45, 60 and 90 days intervals was extracted by using 0.005 *M* DTPA and estimated on AAS. All the treatments significantly increased Zn content over control. In both the soils oxalic acid with and without Zn and in Inceptisol citric acid with and without Zn showed increasing release pattern up to 90 days. In both the soils use of organic acids along with the recommended dose of Zn was more effective in maintaining higher concentration of Zn as compared to organic acids without Zn. The most effective treatment was found to be oxalic acid (10 mg $kg^{-1}$) + Zn (2.5 mg $kg^{-1}$) in both the soils. The results of incubation study showed that organic acids are effective in mobilizing and maintaining sufficient soil Zn for 90 days. To test the result obtained in the incubation study a green house experiment was conducted in Zn deficient Inceptisol using wheat (var. HD 2967) as a test crop. The treatments were oxalic acid (10 and 20 mg $kg^{-1}$ soil), FYM (2.5 g $kg^{-1}$ soil) and Zn solubilising microorganism with different doses of Zn (0, 1.25 and 2.5 mg Zn $kg^{-1}$ soil) applied as $ZnSO_4$. It was observed that by using 5 mg $kg^{-1}$ oxalic acid the recommended dose of Zn could be reduced to half (1.25 mg $kg^{-1}$). These acids especially oxalic acid could be used for soil Zn management under Zn deficient condition.

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# Carbon Mineralization Behavior of Soils Amended with Biochar and FYM

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Biochar carbon mineralization was studied in presence of FYM in three soils *viz*. Mollisols, Inceptisols, and Vertisols. The Walkley Black Carbon and total organic carbon in these soils were 1.12 and 1.44; 0.52 and 0.68, and 0.62 and 1.01 per cent respectively. The treatments included were $T_1$ 0 and 0; $T_2$ : 1 and 0; $T_3$ : 0 and 1; $T_4$ : 1 and 1; $T_5$ : 2 and 1 and $T_6$ : 3 and 1 g or biochar and FYM, respectively per 100 g soil. The carbon mineralization behavior in the presence of FYM in revealed that the cumulative C mineralization was ranged from 61.5 to 116.1 mg $CO_2$-C $100g^{-1}$ in Mollisols, 44.5 to 108.1 mg $CO_2$-C $100g^{-1}$ in Inceptisols and 75.1 to 114.0 mg C $100g^{-1}$ in Vertisols under different rate of biochar and FYM application. The net cumulative C mineralization after excluding the contribution of the soil in Mollisols on account of addition of biochar and/FYM ranged between 12.6 and 54.6 mg $CO_2$-C $100g^{-1}$ soil under different treatment combinations while it varied from 15.1 to 63.6 mg $CO_2$-C $100g^{-1}$ in Inceptisols and 1.9 to 39.0 mg $CO_2$-C $100g^{-1}$ in Vertisols. The net amount of carbon released from biochar was only 1.74% of the added as compared to FYM (5.86%) in Mollisol. However for Inceptisols and Vertisols it was 2.08 and 8.16 per cent and 0.26 and 5.00 per cent, respectively. When more of biochar was added with FYM (2:1 and 3:1) the net rate of C release from biochar did not change significantly despite addition of huge quantity of biochar in any soil that may be attributed to the less quantity of N available for mineralizing more amount of carbon added to the soil. The Cumulative C release followed the order $T_1<T_2<T_3<T_4<T_5<T_6$ in Mollisols and Inceptisols, while it was $T_1<T_2<T_4<T_3<T_5<T_6$ in Vertisols.

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# Effects of Rice Straw Biochar and *Acacia* Biochar on Phosphorus Adsorption and Desorption in Soils with Different Textures

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Biochars differ in influencing chemistry of soil P and thereby P adsorption and desorption. Laboratory incubation study was carried out to investigate the effects of rice straw biochar (RSB) and *acacia* biochar (ACB) on P sorption and desorption in clay loam and loamy sand soils. Soils were treated with three different rates (0, 5 and 10 g $kg^{-1}$) of biochars. Application of both biochars (10 g $kg^{-1}$) resulted in a significant decrease in P adsorption compared to the untreated control. The RCB having higher P concentration was more effective in reducing P adsorption than ACB. Langmuir adsorption isotherm best described the P adsorption. The amount of P adsorbed increased with increase in the amount of P added, irrespective of the biochar treatment. In the clay loam soil, it was revealed from Langmuir isotherms that the P-adsorption capacities of the unamended control, RSB (10 g $kg^{-1}$) and ACB (10 g $kg^{-1}$) were 62.5, 50.0 and 52.6 mg $kg^{-1}$, respectively. The corresponding values of these three treatments for bonding energy are 0.052, 0.039 and 0.043 L $kg^{-1}$, respectively. The effects on P adsorption maxima, bonding energy and adsorption rate constants were lower in loamy sand compared to clay loam soil. The amount of desorbed P was higher with RSB compared to ACB application. The values of desorption maxima (Dm) and desorption rate constant ($K_d$) were highest in control and decreased with application of biochars. The results indicate that biochar application to soil will increase the P availability, and reduce P sorption and desorption.

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# Calcite Dissolution Potentials of Crops for the Phyto-Reclamation of Calcareous Sodic Soils

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Phyto-reclamation of calcareous sodic soils is an effective low cost reclamation approach where reclamation is achieved by the ability of plant roots to increase the dissolution of native calcite, thereby resulting in enhanced levels of $Ca^{2+}$ in soil solution to effectively replace $Na^{+}$ from the exchange complex. Hence an attempt was made to know the calcite dissolution potentials of crops in calcareous sodic soils besides understanding the mechanisms underpinning the calcite dissolution. A pot culture experiment was conducted with eight selected test crops *viz*., *Oryza sativa* (TRY3), *Zea mays* (CO6), *Eleusine coracana* (CO15), *Helianthus annuus* (CO4), *Gossypium hirsutum* (MCU13) *Amaranths cruentus* (CO1), *Medicago sativa* ($CO_2$) and *Sesbania aculeata* (culture) in two calcareous sodic soils (SI and SII) differing in ESP. The crops were grown up to 45 days, sampled and analyzed for various parameters.

Crops differed significantly among themselves in growth and reclamation efficiency. Lesser exchangeable $Na^{+}$ and higher soil $Ca^{2+}$ status was observed with *Zea mays* (8.31 and 29.4 in sodic soil I and 17.5 and 38.9 meq.$100g^{-1}$ in sodic soil II) followed by *Helianthus annuus* (8.27 and 28.7 meq.$100g^{-1}$ in sodic soil I and 18.2 and 37.5 meq.$100g^{-1}$ in sodic soil II). Better performance of these crops could be attributed to higher reduction in pH, salts and free $CaCO_3$ which corroborates with the significant increase in native calcite dissolution and production of organic acids. Lesser reduction in pH, salts and free $CaCO_3$ status in the soils were observed with *Medicago sativa which* indicated its inefficiency in removing $Na^{+}$ and supplementing sufficient $Ca^{2+}$. Higher mean calcite dissolution (21.4%), $Na^{+}$ removal efficiency (31.4%) and $K^{+}$/Na+ ratio (1.26) was registered with *Zea mays while p*oor reclamation efficiency indices were noticed with *Medicago sativa*. Root exudate analysis further confirmed the enhanced dissolution of calcite by *Zea mays* with more number of organic functional groups and higher amount of acetic acid (158 µg $mL^{-1}$) and ascorbic acid (8.54 µg $mL^{-1}$). Hence it can be concluded that, *Zea mays and Helianthus annuus* can be recommended to phyto-reclaim the calcareous sodic soils with suitable management strategies.

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# Quantity-Intensity Relationship and Potential Buffering Capacity in Nalgonda District Soils

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Among the major plant nutrients in soil, potassium is the most abundant nutrient. Its amount in soils varies depending on parent material, degree of weathering, gains through fertilizers and losses through crop removal, erosion and leaching. The quantity – intensity (Q – I) relationship depicts the capacity of a soil system to maintain a certain level of K in solution and gives a visual representation of how the level of K in solution is related to the total amount of K available in the exchangeable and soluble forms. Typical potassium Q-I relationships are useful as index of K availability in a soil and allow comparison of K release to solution relative to other soils

Soil samples from 0-15 cm depth were collected from 50 fields in Nalgonda district. Among 50 samples available potassium content in 22 soil samples were low, 17 samples were in medium and remaining 11 samples were high. Twenty samples ( 2 low, 9 medium and remaining 9 high) were selected for further study based on variations in available potassium contents. The Q/I relationship in soils of Nalgonda is studied at different concentrations of added K *i.e.*, 0, 0.4, 0.8, 1.6, 3.2, 6.4 mM of KCl and these solutions were named as A,B,C,D,E and F, respectively.

Studies on quantity-intensity parameters showed that the experimental soils were low in potential buffering capacity of potassium ($PBC^K$) with the values ranging from 0.3 to 1.0 cmol($p^+$)$kg^{-1}$/ $(\mathit{M}L^{-1})^{1/2}$ x $10^{-3}$ with an average value of 0.65 cmol($p^+$)$kg^{-1}$/$(\mathit{M}L^{-1})^{1/2}$ x $10^{-3}$. Other Q-I parameters such as equilibrium activity ratio $AR_e^K$ varied from 0.2 to 1.2 $(\mathit{M}L^{-1})^{½}$ x $10^{-3}$ with the mean value of 0.44 $(\mathit{M}L^{-1})^{½}$ x $10^{-3}$ and labile potassium ($K_L$) varied from 0.14 to 0.55 cmol($p^+$)$kg^{-1}$ with the mean value of 0.26 cmol($p^+$)$kg^{-1}$.

The $K_X$ ( K held at specific sites) ranged from 0.20 cmol(p+)$kg^{-1}$ to 0.05 cmol(p+)$kg^{-1}$ in these soils under study. The values of $K_o$ (K held at non-specific sites) ranged from 0.08 cmol(p+)$kg^{-1}$ to 0.28 cmol($p^+$)$kg^{-1}$ with a mean value of 0.16 cmol($p^+$)$kg^{-1}$.

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# Potassium Status and Potassium Fractions of the Soils of Nalgonda District

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Among the major plant nutrients in soil, potassium is the most abundant nutrient. Potassium availability to plants, in general, is governed by these different forms of K *viz.,* water soluble K, exchangeable K, fixed K and mineral K. Soil solution K form is most mobile and prone to leaching in soils. Exchangeable and solution K are often considered as forms readily available to plant, while non-exchangeable and mineral K are slowly available forms. Various extractants have been tried for determining their suitability for making recommendations of potassic fertilizers to crops across the globe. However, information on universal reagent for assessing K availability in the soils is needed.

Soil samples from 0-15 cm depth were collected from 50 fields in Nalgonda district. Among 50 samples available K content in 22 soil samples were low, 17 samples were in medium and remaining 11 samples were high. Twenty samples ( 2 low, 9 medium and remaining 9 high) were selected for further study based on variations in available K contents. The different fractions (water soluble K, available K, exchangeable K, non-exchangeable K, total K) were analysed and K was also extracted with eight extractant *viz.*, $NH_4OAc$ (N*N*), oxalic acid (0.01 *M*), citric acid (0.01 *M*), acetic acid (0.01 *M*), boiling $HNO_3$ (1 *M*), $CaCl_2$ (0.01 *M*), HCl (2*M*) and $H_2SO_4$(1.38 *N*) to evaluate their suitability for K extraction. The results obtained in this study were water soluble K in the soils ranged from 12.0 to 67.5 mg $kg^{-1}$ with a mean value of 23.0 mg $kg^{-1}$ of soil. The exchangeable K content was in the range of 26 to 239 mg $kg^{-1}$ with an average of 108 mg $kg^{-1}$ soil. Non–exchangeable / fixed K ranged between 140 to 262 mg $kg^{-1}$ with an average of 194 mg $kg^{-1}$ soil. Total K content in soils of Nalgonda district ranged between 11,500 to 18,000 mg $kg^{-1}$ soil with an average of 14,960 mg $kg^{-1}$ soil. The fractions of K *viz*., water soluble, exchangeable and non-exchangeable/fixed K, on an average, constituted 0.15, 0.72 and 1.30 per cent, respectively of the total K. All the fractions of K have shown significant positive correlation with each other which indicates the existence of dynamic equilibrium among the different fractions of K in the soils of Nalgonda district. Among the different extractants, oxalic acid has extracted the highest amount of K. The decreasing order of K extracted by different extractants is: oxalic acid (0.01 *M*) > boiling $HNO_3$ (1 *M*) > $H_2SO_4$ (1.38 *N*) > $NH_4OAc$ (N*N*) > HCl (2*M*) > citric acid (0.01 *M*)> $CaCl_2$ (0.01 *M*) > acetic acid (0.01 *M*). All the extractants have shown significant positive correlation with each other. Correlation studies also show that available K has recorded significant positive correlation with all the extractants. Available K *i.e.*, potassium extracted by N *N* $NH_4OAc$ has shown highest correlation with 0.01 *M* citric acid, 2*M* HCl, 0.01 *M* $CaCl_2$ and 1.38*N* $H_2SO_4$.

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# Comparative Assessment of Temperature Sensitivity of Soil Organic Carbon Mineralization in Sub-tropical Inceptisol and Alfisol

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Understanding temperature sensitivity of soil organic carbon (SOC) decomposition from bulk soils and aggregates of long-term fertilized plots is very imperative to forecast soil C dynamics under climate change. Hence, we evaluated the impacts of 43 and 44 years of fertilization under wheat (*Triticum aestivum* L.) based cropping systems on temperature sensitivity of SOC decomposition ($Q_{10}$), decay rates (Kc), activation energy (Ea) required for SOC degradation and isotopic abundances of $^{13}C$ in an Alfisol and Inceptisol, respectively. Bulk soils (< 4.75 mm) as well as macro- (> 250µm) and micro- (< 250µm) aggregates were incubated for 24 days at 25 and 35 °C to determine $Q_{10}$, Kc and Ea. Results revealed that irrespective of fertilization, depth and temperature effects, cumulative C mineralization (Ct) values were lower in aggregates than in bulk soils of Inceptisol and Alfisol. Furthermore, Ct values from microaggregates were less than those from macroaggregates in both soils. In the 0-15 cm soil layer, $Q_{10}$ values of bulk soils with NPK + FYM and NPK treated plots were similar, but these values were significantly higher than unfertilized control plots in both soils. Less proportional C mineralization from NPK + FYM treatment may be due to the formation of compounds, which are resistant to microbial action or may be due to matrix stabilization. In both 0-15 and 15-30 cm layers, macroaggregates of Inceptisol and microaggregates of Alfisol were more temperature sensitive than their counter aggregates. Higher Ea values were required for decomposition of microaggregate associated-C of Alfisol than Inceptisol, macroaggregate and bulk soil-C required higher Ea in Inceptisol than Alfisol. The higher $Q_{10}$ values of microaggregates than macroaggregates, like 1.67 (in microaggregates) of NPK + FYM treated plots versus 1.29 (in macroaggregates) in the surface soil of Alfisol indicate higher temperature sensitivity of microaggregates with a temperature rise. Abnormally high Ea in macroaggregates of NP treated plots in both soil layers of Inceptisol could be explained by the highest enrichment factor of SOC within macroaggregates of these soils indicating protection of C. However, high Ea in macroaggregates of sub-surface depth of NPK + FYM could be due to high recalcitrant C (>52%). Similarly, high Ea in microaggregates of 150% NPK in the 15–30 cm soil depth in Inceptisol might be due to the highest enrichment of SOC within microaggregates, indicating protection of C. From natural abundances of $\delta^{13}C$ and $\delta^{15}N$ values, it was observed that SOC in Inceptisol was more stable than Alfisol in all four depth layers. Lower ä$^{13}C$ values within macroaggregates than microaggregates signal for higher temperature sensitivity of macroaggregates in Inceptisol. Similarly, less $\delta^{13}C$ values of microaggregates of Alfisol compared with macroaggregates indicate higher temperature sensitivity of microaggregates. This study highlights consideration of the role of microbial diversity, phosphorus and matrix stabilization within bulk soils and aggregates to understand temperature sensitivity of SOC decomposition, in addition to physico-chemically derived substrate-temperature sensitivity relationship. Our findings imply that changes in the fertilization would influence the stability of intrinsic SOC and soil C sequestration potential through regulation of $Q_{10}$ and NPK + FYM management practice in both soils could lead to less C loss under a sudden temperature rise.

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# Organic Carbon Pools and Available Nutrient Status in Some Rice Growing Soils of Haryana

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A field study was carried out to know the organic carbon pools and available nutrient status in some rice growing soils of Haryana state. Seventy five surface (0-15 cm) soil samples were collected using handheld GPS from farmer's field of Kaithal, Kurukshetra and Karnal districts of Haryana in the month of April and May 2015 and analyzed for organic carbon fractions and available N, P and K by using standard procedures. The organic carbon content varied from 0.35 to 0.68, 0.27 to 0.67 and 0.36 to 0.69 per cent in soils of Kaithal, Kurukshetra and Karnal districts, respectively. Most of the soils were found under medium category (77 %) whereas, only 23 per cent soils were found under low category. The dissolve organic carbon content varied from 50 to 305, 25 to 175 and 50 to 300 mg $kg^{-1}$ in Kaithal, Kurukshetra and Karnal districts, respectively. The DOC was about 0.75 to 4.69 per cent of the total soil organic carbon while the MBC was about 1.63 to 5.77 per cent of total soil organic carbon which varied from 122 to 350, 98 to 223 and 142 to 325 mg $kg^{-1}$ soil in the above districts. The light fraction varied from 0.18 to 1.04, 0.27 to 0.93 and 0.31 to 1.12 g $kg^{-1}$ soil and found 3 to 18 per cent of total organic carbon present in soils of above districts. Similarly, heavy fraction carbon ranged from 2.64 to 5.25, 1.97 to 5.39 and 2.57 to 5.27 g $kg^{-1}$ soil in Kaithal, Kurukshetra and Karnal districts, respectively. The heavy carbon content was 66.83 to 83.18 per cent of total organic carbon content found in rice growing districts of state. Similarly, available N ranged from 112 to 194, 86 to 180 and 115 to 193 kg $ha^{-1}$ and all the soils were found deficient in available N. The available P varied from 9 to 37, 6 to 37 and 9 to 46 kg $ha^{-1}$ and majority of soils were found in medium to high category. Only 17 per cent soils were found low in available P. Similarly, available K varied from 100 to 454, 54 to 306 and 126 to 456 kg $ha^{-1}$, respectively in above districts and majority of soils were in medium to high category, however it shows the decreasing trends as compared to previous years.

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# Adsorption of Metribuzin in Tomato Growing Soils

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Most of the herbicides applied to the soil are subjected to physicochemical, chemical and microbial processes which will decide the fate of herbicide in the soil and its contamination potential of the environment. Among the physic-chemical processes adsorption is a predominant process influencing the fate of the soil applied herbicides. Metribuzin [4-amino-6-tert-butyl-4,5-dihydro-3-methylthio-1,2,4-triazinone], is the most widely used herbicide for the control of a large number of grassy and broad leaved weeds by tomato growers. An experiment was conducted with twenty soil samples collected from tomato growing regions of Ranga Reddy district in Telangana state to study the sorption of metribuzin influenced by soil properties. Sorption behaviour of metribuzin in soil samples was studied through batch equilibrium protocol and the berbicide quantification was done spectro-photometrically by using UV-Vis spectrophotometer at 455 nm.

The adsorption isotherms were mainly parabolic in nature with 'S' shaped character in most of the soil samples except in two soils (samples 5 and 18). In these soils the isotherms were 'L' shaped. The adsorption data of the S shaped isotherms fitted well with Freundlich equation. The $K_f$ values for the soils varied from 0.051 (S-18) to 1.369 (S-10) and the n values varied between 0.74 (S-18) to 1.11 (S-8 and S-10). The co-efficient of determination ($R^2$) values were higher than 0.97, indicating excellent fit of the adsorption data by Freundlich equation. The values of 1/n suggested the existence of non-linear adsorption. Freundlich constant was positively and significantly correlated with organic carbon (r = 0.802** P<0.01), clay content (r = 0.737** P<0.01) and clay + OC (r = 0.741** P<0.01). The soil water distribution quotient $K_d$ values of the twenty soils varied between 0.11 and 0.96. The $K_{doc}$ values for metribuzin in soils varied from 33.36 to 140.31. This adsorption behaviour indicated that metribuzin is weakly retained by the soil. Freundlich K values were significantly correlated with organic carbon per cent, clay per cent, clay + organic per cent. Higher $K_d$ and $K_{doc}$ values were noticed in soils with higher clay content and organic carbon content indicating the stronger affinity of metribuzin for the organic matter in the soil.

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# Study on Persistence of Metribuzin in Tomato Growing Soils

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The fate of herbicides released into the environment is determined by their chemico-physical characteristics, *viz.*, solubility, persistence, volatilization, photolysis, biodegradation, adsorption-desorption, leaching etc. Persistence and degradation are the most important processes which influence the fate of the herbicide in the soil. Metribuzin [4-amino-6-tert-butyl-4,5-dihydro-3-methylthio-1,2,4-triazinone], is selectively used predmoninantly as a post emergence herbicide in tomato crop to control the grassy and broad leaved weeds. Tomato fruits immediately after harvest are consumed freshly and there could be a possibility of residues of herbicides entering into tomato fruits. So, the persistence of soil applied herbicides has become an important topic of investigation particularly in the context of residual toxicity.

A laboratory experiment was conducted with three tomato growing soils of Ranga Reddy district in Telangana state to study the persistence of metribuzin. The persistence studies were conducted under the laboratory conditions at three moisture levels (saturated, field capacity, 50% of field capacity) by incubating the soils samples with predetermined concentration of metribuzin and analyzed the metribuzin present in soil extract at 0, 1, 3, 5, 7, 10, 15, 30, 45, 60, 75, 90, 105 days after incubation. A spectrophotometric method was used for the determination of metribuzin (455 nm). Persistence studies indicated that, disappearance curves of metribuzin consisted of two distinct pathways, an initial faster rate followed by a slower phase of dissipation. The faster mode of disappearance continued till about 30 days followed by a slower rate of disappearance phase which continued till the end of the study. The rate constants for entry of the metribuzin into labile pool (k values) for the soils varied from 0.00321 to 0.00419 at saturation; 0.00279 to 0.00323 at field capacity and 0.00156 to 0.00175 at 50% of the field capacity. The rate constant for entry into the bound pool ($k_1$ values) were in the range of 0.00179 to 0.00236, 0.00178 to 0.00225 and 0.00279 to 0.00323 at saturation, field capacity and 50% field capacity respectively. Metribuzin persisted in the soils upto 60 days after application in the soils where the clay and organic carbon content were relatively higher. Whereas, persistence could be detected up to 45 days after application in light textured soils. Beyond 60 days the metribuzin concentration in the soil reached the detection limit of 0.05 mg $kg^{-1}$.

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# Evaluation of Critical Levels of Zinc for Chickpea in Inceptisols

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A pot culture experiment was conducted during *rabi* 2015 to evaluate the critical levels of zinc (Zn) in soil and plant for chickpea crop in medium deep black swell-shrink soil. The pot culture experiment was conducted on low (<0.60 mg $kg^{-1}$), medium (0.60 to 1.80 mg $kg^{-1}$) and high (>1.80 mg $kg^{-1}$) Zn containing soils and was laid out in completely randomized design with five treatments and two replications. The treatments of soil application of Zn @ 0.0 (T1), 2.0 (T2), 4.0 (T3), 6.0 (T4) and 8.0 kg $ha^{-1}$(T5) were imposed in the soils containing low (7), medium (5) and high (3) zinc content.

The pH of the soils ranged from 7.39 – 8.54 and EC varied from 0.09 – 0.28 dS $m^{-1}$. The organic carbon in soils ranged from 2.40 to 6.59 g $kg^{-1}$ which was low to medium, whereas calcium carbonate was found 2.05 to 4.77 per cent. The major nutrients status showed available N (163.2 to 313.5 kg $ha^{-1}$); P (11.43 to 23.96 kg $ha^{-1}$) which was in low to medium and K (257.6 to 459.2 kg $ha^{-1}$) was found high in soils. The available micronutrients Zn, Fe, Mn and Cu ranged from 0.43 to 2.20 mg $kg^{-1}$, 4.59 to 10.51mg $kg^{-1}$, 11.90 to 22.15 mg $kg^{-1}$and 1.14 to 5.03 mg $kg^{-1}$, respectively.

The results indicated that on three levels of soil having varying zinc content, the application of zinc significantly influenced the dry matter yield of chickpea. The dry matter yield was significantly higher in the treatment of 6.0 kg Zn $ha^{-1}$ in comparison with low levels of zinc indicating that application of zinc up to 6.0 kg $ha^{-1}$ was beneficial in increasing the dry matter yield of chickpea.

The soil application of zinc improved the concentration and uptake of N, P, K and zinc in chickpea plant and in turn reflected in their higher uptake. Application of zinc @ 6.0 kg $ha^{-1}$ had significantly influenced the concentration and uptake of nitrogen, phosphorus, potassium, zinc, iron, manganese, and copper by chickpea. The response of zinc application on dry matter yield and uptake of zinc were found higher under low status of zinc followed by medium and high zinc content in soils. Thus, it is concluded that the critical levels of zinc for growing chickpea in medium deep black swell-shrink soils were 0.63 mg $kg^{-1}$ for soil and 23.05 mg $kg^{-1}$ in chickpea plant for zinc fertilization to meet the requirement of crop.

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# Carbon and Nitrogen Mineralization in Soil Amended with Manures and Fertilizers from Nineteen Years

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An ongoing long-term field experiment started in 1995 on a coarse loamy, Typic Ustochrept soil at CCS Haryana Agricultural University, Hisar was selected to examine the impact of application of manures and fertilizers on carbon and nitrogen mineralization potential after 19 years of fertilization. The seven treatments combinations *viz*. $T_1$ : 150 kg N + 60 kg $P_2O_5$ $ha^{-1}$, $T_2$ : 15 Mg FYM $ha^{-1}$, $T_3$ : 15 Mg FYM + 150 kg N + 30 kg $P_2O_5$ $ha^{-1}$, $T_4$ : 5 Mg Poultry manure $ha^{-1}$, $T_5$ : 5 Mg Poultry manure + 150 kg N + 30 kg $P_2O_5$ $ha^{-1}$, $T_6$ : 7.5 Mg Pressmud $ha^{-1}$, $T_7$ : 7.5 Mg Pressmud + 150 kg N +30 kg $P_2O_5$ $ha^{-1}$ were laid out in permanent plots. Soil samples were collected after 19 cycles of pearl millet- wheat cropping system and amended with different manures and fertilizers for incubation study in laboratory to assess the quantity of $CO_2$ evolved and nitrogen mineralized for a period of sixty days. Soil basal respiration rate increased with application of organic manures, as compared to chemical fertilizers treatments. Further, integrated application of manures and fertilizers showed higher $CO_2$ evolution than recommended dose of NP fertilizers as well as soil amended with organic manures alone. Carbon mineralization increased with the progress of incubation and rate of increase was higher at initial stages and decreased gradually. Among organic manures applied, highest $CO_2$ evolution was obtained with FYM application followed by pressmud and poultry manure. Application of FYM and poultry manure alone reported lower N mineralization potential as compared to recommended dose of N and P fertilizers. Application of NP fertilizers with organic manures significantly increased nitrogen mineralization over the application of manures or fertilizers alone because addition of fertilizer N along with organic manures is known for stimulating mineralization and reduced immobilization. Highest N mineralization potential was observed with application of pressmud due to low C:N ratio and high N content.

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# Studies on Soil Organic Carbon Pools and Available Nutrient Status under Different Land Use Systems of Haryana

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A study on soil organic carbon pools and available nutrient status under different land use system of Haryana was carried out to evaluate the changes in soil quality caused by different land use systems at Department of Soil Science CCS HAU, Hisar. Different land use systems *viz.,* cotton-wheat, rice-wheat, sugarcane-sugarcane pearl millet-wheat (zero tillage), pearl millet-wheat (conventional tillage), citrus orchard, guava orchard and vegetables along with their uncultivated soils were selected for the study. Soil samples replicated five times were selected from each land use systems along with their uncultivated soils and analyzed for organic carbon fractions and available nutrients. The total organic carbon was found highest under horticulture land use system and highest content (9.72 g $kg^{-1}$) was found in guava orchard, however, lowest 4.84 g $kg^{-1}$ was observed under pearl millet-wheat land use system. About 39.66% higher organic carbon was observed under cultivated soils as compared to uncultivated soils. Zero tillage system registered 45.70 % higher SOC content than conventional tillage system under pearl millet-wheat cropping system. The MBC, DOC, LFC and HFC constitute 0.94 to 2.60 %, 1.27 to 11.16%, 5.79 to 18.12% and 77.09 to 97.26% of SOC respectively. These fractions were observed in the range from 136.23 to 238.14 mg $kg^{-1}$ (MBC), 150 to 386 mg $kg^{-1}$ (DOC), 0.50 to 1.76 g $kg^{-1}$ (LFC) and 4.11 to 7.51 g $kg^{-1}$ (HFC) under different land use systems in cultivated soils. The maximum content of MBC, LFC, HFC was found under guava orchard i.e 238.14 mg $kg^{-1}$, 1.76 g $kg^{-1}$ and 7.51 g $kg^{-1}$ while highest (386.00 mg $kg^{-1}$). DOC content was found under cotton-wheat cropping system. Overall, SOC and its fractions found higher in guava orchard under horticulture land use system. The maximum amount of available N (156.8 kg $ha^{-1)}$ was found under sugarcane-sugarcane, P (112.4 kg $ha^{-1}$ ) under citrus, and K (651.40 kg $ha^{-1}$ ) under guava orchard respectively. The maximum increase in the available nitrogen in cultivated soil over uncultivated soils was observed under cotton-wheat which showed 52.2% increment.

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# Transformation and Availability of Zinc in Soil as Influenced by Rate and Frequency of its Application under Paddy-Wheat Cropping System

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Zinc has become as important as NPK with the farmers of Punjab where it is recommended to apply 25 kg zinc sulphate heptahydrate (21% Zn) per acre to paddy in Zn deficient soils which is sufficient for about three years under paddy-wheat cropping system. But the farmers prefer to apply about 5-10 kg zinc sulphate per acre every year to paddy instead of 25 kg. A field experiment was conducted through 2012 to 2015-16 to study the effect of rate and frequency of Zn application under paddy-wheat cropping system. The experimental soil was loamy sand having pH 8.1, EC 0.26 dS $m^{-1}$, OC 0.28% and DTPA-extractable Zn 0.58 mg $kg^{-1}$ soil. The treatments consisted of application of Zn @ 0, 5, 10, 15 and 20 kg zinc sulpahte per acre to paddy crop only every year, alternate year and once only. Zinc was applied as zinc sulphate heptahydrate (21% Zn). The treatments were replicated thrice. The experiment was started during *kharif* season of 2012. Transformation of Zn in soil was studied on soil samples collected after two years of experiment by following the sequential extraction procedure.

It was observed that, during the first two years of study (2012 and 2013), the effect of Zn application on grain yield of paddy was not significant. However, during 2013 and 2014, it was observed that the differences in grain yield of paddy recorded with application of 10 kg zinc sulphate per acre every year to paddy and 20 kg zinc sulphate per acre at one time during the year 2012 were not significant. A paddy grain yield of 58 and 58.7 q $ha^{-1}$ was recorded with application of 20 kg zinc sulphate once and 10 kg zinc sulphate every year, respectively. Application of 5 kg zinc sulphate every year was not effective to produce the grain yield at par with that observed with one time application of 20 kg zinc sulphate. The residual effect of applied Zn on grain yield of wheat was not significant during the period of study.

Transformation of Zn in soil indicated that only a meager amount of applied Zn was recovered in exchangeable (1.13-3.41%) and specifically adsorbed Zn (5.93-9.78%) fractions which are the plant available pools thereby necessitating the need for regular application of Zn fertilizers in soils. The maximum recovery of applied Zn was observed in amorphous oxides (40.7-57%) followed by crystalline (6.7 - 21.7) and manganese oxides (8.7-15.3%) thereby rendering most of the applied Zn in non-plant available forms. It was further observed that the lowest rate of 5 kg zinc sulphate per acre was not effective in influencing the plant available forms.

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# Effect of Sewage Sludge Application on Heavy Metals Content and their Chemical Extractability in Soils

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Waste-water treatment facilities are increasing at a faster rate that too at enhanced efficiencies and consequently sewage sludge generation is increasing. Application of sewage sludge to agricultural soils are common practices worldwide and are used in Punjab, especially in the vicinity of large cities, as these are considered reusable sources of essential plant nutrients and organic C. The substantial amounts of N, P and other plant nutrients in sludge render it to be a useful fertilizer material. However, the relatively high concentrations of toxic metals in sludge can limit its disposal to agricultural land as a fertilizer. Knowledge of how contaminants are partitioned among various chemical forms allows a better insight into the mechanisms of their retention and release and hence their solubility, mobility, and bioavailability in contaminated soil. Hence, a study was carried out to evaluate the effect of sewage sludge application on heavy metal (cadmium, chromium, nickel and lead) contents and their transformations in different chemical forms in agricultural soils. Soil samples were collected from 0-15 and 15-30 cm soil depths after two years and three years of application of sewage sludge from an ongoing experiment at research farm, PAU, Ludhiana with the treatments 1) 100% recommended inorganic fertilizer (control), 2) 50% recommended inorganic fertilizer + sludge @10 t $ha^{-1}$ to rice 3) 75% recommended inorganic fertilizer + sludge @ 5 t $ha^{-1}$ to rice and wheat, 4) 50% recommended inorganic fertilizer + sludge @ 10 t $ha^{-1}$ to rice and wheat. Samples were air dried, ground to pass through 2 mm sieve and stored in plastic containers before using them for analysis. The concentrations of Cd, Cr, Ni and Pb were determined in the sewage sludge samples collected every month. The results indicate that metal levels in sewage sludge produced in the sewage treatment plant at Bhattian, Ludhiana, varied considerably. The heavy metals concentration was highest during winter season followed by in monsoon and least in summer season. It may be concluded from the present study that application of sewage sludge enhanced the concentrations of Pb, Ni, Cr and Cd in surface and sub-surface soils. Movement of Pb, Cd, Cr and Ni was there from surface to sub-surface soil, however, there was not any particular trend of change in their various fractions. The non-residual fractions dominated over the residual fractions of Cd, Ni and Pb in sludge amended soils. Lead (Pb) was more in organic matter bound fraction and Cr in residual fraction. In nutshell, continuous application of sludge for subsequent years leads to increase in heavy metal concentrations in bio-available pool making it hazardous for plants and humans. Accumulation of Pb and Ni in soil may lead to soil deterioration.

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# Impact of Tillage and Residue Management on Nitrogen Dynamics in Maize-Wheat Cropping System

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Conservation agriculture (CA), an alternative practice that involves minimum soil disturbance, crop residue retention and crop rotation, is postulated to conserve soil organic matter (SOM), energy, irrigation water and biodiversity. On the other hand, conventional tillage practices (CT) characterized by excessive tillage, residue removal and monoculture are often associated with the degradation of soil mainly in terms of depletion of SOC, sub-soil compaction and loss of biodiversity. As fertilizer nitrogen (N) is the one of key input in food production, it is typically required in larger quantities than any other nutrients by the crop for its growth and development. Therefore, proper management of N is essential to reap high yield, profit and ultimately with safe environment. In view of scarcity of information on N management protocols under CA, a field experiment was initiated in *kharif* 2013 at IARI farm, to evaluate different N management options *i.e.* basal application of 80, 50 and 33% of total fertilizer requirement followed by need-based top dressing as suggested by Green Seeker, and N sources and methods of application on crop yield, N uptake, N use efficiencies (NUE), and temporal changes in soil organic C and mineral-N in maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) cropping system under CA and CT practices. Results revealed that maize grain yield was statistically similar under both cultivation practices *i.e.* CA (7.47 t $ha^{-1}$) and CT (7.48 t $ha^{-1}$), whereas grain yield of wheat was significantly higher under CA (5.0 t $ha^{-1}$) than that under CT (4.71 t $ha^{-1}$). The N top dressing requirement as assessed by using GreenSeeker was relatively less under CA in both the crops, which ultimately curtailed fertilizer N application in this practice. Averaged across N management options, it was possible to curtail 62 kg fertilizer N $ha^{-1}$ without any grain yield penalty in maize-wheat system. Such advantages of CA were apparently due to higher N use efficiency and better mineralization of N during the cropping period. On an average, N use efficiencies in wheat computed as agronomic efficiency ($AE_N$), partial factor productivity ($PFP_N$) and recovery efficiency ($RE_N$) were 23.2 kg grain $kg^{-1}$ N, 38.4 kg grain $kg^{-1}$ N and 52.5%, respectively under CA; the corresponding values under CT were 15.1 kg grain $kg^{-1}$ N, 26.1 kg grain $kg^{-1}$ N and 37.5%. Among N sources and methods of application band placement of slow release modified urea materials (*i.e.* USG and IFDC-product) resulted in higher yields and NUE compared with urea broadcasting. In CA, Walkley-Black C (WBC) and mineral-N ($NH_4^+$-N + $NO_3^-$N) contents were significantly higher compared with CT in the surface layer (0–15 cm depth). Results thus indicated superiority of CA over CT particularly with respect to increase in SOC and mineral-N content and enhancement in the NUE. The benefits associated with CA present a greater potential for its adoption to sustain soil health and crop productivity of maize–wheat cropping system.

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# Leaching Behavior of Salt Affected Soils of Purna Valley of Vidarbha

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The present investigation was carried out in the Purna valley of Vidarbha region of Maharashtra to study the ionic movement under variable electrolytic concentration in Vertisol. The sampling was done in the month of November, 2014. The soil samples were taken from Raundala village at the depth of 0-20, 20-40 and 40-60 cm respectively. The sampling site was the representative black sodic soil (Vertisol ) from Raundala. For equilibration of soil samples the synthetic waters were prepared with 3 levels of total electrolyte concentrations (TEC) *i.e.* 5, 10, 20 me $L^{-1}$ and three levels of SAR 5, 10 and 20 mmol1/2 L-1/2. Prepared synthetic water was passed through soil column for 45 days. Increase in total electrolyte concentration level from 5 to 20 me $L^{-1}$ calcium, magnesium, sodium, chloride, bicarbonate and sulphate concentration in leachate was increased upto 15 days and thereafter decreases. The results showed that with increase in total electrolyte concentration level from 5 to 20 me $L^{-1}$ electrical conductivity of leachate also increased. With increase in total electrolyte concentration level from 5 to 20 me $L^{-1}$ sodium adsorption ratio of the leachate was increased.

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# Soil Organic Carbon Fractions under Maize-based Cropping Systems in Conservation Agriculture

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Conservation agriculture (CA) is based on principles of minimum soil disturbance, residue retention on soil surface and crop diversification which not only improves healthy functioning of soil but also enhances nutrient availability, its biological quality and aggregate formation. Therefore, a long-term (7 years) study was conducted to evaluate the impact of tillage practices and maize-based cropping systems on soil organic carbon fractions along with some indicators of soil biological health like soil microbial biomass carbon (SMB-C) and dehydrogenase activity (DHA) in a sandy loam soil of north-western Indo-gangetic plain region. The experiment was laid out in a split- plot design during 2008 with 3 tillage practices *i.e.* zero till-permanent bed planting (PB), zero till-flat bed planting (ZT) and conventional tillage (CT) in main plots and four maize- based cropping systems *i.e.* maize-wheat-mungbean (MWMb), maize-chickpea-*Sesbania* (MCS), maize-mustard-mungbean( MMuMb), maize-maize-*Sesbania* (MMS) in sub-plots. In 0-5 cm soil depth total organic cabon (TOC) under ZT or PB (0.79-0.80%) was higher than CT (0.56%). TOC was 39.5, 46 and 22.6 per cent higher under ZT over CT in 0-5, 5-15 and 15-30 cm soil depth, respectively. Walkley-Black C (WBC) content was 21.3 and 19.7 per cent higher under PB and ZT over CT. Among cropping systems, WBC content was in the order: MCS> MWMb >MMS> MMuMb across all other depths. The contribution of SOC pools to TOC, averaged across soil depths was in order of: non-labile C (NLC)> less labile C (LLC)> very labile C (VLC)> less labile C (LLC). Among cropping systems, the differences in very labile C content were significant in all soil depths, and the contents were higher under MWMb and MCS compared with other two cropping systems. The effect of tillage on LC content was quite apparent as ZT and PB showed significantly higher LC compared with CT in the top soil layer *i.e.* 0-5 cm. Depth- wise distribution of LLC under different tillage practices was not significant. Among cropping systems, the LLC content was relatively higher under MMuMb and MMS in the 0-5 cm and 5-15 cm depths. Grain yield of maize was significantly higher under PB and ZT as compared to CT. Among the cropping systems, MCS and MWMb yielded significantly higher compared with MMuMb and MMS. Thus, our long-term study suggests that PB and ZT systems are best suited for sustainable production of maize within maize-chickpea–*sesbania* cropping systems.

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# Depth of Influence of 12-Years of Organic Farming on SOC Stocks, Nutrient Availability and Soil Biological Activity

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A study was conducted for 12-years from 2003-04 to 2014-15 at the College of Agriculture, Rajendranagar, PJTSAU to evaluate the impact of five different organic nutrient management (ONM) practices *vis a vis* to chemical nutrient management (CNM) and Integrated nutrient management (INM) on soil quality, yield, and quality of crops using maize-onion as test crop sequence. The experiment was laid out on large plots of 300 sq.m each. The organic manures *viz.*, farmyard manure (FYM), vermicompost and neem cake were applied on N equivalent basis. The recommended dose of fertilizers (RDF) for maize and onion was 180:60:40 and 150:60:60 kg NPK $ha^{-1}$, respectively. At the end of the 12th year efforts were made to understand the depth influence of various nutrient management practices in improving the SOC stocks, nutrient availability and biological activity by collecting depth wise soil samples from each plot in three locations at every 15 cm interval from 0 to 75 cm.

Soil bulk density was significantly lower in all the depths under organic nutrient management and was ranging from 1.37 to 1.41 Mg $m^{-3}$ in 0-15 cm layer, 1.44 to 1.47 Mg $m^{-3}$ in 15-30 cm layer, 1.45 to 1.52 Mg $m^{-3}$ in subsequent 30-45 cm depth, 1.43 to 1.53 Mg $m^{-3}$ in further 45-60 cm layer and 1.47-1.61 Mg $m^{-3}$ in 60-75 cm deep soil layer. In all the depths or soil layers chemical or integrated nutrient management treatments recorded higher bulk density. Soil organic carbon stock in 0-15 cm layer was ranged between 21.45 to 25.40 Mg C $ha^{-1}$ in organically managed plots and 21.69 Mg C $ha^{-1}$ in INM and 16.60 Mg C $ha^{-1}$ in chemical nutrient management plots. Superiority of ONM in terms of soil organic carbon stock was evident up to lower soil layers of 15-30 cm, 30-45 cm. But in deeper layers of 45-60 cm and 60-75 cm SOC stocks in all the treatments were on par. On the whole, in 0-75 cm soil layer a total carbon stock of 53.6 to 71.7 Mg C $ha^{-1}$ was recorded in ONM plots and 56.2 Mg C $ha^{-1}$ in INM and 42.65 Mg C $ha^{-1}$ in CNM plots. SOC stock under ONM was 25.8 to 68.1 per cent higher in 50% recommended dose of nitrogen fertilizers applied as FYM and 100% recommended dose of nitrogen applied through FYM + vermicompost + neemcake each on 1/3rd equivalent basis of recommended nitrogen.

Availability of P after 12 years of experimentation in the surface layer was more under INM followed by ONM while CNM plots registered lowest amount of available P. In subsequent depths of 15-30 cm and 35-40 cm similar superiority of INM and ONM was observed over CNM. However, in lower (45-60 cm and 60-75 cm) soil layers the differences in availability of P were non significant. Similarly build-up of available K with ONM and INM was seen up to 30-45 cm soil depth. In subsequent soil layers of 45-60 cm and 60-75 cm available soil K was almost similar in all the treatments.

The influence of ONM on soil biological activity was evident only in the surface 0-15 cm and 15-30 cm soil layers with three-fold higher activity of dehydrogenase and two-fold increased activity of acid and alkaline phosphotase enzymes in the surface 0-15 cm soil layer than 15-30 cm layer. In the lower layers soil enzymatic activity was found to be not influenced by the nutrient management practices.

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# Effect of Boron Fertilizers on Transformation and Release Pattern of Boron in Soil

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Humic substances are commercial products that contain elements that improve soil fertility, increase the availability of nutrient elements. Calcium is considered to be an important factor for the maintenance of cell membrane integrity and the regulation of ion transport. The efficiency of soil applied boron fertilizers are very low light textured and calcareous soils as it is subjected to physical processes like leaching and chemical process like precipitation and complex formation. To improve the availability of complex boron fertilizers, humic acid based boron complex calcium boro humate (CBH) improves the use efficiency of boron. The incubation experiments were conducted to study the effect of boron fertilizers on the nutrient availability in soil light and medium textured soil. 200 g of 2-mm sieved soil sample was filled in 250 mL plastic containers. The treatment details include $B_0L_0$ – control, $B_1$ – calcium boro humate (CBH), $B_2$ – boric acid ($H_3BO_3$), $B_3$ – borax ($Na_2B_4O_7 \times 10H_2O$), $B_4$ – polybor ($Na_2B_8O_{13} \times 4H_2O$), levels of boron $L_1$ – 0.5 mg $kg^{-1}$, $L_2$ – 1.0 mg $kg^{-1}$, $L_3$ – 1.5 mg $kg^{-1}$. Each treatment was replicated thrice. The design followed was factorial complete randomized block design (FCRD). The soil samples were drawn on 0, 30, 60 and 90 DAI and analyzed for available B content. Application of graded levels of B from 0 to 1.5 mg $kg^{-1}$ consistently increased the B availability in both the soils and it ranged from 0.44 to 1.98 mg $kg^{-1}$ on 0 DAI, 0.42 to 1.78 mg $kg^{-1}$ on 30 DAI, 0.4 to 1.56 mg $kg^{-1}$ on 60 DAI and 0.37 to 1.38 mg $kg^{-1}$ on 90 DAI. B availability was significantly increased over control by all the four sources of B. Among the four sources calcium boro humate maintained maximum level of B at all stages of analysis. The hot water soluble B is 0.44 mg $kg^{-1}$ in light textured (Typic Orthent) and 0.49 mg $kg^{-1}$ in medium textured (Typic Haplustert).

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# Effect of Tillage Practices and P Fertilization on Soil Inorganic P Fractions

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Limited information is available on the impact of tillage and P fertilization on soil inorganic P fractions and crop yield. Keeping this in view, the study was conducted in *rabi* season of 2013-14 and an ongoing experiment on "Phosphorus management in wheat under different tillage practices in sequence with sorghum crop" initiated in 2011 at Soil Research Farm, Hisar was selected. Experiment was laid out in a split plot design with four replications. Three tillage treatments in main plots [(Zero tillage-ZT (Glyphosate @ 3 L $ha^{-1}$ used as preplant desiccator at 10-15 days before sowing); conventional tillage-CT (two cultivator + two tractor drawn harrowing followed by planking); and minimum tillage-MT (one cultivator + one tractor drawn harrowing followed by planking)] and four P treatments in sub-plots (0, 45, 60 and 75 kg $ha^{-1}$) were applied in wheat. On these plots, sorghum was raised for fodder in *kharif* as per other package of practices. Representative soil samples (0-15 and 15-30 cm) were collected from individual plots after harvesting of wheat crop for estimation of inorganic soil P fractions (Saloid-P, Fe-P, Al-P and Ca-P). The results revealed that increasing levels of P application significantly increased all the inorganic soil P fractions over control and lower P levels. All inorganic P fractions were higher in the surface as compared to subsurface soil under various treatments and distribution in different fractions followed the sequence: Ca-P > Fe-P > Al-P > Saloid-P at both the depths. Calcium-P represented on an average 70.2% of total inorganic P extracted from the soil. The values for Fe-P, Al-P and Saloid-P were 15.5, 12.3 and 2.0%, respectively. Dominance of Ca-P in these soils might be attributed to the presence of higher amounts of exchangeable and soluble Ca which on reaction resulted in the formation of Ca-phosphates. The amounts of Fe and Al bound P can be ascribed to the presence of sesquioxides which might have transformed a portion of added P in these forms. All these fractions were significantly interrelated meaning thereby that the P transformation is the culmination of release processes from all the fractions and the system seemed to be dynamic. Soil P fractions showed insignificant affect of tillage systems on inorganic soil P fractions except Saloid-P in surface, which significantly increased in ZT.

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# Long-term Effect of Manuring and Fertilization on Stability of Clay Humus Complexes in Rice-Potato-Wheat Cropping System

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Soil organic matter (SOM) stability is key to long-term C sequestration and SOM quality is vital for nutrient cycling and soil fertility. The long-term effect of manuring and fertilization on stability of SOM in high intensity potato-based cropping system in Inceptisol of semi-arid sub-tropical India was studied Soil samples were collected from the on-going field experiment involving rice-potato-wheat cropping system continuing since at the research station of Central Potato Research Institute Campus, Modipuram, Meerut, Uttar Pradesh since the year 2005. The treatments used for the present study were control (T1), 100% NPK (T2), 100% NPK-VC (vermicompost (T3), 50% NPK + 50% NPK-VC (T4), 100% NPK+ CR (crop residue (T5), 100% NPK-VC + CR (T6). The stability of clay humus complexes was studied by estimating the desorption rate humus from clay-humus complex. The results indicated that the value of stability constant ranged from 5.2 h in control to 8.7 h in plot receiving 100% NPK–VC in T3 at 0-15 cm soil layer. The general trend among the treatments with relation to stability was T3 (100% NPK-VC) > T6 (100% NPK-VC + CR) > T2 (100% NPK) > T5 (100% NPK + CR) > T4 (50% NPK + 50% NPK-VC) > T1 (control) in 0-15 cm soil layer. Almost the same trend was observed in subsurface layers in which the values ranged from 3.4 h in T1 to 9.1 h in T6 in 15-30 cm layer. The clay humus stability showed that the plots receiving organic amendments e.g. vermicompost and or crop residue continuously for ten years in rice-potato-wheat, the humus desorption rate constant (k) decreased and thereby increased the stability of clay humus complex.

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# Persistence of Bispyribac-Sodium in Rice Soils under Different Methods of Establishment

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A field experiments was carried out during *kharif*, 2015 to study the field-persistence of bispyribac-sodium, a new selective rice herbicide, in aerobic and transplanted rice, in soil, plant and rice grain at College farm, PJTSAU, Rajendranagar, Hyderabad. Rice variety MTU-1010 was planted at a row spacing of 20 cm × 15 cm. Bispyribac sodium was applied as post-emergence herbicide at 20 g a.i. $ha^{-1}$ at 20 days after transplanting. In aerobic rice, the herbicide residues were applied at 20 g $ha^{-1}$ at 15 days after sowing. Initial soil samples were collected and analyzed and the texture of the soil was a clay loam with pH 7.8, EC 0.51 dS $m^{-1}$ and organic carbon 0.60%. The soils were classified as Vertic Haplustepts.

Soil samples were collected on 1, 5, 10, 15, 30 and 60 days after application of the herbicide (DAA) and at harvest. For residue analysis, rice plants and grain, were collected randomly from each plot at harvest time. Residues of bispyribac sodium were determined in soil, grain and plant using HPLC. In soil, the averaged recoveries of the method ranged 87.12%-93.22%, at the fortified levels of 0.02-1.0 mg $kg^{-1}$. The minimum detectable limits in soil were found to be 0.02 mg $kg^{-1}$. In plant and grain samples the recoveries varied between 92.6 - 98.7% and 90.1-94.3%, respectively.

In transplanted rice soils the initial detected concentration (IDA) of bispyribac sodium varied from 0.015 to 0.017 mg $kg^{-1}$. Residues persisted upto 8 days after application and the residue reached below the detection limit by 15 DAA.

In aerobic rice soils, the IDA varied from 0.10 to 0.20 mg $kg^{-1}$. The variation in the initial soil concentration of the bispyribac sodium is due to the presence of large quantity of the undecomposed residue of the green manure on the surface (T4 and T5), which might have hindered the herbicide reaching from soil. In all the aerobic rice treatments, the residues reached the BDL value by 8th DAA.

Residues of bispyribac sodium in the soil samples, rice grain and rice straw samples collected at the time of harvest were below the detectable limit of 0.010 ppm in aerobic and transplanted rice treatments.

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# Measuring the Changes in Soil Carbon Stocks with the help of Carbon Management Index in Lateritic Soils of West Bengal

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Soil organic carbon plays a key role in nutrient cycling of soil and also valuable for attaining the sustainability. The present investigation was aimed at examination of different fractions of soil organic pool and their variability in different cropping systems in the lateritic soils of West Bengal in the year 2016. Soils from different cropping systems and forest soils of Ballavpur sanctuary along with reference samples were analyzed for different fractions *viz.* total organic carbon (TOC), labile carbon (LC), non-labile carbon (NLC) and from these parameters carbon pool index (CPI), carbon lability index (CLI) and carbon management index (CMI) were determined. The TOC fraction was highest in forest soils but it was reduced to a significant extent by human interventions, grazing, deforestation *etc.*, thereby reducing CMI by 61.64% in 0-5 cm layer and 71.97% 5-10 cm soil layer. The non-cropped field was found to be richer in TOC and LC content than every other cropping systems signifying the need of restoration of C pool in crop field. The marked decline in C-pools has ultimately reduced the CMI in the crop field.

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# Plant Available Silicon and Its Relationship with Physicochemical Properties of Soils

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Two hundred surface soil samples from rice fields were collected from different agro-climatic zones (ACZ) of Karnataka. Soil samples were analysed for pH, EC, cation exchange capacity (CEC), particle size distribution, 0.01*M* $CaCl_2$ extractable silicon (CCSi) and 0.5*M* acetic acid extractable silicon (AASi). Zone wise Pearson's correlation coefficients (r) were worked out for soil analytical data. Analysis of soil samples representing nine agro climatic zones of Karnataka revealed that 40 per cent were acidic, 46 per cent were alkaline and 14 per cent were neutral in pH. Whereas 98 per cent of the soil samples recorded normal range of EC, only 2 per cent were slightly saline in nature. Highest soil pH and EC was recorded in north eastern dry zone soil samples and lowest in hilly and coastal zone. The CEC of soil samples ranged from 8.20–122.8 cmol($p^+$)$kg^{-1}$, lower CEC was recorded in hilly zone whereas higher CEC found in southern dry zone soil samples. Textural class of the soil samples varied from sandy to clay. Sand, silt and clay of the soil samples ranged from 15.99 to 93.9 per cent, 0.00 to 60.0 per cent and 0.00 to 62.3 per cent, respectively. The soils dominated with sand fraction are mainly formed *in situ,* under conditions of high rainfall in coastal and hilly zone with alternate dry and wet periods. Among the soils, 30 to 50 per cent of soils were low to medium in plant available silicon (Si) as extracted by both extractants. CCSi and AASi were ranged from 1.41 to 82.89 mg $kg^{-1}$ and 6.69 to 370.2 mg $kg^{-1}$, respectively. Relatively, higher Si content was noticed in northern part of Karnataka soil samples whereas lower Si was recorded in hilly and coastal zone samples. In general, AASi content was found to be higher than that of CCSi. Most of the soil samples collected from different agro climatic zones of Karnataka recorded significantly positive correlation between soil pH, Si content, silt and CEC and negatively correlated with sand content. Soil pH was significantly correlated with Si content of the soil. Irrespective of the soil samples representing different zones, CCSi had positive correlation with AASi. Silicon content analysed by both methods had significant and negative correlation with sand content of the soil samples. The amount of available Si in the soil decreased with increase in the sand fraction. Sand consists basically of quartz minerals and in spite of having high $SiO_2$ content in its composition, has a low Si release potential in the short and medium term. Thus sand fraction of a soil is practically inert. There was a good correlation between Si content with clay and CEC. This may be due to the fact that majority of the clay minerals or clays can act as major source of Si in the soil besides influencing CEC of the soil.

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# Nutrient Dynamics in Soils of Intensive Rice-Rice Cultivation

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Continuous monitoring of soil fertility under intensive cultivation of crops is required because reduction in productivity of several crops is attributed to decreasing soil fertility. The deficiency of several macro and micronutrients are emerging under intensive cultivation due to imbalanced application of plant nutrients. The present study was taken up in rice-rice cropping system of Anaimalai block, Coimbatore district, Tamil Nadu in order to monitor the changes in soil fertility resulting from intensive cropping and management practices. Forty five farm sites representing three major soil series *viz*. Anaimalai, Irugur and Palladam series, growing continuous rice-rice cropping system were selected during 2008 and were continuously monitored. The grain and straw yields during *kharif* and *rabi* seasons were recorded besides collecting post harvest soil and plant samples for assessing the nutrient status. Basic data on fertilizers and manures applied, variety planted by the farmers were recorded. All farm soils were having neutral to alkaline reaction (7.00 to 8.80) with electrical conductivity of 0.17 to 0.46 dS $m^{-1}$. The organic carbon content was low to medium (0.18 to 0.70 per cent). The initial soil fertility of the fields were low in available N, medium in P and medium to high in K and S. Among the micronutrients, Zn was predominantly deficient in Irugur and Palladam soil series. B availability ranged from deficient to sufficient status and rest of the micronutrients were in sufficient status.

The total nutrient removal pattern observed was in the order of K > N > P > S for major nutrients and for micronutrients it was: Fe > Mn > Zn > B > Cu. The nutrient balance was calculated based on the quantity of nutrients applied by the farmers (input) and crop removal (output) for every crop. The nutrient balance worked out for the year 2014-15 indicated negative nutrient balance of K, Zn, Mn, Cu and B in all the three soil series. The negative balance was due to the mismatch between addition and removal of the above said nutrients. Rests of the nutrients were maintained at positive balance in all the soil series.

Fertility rating of the soils at the end of every rice crop was worked out using the nutrient index values. Based on the nutrient index values, the fertility classes were assessed. When compared to the initial status (2008), after growing fourteen rice crops (*rabi* 2014-15), N was maintained at very low level, P build-up and K depletion was observed in all the three soil series. Zn depletion was noticed in Palladam series. The status of S, Fe, Mn, Cu and B in soil were maintained in the same status in all the series. The reduction in availability of soil K and Zn might be due to the application of suboptimal level of potassic fertilizers, non addition of micronutrient fertilizers and organic manures by many of the farmers. Hence, it is necessary to go for balanced fertilization by adopting integrated nutrient management practices for maintaining crop yield as well as soil fertility.

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# Evaluation of Different Extractants for the Estimation of Soil Available Boron

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Boron (B) is an essential micronutrient and therefore, B fertilization is warranted if the soil available B is low. The narrow range between deficiency and toxic limits of B necessitates precise evaluation of soil available B. Hot water extraction of B is the commonly used method for the determination of soil available B. Extracting the soil with boiling water posed problems due to colour from organic matter and turbidity from suspended fine clay particles in the colorimetric determination of B. Besides, adopting this method for large number of samples is difficult. Hence, the present investigation was carried out for evaluating the suitability of 0.05*M* mannitol- 0.01*M* $CaCl_2$ extraction for alkaline soils and 0.1*M* salicylic acid extraction for acid soils for the estimation of available B in comparison with hot water extraction of B.

One hundred georeferenced soil samples with a pH range of 3.37 to 9.51 (50 each in acidic and alkaline pH) collected from different districts of Tamil Nadu were used for the study. For the extraction of available B, 0.05 *M* mannitol- 0.01*M* $CaCl_2$ (alkaline soils) and 0.1*M* salicylic acid (acid soils) were used along with hot water extraction (HWS-B). Boron in the extract was determined colorimetrically using Azomethine-H. Correlation and regression analysis were performed to obtain the relationship between amount of B extracted by 0.05M mannitol - 0.01*M* $CaCl_2$ (alkaline soils) and 0.1*M* salicylic acid (acid soils) with that of hot water soluble B.

In acid soils, available B was in the range of 0.42 to 3.05 (mean of 1.24) mg $kg^{-1}$ for hot water method and 1.06 to 8.83 (mean of 2.65) mg $kg^{-1}$ for 0.1*M* salicylic acid method. Highly significant and positive correlation (0.530**) was observed between hot water method and 0.1*M* salicylic acid method for the extraction of available B in acid soils. Slope of regression line between HWS-B and 0.1*M* salicyic acid B (y=1.465x+0.832) was greater than 1.0, indicating the higher extractability of B by 0.1*M* salicylic acid when compared to hot water.

In alkaline soils, available B was in the range of 0.42 to 2.54 (mean of 1.20) mg $kg^{-1}$ for hot water method and 0.20 to 2.27 (mean of 1.20) mg $kg^{-1}$ for 0.05*M* mannitol - 0.01*M* $CaCl_2$ method. Significant and positive correlation (0.368*) was observed between hot water method and 0.05*M* mannitol - 0.01*M* $CaCl_2$ method for the extraction of available B in alkaline soils. Slope of regression line between HWS-B and 0.05*M* mannitol - 0.01*M* $CaCl_2$ method (y=0.325x+0.805) was less than 1.0, indicating the lower extractability of B by 0.05*M* mannitol - 0.01M $CaCl_2$ extractant when compared to hot water. The results revealed that there is scope for the use of 0.1*M* Salicylic acid and 0.05*M* mannitol - 0.01*M* $CaCl_2$ for the estimation of soil available B in acid and alkaline soils respectively. However, to confirm the comparative efficiency, B extracted by the above extractants has to be correlated with plant B uptake.

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# Effect of Iron on Pigeonpea Yield and its Uptake Kinetics in Different Varieties of Pigeonpea

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Though the nutrients are dissolved in soil solution, the nutrient like Fe is not very mobile because of its entrapment in the water filled fraction of the tortuous pore system of the soil. The mechanistic models are useful tools for evaluating the significance of individual soil and plant parameter in the system through sensitivity analysis. The experiment was aimed to study the uptake pattern of Fe in pigeonpea with the following objectives. 1) To study the effect of iron on growth and dry matter yield of pigeonpea. 2) To investigate uptake kinetics of iron in different pigeonpea cultivars and 3) To evaluate the effect of iron on soil and plant parameters by sensitivity analysis.

A pot experiment was conducted at Anand to on Fe-deficient soil. Three treatments of Fe were given ($Fe_0$, $Fe_{20}$ and $Fe_{40}$) through ferrous sulphate (19% Fe). The pigeonpea was harvested at three different growth stages. For first growth stage, six plants, in second growth stage four plants and at third growth stage only two plants were groun on 15, 18 and 35kg capacity (soil) pots, maintained and harvested after 40, 55 and 70 days after emergence (DAE). To predict Fe uptake and Fe influx as well as to carry out sensitivity analysis of the rhizosphere of pigeonpea, recent version of NST 3.0 nutrient uptake model was used.

In sensitivity analysis, root radius ($r_0$) was most sensitive parameter controlling Fe uptake of pigeonpea, which was followed by maximum net influx ($I_{max}$) and initial soil solution Fe concentration ($C_{Li}$). In no Fe treatment, increasing $r_o$, $I_{max}$ and $C_{Li}$ by a factor of 2.0 individually caused increase in Fe uptake in proportions of 2.1, 1.98 and 1.97 times, respectively, while, increasing $K_m$ and b separately by a factor of 2 resulted in decrease in Fe uptake by a factor of 0.97 and 0.51 times, respectively. The Fe uptake by pigeonpea was affected by $r_0$, $I_{max}$, $C_{Li}$, and $k_m$.

Thus, from sensitivity analysis on the basis of nutrient uptake model higher values of $r_o$, $I_{max}$ and $C_{Li}$ are found beneficial to increase Fe uptake by pigeonpea, while it was true for lower value of $k_m$. Application of Fe @ 40 mg $kg^{-1}$ on Fe-deficient soil to Fe- inefficient pigeonpea variety C-11 is desirable for good growth of the crop besides Fe content in plant.

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# Spatial Variability of Available Micronutrients in Cashew Orchards of Konkan Region, Maharashtra

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In order to assess the spatial variability of available micronutrients *viz.,* Fe, Mn, Zn and Cu in different cashew orchards of Ratnagiri district, Maharashtra, 70 cashew orchards of 5 to 20 years old were selected at random, covering the entire range of management and yield level. Surface soil (0-30 cm) samples collected from each orchard were utilized for the present study.The range and mean values of DTPA-extractable micronutrient contents in soils showed wide variation among orchards. The content of DTPA-Fe varied from 5.48 to 42.63 mg $kg^{-1}$ with an average value of 15.44 mg $kg^{-1}$. The Mn situation in cashew orchards is very similar to that of Fe. The DTPA-Mn content varied from 12.86 to 34.93 mg $kg^{-1}$ with mean value of 30.10 mg $kg^{-1}$. The DTPA-Zn contents of soils vary largely from one site to another. It varied from 0.1 to 3.64 mg $kg^{-1}$ with mean value of 0.97 mg $kg^{-1}$. Similarly, the DTPA-Cu contents varied largely, extremely very low and very high values, it ranged from 0.06 to 19.92 mg $kg^{-1}$ with an average value of 1.67 mg $kg^{-1}$.

The frequency distribution of available micronutrients showed that, in most parts of the study area, the DTPA-Fe content is greater than 10.0 mg $kg^{-1}$, while, in a few places, the content varied between 5 and 10 mg $kg^{-1}$. In whole study area, DTPA-Mn content was higher than 10 mg $kg^{-1}$, revealing that available Fe and Mn content of all cashew orchards under study were sufficient to meet the crop demand for longer period. Though the contents of DTPA-Zn vary widely between high and low, only in a small part of the study area, DTPA-Zn content was < 0.5 mg $kg^{-1}$, while in other parts it varied from 0.5 to >1.0 mg $kg^{-1}$. On the basis of critical limits of available zinc, 18.6 per cent soil samples were deficient, 44.3 per cent samples were marginal and 37.1 per cent samples were sufficient in available zinc. Although the DTAP-Zn content of most cashew orchard soils (44.3% of soil samples) of Ratnagiri district seems to be medium (>0.5-1.0 mg Zn $kg^{-1}$ soil), which may potentially be at risk to Zn deficiency in future, if no external sources are applied. As is the case for DTPA-Zn, the variation of soil DTPA-Cu is very wide. Of the 70 soil samples, 8.6 per cent of cashew orchard soils fall in deficient, 11.4 per cent occur in the marginal and 80.0 per cent of cashew orchard soils of Vengurla falling in sufficient categories. Only in very few locations, Cu deficiencies have been noted. However, a great number of samples show alarmingly high contents of Cu (>1.0 mg $kg^{-1}$). The data clearly indicates the deficiency of a single micronutrient prevails in different cashew orchards of Ratnagiri compared to the multiple micronutrient deficiencies.

The nutrient index values for DTPA-Fe and DTPA-Mn were 3.00 and for DTPA-Zn and DTPA-Cu, it was 2.18 and 2.71, respectively. Based on the nutrient index value, cashew orchard soils of Ratnagiri district were high in DTPA-Fe and DTPA-Mn contents while, majority of soils were medium in DTPA-Zn and high in DTPA-Cu status. The research findings of the present study would help to develop site specific micronutrient management for high yield and quality of cashew in Ratnagiri district of Maharashtra.

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# A New Approach for Fixing Permissible Limit of Metal and Metalloid in Contaminated Soil

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Pollutants are released into the environment from both natural (geogenic) and anthropogenic sources. Moderate to severe extent of metal contamination have reported from various places in India. Build-up of metals in agricultural soils is a matter of serious concern as these metals induce adverse effect on animal and human health by getting into food chain. Other important routes of entry of these metals into animal and human include dust inhalation, direct soil ingestion and drinking water. Fixing permissible limit of metal and metalloid in soil for proper risk assessment is an important step for protecting animal and human health. Risk assessment of metal contaminated soil is relatively new concept, which helps in deciding the suitability of lands to be used for crop production. According to United States Environmental Protection Agency risk assessment is the determination of quantitative or qualitative value of risk related to a concrete situation and a recognized threat (also called hazard). There are several ways of assessing risk of metal-contaminated soils. Success of risk assessment depends on how precisely one can predict transfer of metal and metalloids from soil to plants. However, current legislation in most countries utilizes total metal concentrations in soils as a single index of hazard in contaminated soils. However, the total metal load takes no account of the soil characteristics that modify the solubility of metal pollutants in soil. Ideally, permissible limit of metal and metalloids in soils should be prescribed based on i) solubility of metal and metalloid in contaminated soils as affected by soil properties, ii) transfer of metal and metalloid from contaminated soil to plant and iii) health hazard associated with dietary intake of metal and metalloid by human through food materials grown thereon. Following this approach, we could successfully workout the permissible limit of chemically extractable metals and metalloid in soils for leafy green vegetables and cereals. Similarly, protocol was developed for fixing permissible limit of sludge to be applied in agricultural land. For example, permissible limit of EDTA extractable Cd would be 0.5 mg $kg^{-1}$, if soil pH and Walkley-Black organic C are 6.5 and 0.5%, respectively. At the same level of soil organic C, EDTA-extractable Cd would be 0.9 mg $kg^{-1}$, if pH is 7.5. Using similar approach, in a 90-day pot experiment, safe rates of sludge application were worked out as 4.48 and 71.6 g $kg^{-1}$ for acid and alkaline soils, respectively. Toxic limit of extractable Cd and As in soil for rice in relation to soil properties and human health hazard associated with consumption of rice grain by human was established. Similar exercise was also done in respect of Cd in soil for wheat. Development of such conceptual framework of fixing the toxic limit of extractable metals and metalloid in soils with respect to soil properties and human health under modeling-framework will go a long way in routine risk assessment of trace element-polluted soils. Further work is clearly needed to assess the bioavailability of metals inside the human body.

## Commission 2.3: Soil Biology

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# Effect of FYM and Fertility Levels on Productivity of Soybean (*Glycine max* L.) and Biological Properties of Typic Haplustepts

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A field experiment was conducted at the Instructional farm, Rajasthan College of Agriculture, Udaipur during *kharif* season of 2014 with the objectives to work out the most appropriate doses of fertilizers and FYM for soybean cultivation in Typic Haplustepts.

The soil of experimental site was medium in available nitrogen (281.3 kg $ha^{-1}$), phosphorus (20.7 kg $ha^{-1}$) and high in available potassium (427.8 kg $ha^{-1}$). The experiment consisting of 16 treatment combinations comprising four levels of fertilizers (0, 75, 100 and 125% RDF) in integration with four levels of FYM (0, 5, 7.5 and 10 t $ha^{-1}$). The experiment was laid out in factorial randomized block design with three replication. The results of the experiment indicated that application of 125% RDF improved the yield of the crop in terms of number of nodules per plant, number of pods per plant, number of grain per pod, grain, straw and biological yield of soybean. Available N, P and K in soil after harvest of crop increased significantly under 125% RDF. Available Zn, Fe, Mn and Cu in soil were positively affected with increasing levels of fertility. The bacteria, fungi and actinomycetes population with microbial biomass carbon and dehydrogenase activity significantly increased with the application of 125% RDF. Application of FYM @ 10 t $ha^{-1}$ significantly increased the number of nodules per plant, number of pods per plant, number of grain per pod, grain, stover and biological yield of soybean. Available N, P and K in soil after harvest of crop increased significantly by10 t $ha^{-1}$ FYM. Available Zn, Fe, Mn and Cu in soil were positively affected with increasing levels of fertility. The bacteria, fungi and actinomycetes population, microbial biomass carbon and dehydrgenase activity significantly increased with the application of FYM @ 10 t $ha^{-1}$.

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# Sustaining Soil Quality under IPNS for Hybrid Maize on Inceptisol

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Soil enzymes play a substantial role in maintaining soil health and its environment. Soil enzymes activity is mainly of microbial origin and are the vital activators of life process. Soil enzymology is nowadays of practical importance because the influence of agro-chemicals, industrial waste, heavy metals, as well as soil fertility management can be measured. This knowledge of soil enzymology can be applicable as bio indicator to human endeavour of ecosystem perturbation, agricultural practices and xenobiotic pollution. Maize (*Zea mays* L.), regarded as the queen of cereals, in which inadequate nutrition is the fore most factor that leads to decline in productivity. Under these circumstances, it is essential to evaluate the soil enzyme activity to increase the productivity of maize hybrid with sustained soil health. To accomplish this, a field experiment was conducted at farmer's holding of Allapalayam village, Annur block, Coimbatore District of Tamil Nadu during *rabi* 2015-16. The field experiment was laid out in a randomized block design with three replications comprising thirteen treatments with different levels of NPK (STCR-NPK alone) and STCR-IPNS (NPK + FYM @ 12.5 t $ha^{-1}$). The fertilizer doses were worked out for the yield target of 5 t $ha^{-1}$ as 100% and increased up to 200%. The higher urease activity was recorded in plots receiving combined application of NPK + FYM. Among the STCR-IPNS-200% of FD for 5 t $ha^{-1}$+ FYM @ 12.5 t $ha^{-1}$ ($T_{10}$) registered the highest urease activity of 216.3, 290.4, 173.2 and 166.5 mg $NH_4$ - N $g^{-1}$ $h^{-1}$ at 30, 60 and 90 DAS and at harvest stages, respectively. The increase in alkaline phosphatase activity might be due to the increased contents of SOM, total N, P, K, ammonium ion ($NH^+_4$) and available P, K, which further led to increased activity of phosphatase (alkaline) enzyme. The STCR-IPNS-200% of FD for 5 t $ha^{-1}$+ FYM @ 12.5 t $ha^{-1}$ ($T_{10}$) registered the highest phosphatase activity of 50.4, 52.5 and 63.2 mg PNP $g^{-1}$ $h^{-1}$ at 30, 60 and 90 DAS, respectively. Irrespective of the treatments, the dehydrogenase activity increased steadily from 30 DAS to 90 DAS and declined at harvest. STCR-IPNS-200% of FD for 5 t $ha^{-1}$+ FYM @ 12.5 t $ha^{-1}$($T_{10}$) registered significant and the highest dehydrogenase activity of 44.19, 48.21, 50.24 and 47.26 mg TPF $g^{-1}$ $h^{-1}$ at 30, 60, 90 DAS and harvest stages, respectively. Urease activity found to increase with advancement of time which indicates that the substrate availability (nitrogen) is prolonged with time and it confirmed the supply of N by slow release of nutrients by FYM. Higher alkaline phosphatase activity would promote the rate of hydrolysis of organic P compounds and more inorganic P will be formed. Whereas, maximum dehydrogenase activity was reported with NPK + FYM when compared to FYM alone, indicating maximum carbon mineralization in FYM alone than FYM + NPK treatments.

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# Long-Term Integrated Nutrient Management Foster the Biological Activities and Carbon Sequestering Capacity of Flooded Rice Soil

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Monitoring the qualitative and quantitative changes of soil organic carbon (SOC) is very much essential to keep the soil viable and productive for long-term sustainability. Impact of long-term (24 years) enforcement of farmyard manure (FYM) and inorganic nutrient management practices on changes in physio-chemical, microbiological properties and enzymatic activities of flooded rice soil was assessed along with soil carbon pools. The treatments considered of unfertilized (control), inorganic N fertilizer (90 kg $ha^{-1}$), inorganic fertilizer (NPK @ 90-60-60 kg $ha^{-1}$ ), FYM @ 10 t $ha^{-1}$ ) and inorganic fertilizer (NPK @ 90-60-60 kg $ha^{-1}$) in rice-rice cropping system at Andhra Pradesh Rice Research Institute, Maruteru, West Godavari District, Andhra Pradesh. The results revealed that the fractions of SOC, microbial biomass carbon, acid and alkaline phosphatases increased significantly in Farmyard manure amended soil. Fourier transform infrared spectroscopy analysis of humic acid revealed that organic fertilized soil fractions were more aromatic with greater diversity than did the inorganic fertilized soil fractions. This study emphasizes the importance of FYM and underscores the recommended dose of inorganic fertilizer to maintain the soil biological properties in flooded rice soil.

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# Effect of Biofertilizers on Soil health and Productivity of Black gram (V*igna mungo* L.)

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A field experiment was conducted during *kharif* season of 2014 on clay loam soil to study the effect of inorganic fertilizer and biofertilizers on soil fertility, yield and quality of blackgram. Black gram plays an important role in maintaining and improving the soil fertility through its ability to fix atmospheric nitrogen in the soil through root nodules which possesses *Rhizobium* bacteria. On the basis of one year field experimentation, it can be concluded that under agro-climatic condition of zone IVa (Sub-humid Southern Plain and Aravali Hills) of Rajasthan, application of 100% RDF + *Rhizobium* + PSB ($F_3B_3$), is the better option for realizing higher productivity, content and uptake of nutrients and net returns of black gram and it is the better option for improved fertility status of soil with good soil health. Seed inoculation with *Rhizobium* + PSB significantly increased the number of pods plant$^{-1}$, number of seeds pod$^{-1}$, seed, straw and biological yield, N, P, K, Cu, Zn, Fe and Mn content and uptake by seed and straw, number of total and effective root nodules, microbial population and net returns.

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# Different Particle Size of Rice Residues had Effects on Soil Enzymatic Activity in Salt Affected Soils

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Soil enzymes activities from organic materials added to soil depends on the quality of the substrate as a source of carbon, energy and nutrient for the saprophytic microflora. Quality reflects in a combination of biochemical and physical attributes. Incubation study was conducted to evaluate the effect of particle sizes of rice residue (powder, 1 mm, 2 mm, 5 mm and 10 mm) on enzymatic activities in three soils (normal, saline and sodic). The soils used in the study were alkaline in reaction having pH range 7.05 to 8.86 and had electrical conductivity gradient from 0.41-2.5 dS $m^{-1}$. Significant changes in soil enzyme activities (dehydrogenase, fluorescein diacetate, acid and alkaline phosphatase) due to incorporation of rice residue of different sizes were observed as compared to non-sodic /non-saline soils. The enzymatic activities were substantially enhanced after addition of different sized rice residues during initial days of incubation. Maximum enzymatic activities were observed in the order of normal > sodic > saline. It was found that the incorporation of powdered rice residue increased enzymatic activity in normal followed by sodic and least in saline soil. Our results suggested that soil enzymes activities respond sensitively to soil characteristics, magnitude of which is influenced by particle sizes of rice residue. Laboratory incubation study can provide early information about the changes in soil enzymatic activity with varying soil reaction, salt levels, and sizes of residues for local agricultural ecosystem managements, soil productivity and sustainability.

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# Effect of Arbuscular Mycorrhizal Fungi and PGPR on Nodulation, Nutrient Uptake and Yield of Soybean (*Glycine max* (L) Merrill) in Black Soil

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A field experiment was undertaken to find out the effect of *Arbuscular mycorrhizal* fungi and PGPR on nodulation, nutrient uptake and yield of soybean (*Glycine max* (L) Merrill) in black soil during *kharif* season 2015 on the field no. 12 of the research farm of R.A.K. College of Agriculture, Sehore (M.P.) under All India Coordinated Research Project on soybean. Experiment consisted of seven treatments, laid out in randomized block design with three replications with the plot size 2.8 m × 4 m. The treatment included Uninoculated control ($T_1$), *Burkholderia arboris* ($T_2$), *Paenibacillus Polymyxa* ($T_3$), AMF *(Glomus intraradices+G.geosprum+ G.mosseae)* ($T_4$), *Burkholderia arboris* +AMF ($T_5$), *Paenibacillus Polymyxa* +AMF ($T_6$), *Paenibacillus Polymyxa* + *Burkholderia arboris* +AMF ($T_7$). The soil at experimental field was medium black (Vertisol) having clay loam texture, low in available nitrogen (198.2 kg N $ha^{-1}$), medium in available phosphorus (12.8 kg P $ha^{-1}$), high in available potassium (420.4 kg K $ha^{-1}$) and normal in available sulphur (9.1 ppm S $ha^{-1}$) with pH of 7.5. Soybean var. RVS 2001-04 was sown on 12th of Juiy, 2013 and harvested on 5th Octomber, 2015. Various yield attributing characters to support grain and straw yield and the content of N, P, K and S, their uptake in straw and seed were studied and found that the application of *Paenibacillus Polymyxa* + *Burkholderia arboris* +AMF ($T_7$) significantly influenced Yield attributing characters *viz*., pods per plant, seed per pod, seed index, grain yield (1.22 t $ha^{-1}$) and straw yield (1.13 t $ha^{-1}$) over control ($T_1$), followed by *Paenibacillus Polymyxa* +AMF ($T_6$) which remained at par with ($T_7$). The application of *Paenibacillus Polymyxa* + *Burkholderia arboris* +AMF ($T_7$) significantly influenced the N, P, K and S contents and their uptake in seed and straw over control ($T_1$), followed by *Paenibacillus Polymyxa* +AMF ($T_6$) which remained at par with ($T_7$). The application of *Paenibacillus Polymyxa* + *Burkholderia arboris* +AMF ($T_7$) recorded the highest net returns (Rs. 23995.42 $ha^{-1}$) follow by the treatment *Paenibacillus* Polymyxa +AMF $T_6$ (Rs. 23691.57 $ha^{-1}$) further the maximum B:C ratio was noted under *Paenibacillus Polymyxa* + *Burkholderia arboris* +AMF ($T_7$) followed by 1:2.3 in *Paenibacillus Polymyxa* +AMF ($T_6$) .

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# Symbiotic Traits, Nutrient Uptake, Quality and Yield of Soybean as Influenced by Micronutrients, Organics and Biofertilizers Application in Vertisol

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Soybean (*Glycine max* (L.) Merrill) is a *kharif* season oilseed crop grown in 6.26 ,12.22 and 113.10 million hectares (Mha) with annual production of 5.62, 11.86 and 283.74 million tonnes (Mt) in Madhya Pradesh, India and World respectively during 2013-14. However, despite of available potential varieties the average productivity of this crop is around 897 kg $ha^{-1}$ in M.P. and 971 kg $ha^{-1}$ at national label which is very low as against world average productivity of 2.50 t $ha^{-1}$. This may be attributed to a variety of factors like pest incidence, uneven and erratic rainfall , imbalance use of nutrients and inadequate BNF resulting from poor rhizobial activity due to short supply of micronutrients responsible for nitrogen fixation through host-*Rhizobium* symbiosis. In order to study the effect of various micronutrients and FYM along with *Rhizobium and PSB* inoculation on symbiotic traits, yield attributes, nutrient uptake, quality, and yield of soybean in Vertisol, field experiments conducted during 2013 and 2014 at RAK College of Agriculture, Sehore, M.P. in *kharif* season on soybean variety JS 335. The treatments includes $T_1$: RDF (recommended dose of fertilizer) 20:60:20:20, N:$P_2O_5$:$K_2O$:S kg $ha^{-1}$ , $T_2$: RDF + *Rhizobium* + *PSB inoculation*, $T_3$: RDF + $ZnSO_4$ 25 kg $ha^{-1}$+ *Rhizobium*+ *PSB inoculation*, $T_4$: RDF+ ammonium molybdate 1g $kg^{-1}$ seed +*Rhizobium* +*PSB* inoculation, $T_5$: RDF+ borax 5 kg $ha^{-1}$ + *Rhizobium* + *PSB* inoculation, $T_6$: RDF + $FeSO_4$ 10 kg $ha^{-1}$+ *Rhizobium* + *PSB* inoculation, $T_7$: RDF+$MnSO_4$ 25kg $ha^{-1}$ +*Rhizobium* +*PSB* inoculation, $T_8$: RDF +FYM 5t $ha^{-1}$+*Rhizobium*+*PSB* inoculation. Eight treatments were replicated thrice in a randomized block design. The soil of experimental field was medium black Vertisol low in organic carbon (0.40%) and available nitrogen (215.3 kg $ha^{-1}$), medium in available phosphorus (13.2 kg $ha^{-1}$), high in potassium (455.2 kg $ha^{-1}$), pH 7.5, EC 0.30 dS $m^{-1}$ and with available S, Fe, Zn, Mn and Mo content value of 9.4 11.2, 0.51, 5.8 and 0.02 ppm (low Mo), respectively. The results obtained indicates that various treatments which includes the use RDF + dual inoculation of *Rhizobium*+*PSB* and application of RDF+ micronutrients *viz*., Zn, Mo, B, Fe, Mn and organics i.e. FYM along with *Rhizobium*+*PSB* (Treatments:$T_2$ to $T_8$) could significantly increase the nodulation, pods $plant^{-1}$, seed yield (10.0 to 20.5% over RDF yield of 1.45 t $ha^{-1}$), straw yield, crude protein in seed, N, P, S, Fe, Mn, Zn and Mo uptake over the control (RDF alone). However, the micronutrients treatments of Zn, B, Fe and Mn along with RDF+*Rhizobium*+*PSB* ($T_3$,$T_5$,$T_6$ and $T_7$) were statistical identical with the treatment RDF+*Rhizobium*+*PSB* ($T_2$) in respect of grain yield enhancement. The treatments RDF+Mo (as ammonium molybdate 1g $kg^{-1}$ seed) along with *Rhizobium*+*PSB* ($T_4$) and RDF+ FYM 5t $ha^{-1}$ along with *Rhizobium*+*PSB* ($T_8$) were significantly superior even over the RDF +*Rhizobium*+*PSB* inoculation ($T_2$) in respect of grain yield enhancement (20.5 and 19.8% respectively over RDF grain yield of 1.45 t $ha^{-1}$). Further maximum additional net return of Rs 7966 $ha^{-1}$ obtained by the use of RDF+ ammonium molybdate 1g $kg^{-1}$ seed +*Rhizobium* +*PSB* inoculation over RDF alone.

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# Role of Microbial Inoculants in Preparation of Good Quality Compost

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In Punjab about 17.7 Mt of rice straw is produced annually after combine harvesting out of which 14.4 Mt is burnt. Burning causes, large losses of plant nutrients (80% N, 25% P, 21% K and 4-60% S), significant air pollution, killing of beneficial soil microorganisms and depletion of soil organic carbon. On the other hand, the cattle dung and urine are not properly handled and managed. There is no bedding material used to collect urine. Substantial amount of N, K and S present in cattle urine does not form a part of FYM. Rice straw soaks 3-4 times urine of its dry weight and can be effectively used as bedding under animals. The proper ratio of mixing rice straw, fresh animal dung and urine for compost making through microbes has not yet been worked out. Keeping these things in mind, twenty on farm trials were conducted by KVK Moga at farmers fields. After harvesting of rice with combine, loose straw was collected. The straw was chopped with fodder cutting machine and spread under animals @ 5, 10 and 15 kg per animal per day. The straw was collected and 4 piles were made with 5, 10 and 15 kg straw each, totaling of 12 piles. Seventeen kg fresh cow dung and 8 litres of urine were added to each pile. *Azotobactor* @ 2.5%, *Tricoderma viride* @ 2.5% and combinations of the both were added to each pile along with control. Periodic weighing of each pile was recorded. Samples of compost at different intervals were taken and analysed in the Department of Soil Science, Punjab Agricultural University Ludhiana. The C:N ratio of the compost prepared with *Azotobactor* treatment was narrow indicating that non symbiotic atmospheric nitrogen was fixed which improved the quality of the compost compared to control. When the amount of rice straw was increased the composting process was delayed by 10-20 days. However, there was no significant difference in the compost quality with respect to dose of the rice straw. The C: N ratio of *Trichoderma viridi*, *Azotobacter* and a combination of both treatments was 14.80, 15.43 and 14.25 as compared to the control (15.70). Nitrogen content of the compost was 1.53, 1.52 and 1.47 times under *Tricoderma virdi+ Azotobactor*, *Tricoderma virdi* and *Azotobactor* treatments compared to control respectively. Maximum population of bacteria and fungus was found in *Trichoderma virdi* and *Azotobactor* treatments.

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# Appraisal of Methods for Measuring Soil Microbial Biomass Carbon in Temperate Fruit Tree-based Ecosystems

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The measurement of microbial biomass is a basic procedure for soil ecological studies. Therefore, it is important to have an accurate and rapid method to measure microbial biomass carbon (MBC). The chloroform fumigation-extraction (CFE) method is used by most researchers, but it is quite tedious and produces erroneous results. The substrate-induced respiration (SIR) method is a simple, rapid and economical method to determine MBC in soils but, also not beyond criticism. We investigated the abilities of three methods of quantifying microbial biomass carbon *viz.,* chloroform fumigation-extraction (CFE) following organic C estimation through Vance method (CFE-V) and Snyder-Trofymow method (CFE-ST), and substrate-induced respiration (SIR) method in soils under various temperate fruit crops namely apricot, peach, plum and cherry along with a control (no-plantation) at two different depths (0–20 and 21–40 cm). We also intended to study the relationship of these different methods of biomass C estimation with some soil chemical properties. Chloroform labile organic C varied from 307 to 1000 mg $kg^{-1}$ soil measured with CFE-ST method and from 586 to 1198 mg $kg^{-1}$ soil measured with CFE-V method, whereas, MBC measured by SIR method raged between 242 to 1064 mg $kg^{-1}$ soil in the above said orchards. CFE methods have shown significant ($p$<0.05) increase in chloroform labile C in all orchards as compared to the control in surface soil. Same was the case with SIR method also. The interaction between the fruit crops and methods, although significant ($p$<0.01), indicated that CFE-ST and SIR methods were statistically at par with each other within the same fruit crop, except peach plantation (CEF-ST significantly lower than SIR) in 0 to 20 cm soil depth. However, paired $t$-test has resulted significant differences in mean chloroform labile C estimates by CFE methods, and MBC by SIR method. The coefficient of variation recorded for MBC estimates by SIR method makes it more precise than the other two methods. The correlation study also confirmed that the SIR had the strongest correlation with soil organic C content. The other two methods also showed significant correlation with soil chemical parameters. More than 90% (91.7 to 99.0%) of the variations in different methods of biomass C estimation could be explained by the independent variables considered in 21 to 40 cm soil depth; whereas, the influence of the independent variables in the variability of chloroform labile C estimates was much narrower (66.8 to 81.3%) in 0 to 20 cm soil depth. Among the three methods, as SIR was found to be most sensitive to orchard plantations, and more specific to soil organic C could be recommended for estimation of MBC in such soils. As an alternative to CFE-V method, CFE-ST may also be used for estimation of chloroform labile organic C in soil.

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# Soil Organic Carbon, Dehydrogenase Activity and Fluorescein Diacetate as Influenced by Contrasting Tillage and Cropping Systems in Vertisols of Central India

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The present study was aimed to compare the effects of different tillage system (conventional, reduced and no-tillage) and cropping systems (soybean + pigeon pea (2:1), soybean —wheat, maize + pigeon pea (1:1), maize —gram) on soil biological environment in terms of soil organic carbon, $KMNO_4$ extractable soil carbon, dehydrogenase activity (DHA) and fluorescein diacetate (FDA) hydrolysis. Soil samples were collected after three crop cycles from the layer of 0-5 cm and 5-15 cm depth. Within tillage system, SOC was reported higher in reduced tillage (0.67%), compared to no-tillage (0.66%) and CT (0.62%) at 0-5 cm. At 5-15 cm depth, reduced tillage (0.57%) and no-tillage (0.58%) registered significantly higher SOC compared to CT (0.52%). The $KMNO_4$ extractable organic carbon in surface soil (0-5 cm) was followed same trend of SOC, whereas at 5-15 cm depth, it follows the trend of no-tillage>reduced tillage> conventional tillage. Further, both tillage and cropping systems significantly affect this fraction of carbon at both the depths. Moreover, soil enzymatic activity was significantly affected by the imposed tillage system. The dehydrogenase activity was reported 15 and 66 per cent higher in no-tillage system compared to reduced tillage and conventional tillage; whereas fluorescein diacetate hydrolysis was reported higher in reduced tillage followed by no-tillage and conventional tillage at surface soil (0-5 cm). Pearson correlation (r) showed significant correlations between soil organic carbon and studied soil biological parameters. The results of this study also confirmed effectiveness of studied parameters as soil indicators owing to sensitiveness towards management practices.

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# Soil Microflora under Sugarcane Multiratooning in Different Soil Textural Classes of North Coastal Zone, Andhra Pradesh

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Sugarcane cultivation in India is characterized by raising of as many number of ratoons owing to its substantially low cost of production. Such a approach for a long duration production system, often leads to significant deterioration in soil health. Hence, the present study was formulated to study the effect of sugarcane multiratooning on sugarcane rhizosphere microflora and soil fertility in different textural classes of popular sugarcane growing areas of Visakhapatnam district of Andhra Pradesh. Three major soil types (sandy loam, red loam and clay loam) with 30 surface and 30 subsurface soil samples from selected soil types were collected from plant crop, 1st, 2nd, 3rd and 4th ratoons. Results revealed that, among different textural soils, highest rhizosphere microflora were recorded in clay loam soils than sandy loam and red loams. Irrespective of the soil type, surface soil (0-30 cm) recorded highest microflora compared to subsurface soil (30-60 cm). Compared to plant crop succeeding ratoons exhibited highest microbial counts in all the soils. In sandy loam soils *Azospirillum* counts ranged between $69 \times 10^4$ (plant crop) to $163 \times 10^4$ c.f.u. $g^{-1}$ soil (4th ratoon) in surface soil, whereas in subsurface it varied from $89 \times 10^4$ c.f.u. $g^{-1}$ soil (plant) to $119 \times 10^4$ c.f.u. $g^{-1}$ soil (2nd ratoon). Highest *Azatobactor* counts of $350 \times 10^4$ c.f.u. $g^{-1}$ soil were recorded in subsurface soil of 2nd ratoon and lowest counts ($56 \times 10^4$ c.f.u. $g^{-1}$ soil) were recorded in subsurface soil of Ist ratoon followed by surface soils of plant crop ($85 \times 10^4$ c.f.u. $g^{-1}$ soil). Phosphorus solubilizing bacteria in surface soil varied from 55 to 101, whereas in subsurface it was $18 \times 10^4$ c.f.u. $g^{-1}$ soil (2nd ratoon) to $101 \times 10^4$ c.f.u. $g^{-1}$ soil (4th ratoon). In clay loam soil highest *Azospirillum* counts were recorded in subsurface soil of plant crop and lowest counts were recorded in subsurface soils of 4th ratoon. Regarding phosphorus solubilizing bacteria highest and lowest counts were recorded in subsurface soil of 1st ratoon and subsurface soil of 4th ratoon, respectively. In red loam soils highest counts of *Azospirillum*, *Azatobactor* and phosphorus solubilizing bacteria were recorded in sub-surface soil of 2nd ratoon, surface soil of 4th ratoon and surface soil of 4th ratoons, respectively. The changes in microbial counts are usually in response to organic matter cycles within the soil. Microbial population fluctuates due to changes in available carbon substrates and nutrients. After harvesting at the end of ratoon crop there is amendment or incorporation of huge crop residue per hectare. This crop residue is adding organic carbon in the soil and might be responsible to induce the changes in soil microflora. This may be the reason for hasten up of microbial counts under multiratooning of sugarcane. In conclusion, our findings indicated that the microbial population was not influenced with multiratooning where as soil physical properties and fertility status under monocropping were negatively influenced with increasing frequency of ratooning in all the textural classes. However, more influence was observed under clay loam soils compared to sandy loams.

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# Mechanized and Traditional Farming of Farmer's Field on Physicochemical Characteristics of Soil under Different Land Use

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The field investigation in relation to mechanized and traditional farming systems on physicochemical characteristics of soil and their correlation between mechanized and traditional farming systems with soil properties under different land use" was carried out at four locations of Nagpur district during 2015-16. The different land uses were seasonal crop-maize, annual crop-cotton and perennial crop Nagpur mandarin. Soil samples were collected from mechanized and adjacent traditional farming adopted farmer's fields since from last five years in each land use at all the locations. Three depths of soil samples were collected randomly from all the fields (0-20, 20-40 and 40-60 cm). The results revealed that, the intensive mechanization without addition of organic matter and mechanized tillage at the same depth increased the bulk density, reduced the total soil porosity, per cent water stable aggregates (>0.25 mm) and ultimately the hydraulic conductivity of soil in all the land use systems. The soil reaction (pH) and electrical conductivity (EC) were not influenced by mechanization in surface soil but below the tillage depth there was drastic increased in pH and EC in all the land use compared to adjacent traditional farming fields. The organic carbon content was found lesser in intensively mechanized farming systems without addition of organic matter. The higher available N was found more under traditional farming systems and available P in mechanized farming systems with more fertilizer and organic manure added soils over each other. The available K was not altered by mechanization but mainly influenced by fertilizer rates. In general the available N, P and K were lesser in seasonal crop maize growing soils than annual crop cotton and perennial crop Nagpur mandarin, because maize is highly nutrient exhaustive crop. The soil microbial biomass carbon and permanganate oxidizable carbon were found lower in intensively mechanized fields without addition of organic matter than the traditionally less tilth soils. The intensively mechanized farming systems without addition of organic matter deteriorating the soil physical and chemical properties both in surface and subsurface soils, whereas, traditional farming with minimum shallow tillage improves these properties. In seasonal cropping systems the tractor movement and farming operations are more as compared to annual cotton and perennial Nagpur mandarin growing soils. Crop residue incorporation by maize was also less as compared to annual and perennial cropping systems. The maize is highly nutrient exhausting crop and hence the macro nutrient availability is lower as compared to cotton and Nagpur mandarin growing soils. Conservation of soil quality in terms of both physical and chemical properties we have to go for minimum tillage operations, avoiding of the mechanized operations on moist soil, addition of adequate amount of organic matter, vary the tillage depth every year, add optimum amount of inorganic fertilizers to sustain the productivity in all the land use systems.

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# Soil Quality Assessment through Minimum Dataset under Different Land Uses of North-Western Tract of India

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Degradation of soil quality is major challenge in the north-western tract of India, due to ill distribution of rainfall in time and space, structurally poor, highly erodible soils, deep to very deep water table and undulating topography. This is posing great threat to inherent capacity of the soil ie soil quality, which may be defined as the capacity of the soil to function within the ecosystem boundaries to sustain biological productivity, maintain environment quality and promote plant and animal health. Soil quality integrates soil physical, chemical and biological attributes into the framework for soil resource evaluation. To improve soil quality and maintain the sustainability and productivity of soil in the area requires comprehensive assessment of soil quality. So, with this a study was carried out to addresses the selection of most appropriate soil quality indicators and to know the status of soil quality in the north-western tract of India under different land uses. Principal component analysis (PCA) approach was used to get the minimum data set form the large existing data. Geo-referred soil samples (0-20 cm depth) were collected from five different land uses ie crop land, horticultural land, plantation crop, grassland and fallow land, on a 100 by 100 m grid across the 150 ha watershed of zonal research station for Kandi area, Ballowal Saunkhari, Shahid Bhagat Singh Nagar and analysed for different physical, chemical and biological attributes. PCA was performed on the measured attributes, which screened the six principal components (PC) with eigen-value >1. These six PCs explained 62.65% of total variation. Varimax rotation with Kaiser Normalization identified soil organic carbon, electrical conductivity, silt, sodium, calcium and available water as most important indicators to evaluate soil quality. Indicators were transformed into scores (linear scoring function), on a scale of 0-1 and weight is obtained from the PCA, which were again integrated to obtain a single soil quality index value under different land uses. Soil quality index was obtained highest in crop land (0.71) followed by plantation crop (0.69), horticultural crop (0.65), grassland (0.61) and fallow land (0.59). Electrical conductivity contributed highest in soil quality *i.e.* 29.03% followed by organic carbon, (24.11%), silt content (15.50%), sodium (13.19%), calcium (11.88%) and available water (6.29%). It is evident from the results that study area fall under the medium soil quality. Conclusively, electrical conductivity and organic carbon content holds key to improve the soil quality. Thus, to improve soil quality and productivity of the area appropriate measures need to be taken to maintain the carbon, nutrients and water status in the soil.

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# Land Use Options and Soil Site Suitability for Sugarcane-growing Alfisols, Inceptisols, Entisols and Vertisols of Semi Arid Tropics of Telangana

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A reconnaissance soil survey was undertaken in sugarcane growing red soils, red laterite soils and black soils of semi arid tropics of Telangana to evaluate the soil suitability characteristics for developing the strong soil resource database for proper appraisal of their productivity potential and their rational use. This study was an embodiment with an objective of land use options and crop suitability of some sugarcane growing red soils, red laterite soils and black soils. Land capability classification was done based on the inherent soil characteristics, external land features and environmental factors. The red and red laterite soils of sugarcane cane growing area fall under one land capability class with three subclasses, *viz.,* 'III stef' and 'III tsdef' due to the limitations of slope, texture, soil depth, coarse fragments and soil fertility. The black soils fall under 'III swef' land capability sub-class due to the limitations of drainage, texture, erosion and soil fertility. Four fertility capability units were identified in the study area. The conditions modifiers identified in the study area were'd' dryness, 'v' high clay content, 'b' basic reaction, and 'h' acid but not Al-toxic. The condition modifier'd' dominated in its occurrence followed by the condition modifier 'h', 'v' and 'b'. The land evaluation for crop suitability indicated that the black soils were moderately suitable to highly suitable, red soils were marginally to moderately suitable and red laterite soils are marginally suitable for cultivation of sugarcane. Soil productivity can be improved by the maintenance of enhanced soil fertility, addition of organic matter, proper drainage facilities, reduced sub surface crusting and erosion control practices.

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# Land Evaluation of Halayapura Micro Watershed of Tumkur District Karnataka, using Remote Sensing and GIS

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Land evaluation studies such as land capability classification and land suitability for major crops are essential for planning appropriate measures to sustain productivity. An attempt was made to prepare land capability classification and land suitability studies for Halayapura 1 micro watersheds located at North latitude 11°40′58″ and 12°06′32″ and East longitude 76°24′14″ and 77°46′55″ covering an area of about 503 ha in Tumkur district, under southern transition zone of Karnataka using remote sensing and GIS techniques. The detailed soil characterization resulted in four soil series which were evaluated for land capability classification and land suitability. The four soil series were grouped into twenty six soil phases. Land capability classification was worked out for these twenty six soil phases which showed II and III classes. Twenty two soil phases belongs to land capability class II having four subclass, IIs occupied 166 ha (32.9%) of the study area. These soils had none to slight limitations ranging from slope, erosion, drainage, depth, texture, coarse fragments, $CaCO_3$, pH and organic carbon. Four soil phases belongs to class III having two subclass, IIIes occupied 57 ha (11.4%). Soil site suitability evaluation for field crops like ragi, ground nut, red gram, castor and horticulture crops like coconut, areca nut mango, sapota, guava, marigold showed that some of soil series were highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable for some soil phases. Major proportion of the study area belonged to land capability class IIs followed by IIes, IIew, IIIes, IIw, IIIs respectively in the order of land capability rating. The land evaluation will help plan for most suited crops resulting the enhanced productivity.

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# Influence of Different Levels of Irrigation and Nitrogen on the Yield and Quality of Capsicum under Mulch Condition

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A field experiment was carried out to find the effect of different irrigation and nitrogen levels on the yield and quality of capsicum and water expense efficiency under mulch condition in loamy sand soil at Punjab Agricultural University, Regional Research Station, Bathinda during 2011-14. The experimental field was non saline and alkaline in reaction having EC 0.143 dS $m^{-1}$ and pH 8.4, organic carbon (2.5 g $kg^{-1}$), available phosphorus 13.1 kg $ha^{-1}$ and available potassium 364 kg $ha^{-1}$. The treatmens comprising with three levels of irrigation *viz*. $I_1$ = 0.6, $I_2$ = 0.9 and $I_3$ = 1.2 IW/CPE and three levels of nitrogen as $N_1$ 100 kg, $N_2$ 125 kg and $N_3$ 150 kg $ha^{-1}$ was applied under no mulch and mulch (rice straw) condition in different 18 treatments combinations in split plot design with three replications. The rice straw mulch @ 6 t $ha^{-1}$ was applied under study. During the years under experimentation, capsicum was transplanted during mid February and harvested in the month of July. The recommended package and practices of Punjab Agricultural University were followed for raising the crops. The results of the experiment revealed that the rice straw mulch application @ 6 t $ha^{-1}$ significantly increased the capsicum yield. Application of nitrogen significantly improved the capsicum yield up to level of 125 kg N $ha^{-1}$ under mulch and 150 kg N $ha^{-1}$ under no mulch condition, respectively. Application of irrigation at IW/CPE = 1.2 has shown significant effect on capsicum yield as compared than $I_1$ and $I_2$ levels of irrigation. The highest water expense efficiency was observed at $I_3$ = 1.2 IW/CPE level of irrigation and $N_3$ 125 kg $ha^{-1}$ level of nitrogen under mulch condition. The highest dry matter (%) was also observed under $I_3$ irrigation and $N_3$ level of nitrogen under mulch condition.

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# Effect of Tillage, Residue and Nitrogen Management on Grain Yield and Water and Nitrogen Use Efficiency of Wheat in an Inceptisol

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Farmers usually adopt conventional tillage system involving excessive tillage operation with increased application of fertilizers and irrigation to attain higher productivity. But these practices usually lead to degradation of soil by depleting organic matter, deteriorating its structure, formation of subsurface hard pan, and decreased fertility of soil. Thus, there is a need to adopt conservation agricultural practices to maintain soil health, attain sustainable production, and to provide economic benefit to the farmers. There is also a need to optimize the nitrogen (N) and irrigation management with respect to various tillage and residue management practices for achieving higher input use efficiency. In this backdrop, field experiments were conducted during *rabi* season for two years (2014-15 and 2015-16) on wheat cultivar HD-2967 in a sandy loam soil at the research farm of the Indian Agricultural Research Institute, New Delhi with the objective to study the effect of tillage, residue and N management on the grain yield, water use efficiency (WUE), N uptake and N use efficiency of wheat. The treatments comprising of two levels of tillage as main plot factor (conventional tillage (CT) and no-tillage (NT)), two levels of residue as subplot factors (maize residue @ 5 t $ha^{-1}$ ($R_+$) and without residue ($R_0$)), and three levels of N as sub-sub plot factors (60, 120 and 180 kg N $ha^{-1}$, representing 50%, 100% and 150% of recommended dose of N, respectively), were evaluated in a split-split plot design with three replications. During the year 2015-16, very low rainfall was received (2.8 mm) compared to the year 2014-15 (315.8 mm). The average maximum temperature during the year 2015-16 was also higher than that of the year 2014-15. It was observed that irrigated wheat crop under stress free weather conditions (2014-15) produced better grain and biomass yield than that of the year 2015-16. During the year 2014-15, the grain yield under conventional tillage and no tillage treatment, responded upto 120 kg N $ha^{-1}$ but under temperature and moisture stress condition (2015-16), the crop under no-tillage performed better and responded upto180 kg N $ha^{-1}$. However, under both the years, the grain and biomass yield of wheat with120 and 180 kg N $ha^{-1}$ were significantly higher than that of 60 kg N $ha^{-1}$. The mean evaporation flux under mulched condition (0.56 cm $day^{-1}$) was significantly lower than the un-mulched treatment (0.74 cm $day^{-1}$) but the deep percolation loss under mulched treatment (17.7 cm) was more than that of un-mulched (13.3 cm) treatment. Tillage and residue management did not influence WUE and N uptake of wheat significantly, but WUE and N uptake by grain and straw increased significantly with increase in N levels. Similarly, tillage and residue management effect on NUE and PFPN of wheat was not significant, but they decreased with increase in N levels. There was no significant interaction between tillage, residue and N management on grain and biomass yield, WUE, N uptake, NUE and PFPN of wheat. So, there is a need to revise fertility ratings for irrigated wheat crop grown in Inceptisols, particularly under low rainfall and high temperature condition. As there was no significant difference between conventional tillage and no tillage, farmers could successfully adopt no-tillage system with crop residue mulch to get economic benefit by saving fuel, implements and labour.

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# Effect of Cow Urine and Bio-fertilizers-based Fertigation Schedule at Varying Levels of Drip Irrigation on Yield, Nutrient Uptake and Economics of Cucumber under Protected Condition

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An experiment was conducted in a naturally ventilated polyhouse during summer 2015 on cucumber (*Cucumis sativus)* in the Water Management Farm, Department of Soil Science, CSK HPKV, Palampur. The experiment was conducted in a randomized block design with treatments comprising of (a) two drip irrigation levels *viz.,* $I_2$(IW/CPE = 0.4) and $I_4$ (IW/CPE = 0.8), (b) five fertigation treatments *viz*., $F_1$= 50% and $F_2$= 100% NPK (nitrogen, phosphorus and potassium) doses, 1/3rd N, full P and K applied as basal and 2/3rd N through fertigation+*Azotobacter*+ PSB (phosphate solubilizing bacteria)+ 5% cow urine, $F_3$= 50% and $F_4$= 100% NPK doses (1/4th N, P and K) applied as basal and 3/4th NPK through fertigation+*Azotobacter*+PSB+5% cow urine, $F_5$= 100% RDF through water soluble fertilizers (RDF= 100:50:60), (c) farmers' practice – FYM @ 1 kg $m^{-2}$ + 10 $g^{-2}$ IFFCO(12:32:16) + 2 g $L^{-1}$ of 19:19:19 at 15 days intervals and drip irrigation applied at rates 2 L $m^{-2}$ daily.

The results revealed that the yield was statistically higher in different treatments compared to farmers' practice (4.47 kg $m^{-2}$) except treatments $F_3I_2$ and $F_3I_4$ which were statistically at par with the farmers' practice. The highest yield was recorded in $F_2I_4$ (7.61 kg $m^{-2}$). Similarly, the gross return and B:C ratio were highest in treatment $F_2I_4$ having respective values of Rs.152.20 and 2.68 and were lowest under farmers' practice (Rs. 89.44 and 1.16, respectively). However, the irrigation levels didn't influence the marketable yield as indicated by the yield values which were statistically at par for both $I_2$ and $I_4$. The total plant nutrient uptake determined at harvest indicated that treatment $F_2I_4$ was having statistically highest NPK uptake with respective values of 124.4, 41.09 and 116.0 kg $ha^{-1}$.The overall results indicated that combined application of biofertilizer along with fertilizer has positive effect on yield and nutrient uptake due to addition of nutrients and hence can be exploited as a sustainable approach under integrated nutrient management.

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# Effect of Irrigation and Nitrogen Regimes on Performance of Dry Direct Seeded Rice

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A field experiment was conducted at the research farm of the Department of Soil and Water Engineering, Punjab Agricultural University, Ludhiana, during *kharif* 2015 to study the effect of irrigation and N regimes on performance of dry direct-seeded rice (DDSR). The treatment included combination of five irrigation regimes [5 cm amount of irrigation at 2 days interval ($I_1$), drip irrigation of 2.5 cm at 10 kPa soil matric tension ($I_2$), drip irrigation of 2.5 cm at 20 kPa soil matric tension ($I_3$), drip irrigation of 2.5 cm at 30 kPa soil matric tension ($I_4$) and drip irrigation daily 1.5 times deficit ETc ($I_5$)] in main plots and four N levels [0 kg N $ha^{-1}$ ($N_0$), 90 kg N $ha^{-1}$ ($N_1$), 120 kg N $ha^{-1}$ ($N_2$) and 150 kg N $ha^{-1}$ ($N_3$)] in sub-plots in split plot design. Irrespective of N regimes, it was observed that the plant height was significantly greater in $I_5$ and $I_2$ irrigation treatments than all other irrigation treatments. Leaf area index was significantly higher in $I_5$ than $I_1$, $I_3$ and $I_4$ at 60 days after sowing where as results were at par when compared to $I_2$ at all growth stages. At 85 days after sowing leaf to stem ratio was significantly lower in $I_5$ compared to other irrigation treatments with values of 2.7, 4.1, 6.8 and 14.9 per cent lower than $I_2$, $I_1$, $I_3$ and $I_4$ irrigation treatments respectively. Irrespective of irrigation treatments, plant height was found to be significantly more in $N_3$ than $N_0$, $N_1$ and $N_2$ nitrogen levels. At the time of harvesting maximum plant height was found under $N_3$ (90.1 cm) which was 23.3, 12.8 and 5.5 per cent higher than $N_0$ (69.1 cm), $N_1$ (78.6 cm) and $N_2$ (85.1 cm) N levels, respectively. Application of higher levels of N significantly improved the leaf area index and decreased the leaf to stem ratio than the lower levels of N treatment throughout the cropping season. The rice yield was significantly influenced by irrigation and nitrogen regimes. Irrigation treatment $I_2$ and $I_5$ showed significantly higher grain yield compared to other irrigation treatments. Maximum grain yield was observed under treatment $N_3$ which was 14.4, 35.4 and 49.8 per cent higher over treatment $N_2$, $N_1$ and $N_0$, respectively.

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# Effect of Residue Management Tillage and Irrigation Levels on Soil Physical Characteristics

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Adoption of proper tillage and residue management practices is necessary for sustaining productivity. Therefore, field study was conducted during *rabi* 2012-13 in ongoing experiment initiated during 2009 in sandy loam (SL) and loamy sand (LS) soils separately at research farm, Department of Soil Science, Punjab Agricultural University, Ludhiana. The treatments included four tillage practices *i.e.*, no-tillage with residue (NTR), no-tillage without residue (NT), roto-tillage (RT) and conventional tillage (CT) in mail plots and three irrigation levels based upon IW/PAN-E ratios 1.2 ($I_1$), 0.9 ($I_2$) and 0.6 ($I_3$) in sub plots in split plot design. Irrespective of irrigation levels, results indicated that NTR compared to CT under both sandy loam and loamy sand soils, resulted in lower bulk density (1.56 vs 1.66 and 1.60 vs 1.70 Mg $m^{-3}$), lower penetration resistance (PR) (1.85 *vs* 2.12 and 1.98 *vs* 2.23 MPa), higher mean weight diameter (0.87 *vs* 0.47 and 0.66 *vs* 0.34 mm), higher water stable aggregates (55.2 vs 32.0 and 50.3 vs 30.3%), respectively. NTR resulted in higher amounts of macroaggregates (0.25-2 mm) as compared to other tillage and residue management practices. The amounts of macroaggregates (%) under NTR, NT, RT and CT were 43.6, 33.8, 23.9 and 26.4 for SL soil and 42.5, 33.9, 26.5 and 27.3 for LS soil, respectively. Irrespective of tillage and residue management practices, PR varied significantly among irrigation levels for both SL and LS soils. PR decreased with the increase in IW/PAN-E ratio (0.6 to 1.2). For both SL and LS soils, the PR (MPa) was observed to be maximum under CT (2.79 and 2.79 MPa) with $I_3$ and least in NTR (0.90 and 1.03MPa) with $I_1$.

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# Impact of Climate Change and Management Interventions on Wheat Yield, Water Use Efficiency, Water and Nitrogen Stress

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Field experiments for six seasons of present time slice (2008–09 to 2013–2014) and simulations with CERES-Wheat model for present time slice, PTS (1989-2013) and mid century, MC (2021-2050) were carried out to understand the effect of management interventions (three planting dates, two varieties and two irrigation schedules) and climate variation, especially temperature, on wheat yield, water use efficiency (WUE) and water and nitrogen stresses. In field experiments, the treatments effect of year, date of planting, variety and irrigation; and interactions were significant at $p \leq 0.05$. The interactions confirm that growing of longer duration varieties in last week of October with adequate irrigation, medium to longer duration in 1st week of November is the practical adaptive measure to minimize impact of temperature variability on wheat yield. The WUE based on ET and applied irrigation water was more in the years when transpiration and rainfall were more or applied irrigation water was less or crop duration is shortened. In mid century wheat yield in different time slices would be reduced (17-27%) by shortening of crop duration (1-11 days), due to increased Tmax (0.4-2.9 ºC) and Tmin (1.0-1.8 ºC) compared to PTS. In MC, there was an increase of yield by shifting planting dates by 15 (D2) and 30 (D3) days as compared to that planted in last week of October (D1). In MC, WUE was reduced by 14.8 per cent compared to PTS. Like yield, WUE was also increased by delaying planting date in MC. In the present study 4% reduction in wheat yield in I2 treatment compared to I1 was because of 7% water and 6% nitrogen stress. In MC wheat showed relatively higher water stress than PTS. Delaying planting date of wheat crop by 15–30 days in this region during mid century emerges as the best adaptation measure to tackle climate change impact for sustaining yield and having higher water use efficiency.

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# Interactive Effect of Phosphorus and Types of Salinity on Chemical Composition of Tomato

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Tomato (*Lycopersicon esculentum*) is the major vegetable crop throughout the world. Tomato is moderately tolerant to salinity and can perform well under ECe up to 4-6 dS $m^{-1}$. Studies showed that there were positive effects between soil salinity and amount of phosphorus consumption in improving plant functions. Thus the present research work had been planned to study the interactive effect of phosphorus and types of salinity on yield and chemical composition of tomato. The experiment was laid out in screen house by taking two types ($Cl^-$ and $SO_4^{2-}$ dominated) and levels of salinity (0 and 6 dS $m^{-1}$) along with four levels of P (0, 12.5, 25 and 50 ppm) in completely randomized design having three replications. The fruit yield increased from 0.11 to 1.45 kg $pot^{-1}$ and 0.27 to 1.59 kg $pot^{-1}$ in chloride and sulphate dominated salinity, respectively, as the P levels increased from 0 to 50 ppm. The TSS decreased significantly with increase in applied P levels from 0 to 50 ppm in soil, from 10.5 to 6.0 Brix (43%) and 11.67 to 7.0 Brix (40%) in chloride and sulphate dominated salinity, respectively. The firmness increased significantly with increase in applied P levels from 1.67 to 3.26 (95%) and 1.77 to 3.85 (117%), in chloride and sulphate dominated salinities, respectively. Ascorbic acid decreased from 29.3 to 21.0 mg $100g^{-1}$ and 25.6 to 20.0 mg $100g^{-1}$ in chloride and sulphate dominated salinity, respectively, as the P level increased from 0 to 50 ppm in soil. As the P level increased, titratable acidity decreased from 0.80 to 0.65% and 0.77 to 0.63% in chloride and sulphate dominated salinity, respectively. The plant $Cl^-$ content decreased from 2.95 to 1.73%, 7.61 to 6.41% and 5.78 to 4.66% as the added P level increased from 0 to 50 ppm in soil in non-saline control, chloride salinity and sulphate salinity, respectively. The Sulphate-Sulphur content of plant was significantly increased by increasing level of P irrespective of levels and types of salinity. However, values of all these fruit quality parameters decreased with increased application of P due to stress mitigation by P under saline soil conditions. A synergistic relationship between P and $SO_4^{2-}$ and an antagonistic one between P and $Cl^{-1}$ ions was established.

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# Water Conservation Measures on Farm Production in NICRA Adopted Eastern Indian Villages

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During last few decades major and important issue in agriculture is climate change. It is gradually becoming a serious Indian concern too as most of India's population depend on agriculture for their livelihood. In India, significant negative impacts have been implied with medium-term (2010-2039) climate change which includes reduction of crop yields by 4.5 to 9.0 per cent. Farmers need to adapt to the changing climate in order to sustain crop yields and farm income. Enhancing resilience of agriculture to climate risk is of paramount importance for protecting livelihoods of small and marginal farmers. Traditionally, technology transfer in agriculture has aimed at enhancing farm productivity. Farmers need to adapt quickly to enhance their resilience to increasing threats of climatic variability such as droughts, floods and other extreme climatic events. Over the years, an array of practices and technologies has been developed by researchers towards fostering stability in agricultural production against the onslaught of seasonal variations. Adoption of such resilient practices and technologies by farmers appears to be more a necessity than an option. To reorient the whole gamut of technology transfer in Indian perspective, a national-wide initiative, namely, National Innovations on Climate Resilient Agriculture (NICRA) was taken up during the year 2011-12 and constant and critical reviewing of one of its important modules, *i.e.*, technology demonstration component (TDC) brought out some salient effects of technology demonstration which can lead to more resilience of Indian agriculture to the climatic vagaries. Out of 13 NICRA KVKs Bihar (7 KVKs) and Jharkhand (6 KVKs) selected a village and after preliminary baseline works, the agro-climatic characteristics were outlined for the purpose of future improvement of their livelihood. All areas were hot and dry. Crop production was very poor, farmers used local variety and only one crop was produced in a season in most of the villages under study. After NICRA project launched KVKs, University and ICAR scientists take the initiative to enhance the crop production and change their livelihood. Natural resource management is the major activities to change the cropping intensity in these villages. This module consists of interventions related to *in-situ* moisture conservation, rainwater harvesting and recycling for supplemental irrigation, improved drainage in flood prone areas, conservation tillage where appropriate, ground water recharge and water saving irrigation methods, mulching, crop residue recycling, land and soil health management.

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# Mapping of Water Quality and its Temporal Changes in *Musi* Project Command Area

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The *Musi* river, a tributary of the Krishna river flows through the city of Hyderabad getting mixed with city sewerage and carrying loads of nutrients and pollutants. The *Musi* project was constructed across *Musi* river, in Nalgonda district of Telangana state. The *Musi* project with a live storage of 130.31 $Mm^3$ (4.6 TMC) of water intended to irrigate cultivable command area of 13,360 ha per annum during *rabi* season, having major crops of rice, cotton and pulses. Water samples were collected in three different intervals during *rabi* 2012-13 from *Musi* project canals and distributaries from the entire command area to study the temporal variations in water quality starting from first release of canal water to the last release. The first set was collected during third week of November, 2012, second set during first week of February, 2013 and the third set was collected during last week of March 2013. Number of samples collected were 50, 92 and 110 in I, II and III sets respectively. Collected samples were analysed for different irrigation water quality parameters, nutrient elements and heavy metals and mapped by using krigging function in Arc GIS.

All the samples collected were alklaine in pH, and it got reduced from I set to the III set with mean values of 8.65, 8.45 and 8.21 in I, II and III sets, respectively. Samples having pH < 8.5 occupied 4.3, 99.2 and 94.4%, pH between 8.50 to 8.75 occupied 38.3, 0.8 and 5.6% and pH > 8.75 occupied 57.4, 0.01 and nil per cent in I, II and III sets respectively. All the samples collected were having EC in $C_3$ category and it decreased from I set to II set which again increased in III set more than I set, with mean values of 1.12, 1.08 and 1.23 dS $m^{-1}$ in I, II and III sets, respectively. Samples having EC < 1.0 dS $m^{-1}$ occupied 5.5, 39.4 and 3.6%, EC between 1.0 to 1.5 dS $m^{-1}$ occupied 94.1, 60.6 and 96.0% and EC > 1.50 occupied 57.4, 0.01 and nil per cent in I, II and III sets, respectively. The SAR was in $S_1$ category, which decreased from I set to II set, but again increased by III set, more than I set with mean values of 5.37, 4.36 and 5.60, respectively. Samples having SAR < 5.0 occupied 27.6, 100 and 24.0%, SAR between 5.0 to 7.5 occupied 72, Nil and 76% and SAR between 7.5 to 10.0 occupied 2.0, Nil and 0.01 per cent in I, II and III sets, respectively. The RSC ranged from safe to unsafe, which decreased from I set to II set, but again increased by III set with mean values of -0.198, -0.024 and 0.00, respectively. Samples having RSC < 1.25 (safe) occupied 99.0, 95.1 and 75.2%, RSC between 1.25 to 2.50 (slight to moderate) occupied Nil, 4.6 and 14.9% and RSC > 2.50 (unsafe) occupied 1.0, 0.3 and 10 per cent in I, II and III sets, respectively. The chlorides content ranged from slight to moderate to unsafe, which increased from I set to III set, with mean values of 7.08, 8.76 and 9.30, respectively. Samples having Cl < 4.0 me $L^{-1}$ (safe) occupied nil in all the sets, Cl between 4.0 to 10.0 me $L^{-1}$ occupied 100, 98.5 and 89.1% and Cl > 10.0 me $L^{-1}$ occupied nil, 1.7 and 10.9 per cent in I, II and III sets, respectively. The nitrates content ranged from slight to moderate to severe, which increased from I set to III set, with mean values of 25.2,

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25.6 and 30.5, respectively. Samples having $NO_3$ < 5.0 mg $L^{-1}$ (safe) were nil in all the sets, $NO_3$ between 5.0 to 30.0 mg $L^{-1}$ (slight to moderate) occupied 97, 100 and 36% and $NO_3$ > 30.0 me $L^{-1}$ (severe) occupied 3.1, nil and 64.4 per cent in I, II and III sets respectively. The other nutrient elements like phosphates, potassium and sulphates were also analyzed. The mean phosphate contents were 0.545, 0.495 and 0.658 mg P $L^{-1}$, potassium contents were 7.08, 11.95 and 12.1 mg K $L^{-1}$ and sulphate contents were 26.4, 22.58 and 24.8 mg S $L^{-1}$ in I, II and III sets, respectively. It indicated that the *Musi* water is carrying considerable amounts of nutrient loads of nitrates, potassium and sulphates and nominal amounts of phosphates which also increased from first release of water to the last release of canal water. Regarding the heavy metals, Pb was found to be in safe limits in all the three sets. The Ni and Cr contents were in safe levels in II and III sets and 0.45% and 1.40% of samples were in unsafe category in I set, respectively. The Cd content ranged from safe to unsafe levels ranging from traces to 0.002, traces to 0.003 and traces to 0.071 mg $L^{-1}$ in I, II and III sets, respectively. The percentage of samples under unsafe Cd level were nil in I and II set but it increased to 83.4% in III set. Similarly the Co contents ranged from traces to 0.045, traces to 0.014 and traces to 0.093 mg $L^{-1}$ and samples under unsafe category were nil in I and II sets but increased to 12% in III set. Thus, it was noticed that with advancement of *rabi* season, released *Musi* project canal water was found to be deteriorated in quality with regard to EC, RSC, chlorides and nitrates and not much affected with regard to EC and SAR. The water carried considerable quantities of N, K and S suggesting for reduction in their application to the crop through fertilizers.

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# Effect of Soil Erosion on Organic Carbon Stock in Undulating Terrain of Semi-Arid Tropics, Karnataka

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Organic carbon in soil sustains its physical, chemical and biological fertility; hence, the enrichment of carbon in soil improves the soil productivity. Assessment of organic carbon in soil is to understand its status and to plan improved management practices (IMP) further to increase the organic carbon stock. Soil organic carbon stock was assessed in severely eroded undulating landscape in Kolar district (Karnataka) which has the highest eroded land in southern Karnataka. Sampling sites were selected in transacts using satellite imageries (false colour composite) and respective topo-sheets. Three transacts were marked representing upland and lowland near Jangamakote (named as Jangamakote transact, JKT), Bakhtarahalli (named as Baktharahalli transact, BKT) and Bagalahalli (named as Bagalahalli transact, BGT) villages and five, two and two numbers of profiles were opened respectively then soil samples were collected horizon-wise. Bulk density was estimated through core sampling and organic carbon by wet digestion method. Soil organic carbon stock was estimated and expressed as kg $m^{-3}$. The soils of the region are red and lateritic. Land uses and land cover has determined the organic carbon storage in the region. Low rainfall with undulating terrain and poor soil and water management practices, the land cover management was poor and the erosion was severe. These factors are affecting the soil organic carbon stock in the region. Soil depth of the profiles varied from 55 cm to more than 150 cm in the region. Weighted average of organic carbon in the profile indicates that soils under natural forest maintained more carbon (1.22%) than the severely eroded skeletal soil (0.34%). Soil bulk density (weighted) was found maximum in skeletal soil which is severely affected with water erosion (1.69 Mg $m^{-3}$) and the minimum in cultivable fallow land (1.37 Mg $m^{-3}$). Soil organic stock was recorded highest in natural forest with 25.42 kg $m^{-3}$ under JKT followed by afforested slopy land (18.73 kg $m^{-3}$), intensively cultivable land (15.30 kg $m^{-3}$ ), cultivable fallow land (7.03 kg $m^{-3}$ ) and the lowest organic carbon stock (3.13 Mg $m^{-3}$) at moderate slope condition with severely eroded land in the same transact. Soil organic carbon stocks were 16.51 kg $m^{-3}$ in the *Eucalyptus* afforested mild slopy land and 15.48 kg $m^{-3}$ in the intensively cultivable summit flat land in the BKT transact. Under BGT, soil organic stock was 12.64 kg $m^{-3}$ in intensively cultivable land and 8.72 kg $m^{-3}$ in cultivable fallow land in the same transact. These eroded landscapes are devoid of vegetation in most of the areas and has huge scope for afforestation, agroforestry and intensive cultivation with appropriate soil and water conservation measures for increasing soil organic carbon stocks.

## Commission 3.3: Soil Fertility and Plant Nutrition

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# Nitrogen Management through *Gliricidia* in its Alley Cropping System

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The potential of nutrient-rich *Gliricidia sepium* pruned fresh leaves as manure has role in sustaining microbial diversity and crop productivity due to rich nutrient content and biological nitrogen fixation in soils of humid climate. With this background, an experiment was conducted to evaluate dose, method and time of application of fresh leaves/prunings for nitrogen cycling and yield of brinjal under *Gliricidia's* alley-cropping system at Sippighat Farm of Central Island Agricultural Research Institute, Port Blair, India. Results reveals that release of nitrogen was maximum (67.12 kg N $ha^{-1}$) within 30 days from sowing of brinjal, whereas fresh prunings biomass applied before one week of sowing of crop resulted in decline in N release with time and was lowest (6.68 kg N $ha^{-1}$) at 75 days. It seems that the rate of mineralization and nitrogen uptake synchronized best in a treatment which received prunings in soil before one week of sowing and facilitate both higher brinjal yield and microbial diversity compared to that in two and four week after sowing. Both yield (11.6 t $ha^{-1}$) and returns (2.14 B:C ratio) were highest when 5 t *Gliricidia* fresh lopping $ha^{-1}$ was applied. However, the 8 t of fresh lopping leaves were increased the 47.4 and 38.9 per cent organic carbon as source for microbial diversity and nitrogen, respectively over control. Therefore, the *Gliricidia-alley* cropping system seems comparatively more profitable and socially desirable besides maintaining the agrobiodiversity benefits, once it is established in fragile agro ecosystem of Andaman Island.

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# Phosphorus Nutrition in Maize under Conservation Practices

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A field experiment on maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) cropping system commenced in July 2013 at IARI Farm, New Delhi with twenty treatment combinations, using split-plot design. Treatments of main-plot were varying percentage of crop residue retention *i.e.* $T_1$: residue removal (no-residue), $T_2$: 25% crop residue, $T_3$: 50% crop residue, $T_4$: 75% crop residue and in sub-plot treatments were $S_1$: No-phosphours, $S_2$: 50% recommended dose of phosphorus (RDP), $S_3$: 100% RDP, $S_4$:150% RDP, $S_5$: 50% RDP + PSB+AM. Maize (*cv.* PHM-1) was sown in first week of July and harvested during end of October, 2015. Previous wheat crop was harvested manually from ground level and aboveground biomass/residues were retained in the plots. Maize crop was raised under assured irrigated condition, and prescribed weed and pest control measures were adopted. Plot-wise grain and plant samples were collected at the time of harvesting of maize.

Results of the study indicated that crop residue retention and P fertilization either alone or in combination enhanced the grain yield of maize over control (4.33 t $ha^{-1}$). Average grain yield of maize increased significantly from 5.42 t $ha^{-1}$ (No-CR) to 5.88 t $ha^{-1}$ (75% CR) with increasing rates of crop residue retention, whereas maximum grain yield of 5.88 t $ha^{-1}$ was recorded with crop residue retention @ 75% CR followed by 5.82 t $ha^{-1}$ (@ 50% CR). Application of 100% RDP was statistically at par with 100% RDP and 50% RDP + PSB + AM treatments, but these treatments were significantly higher as compared to 50% RDP. Integrated use of 50% CR + 150% RDP and 75% CR + 100% RDP resulted in similar grain yield of 6.37 t $ha^{-1}$ and 6.34 t $ha^{-1}$, respectively. The maximum total P uptake (23.7 kg $ha^{-1}$) was recorded with crop residue retention @ 75% CR followed by crop residue retention @ 50% CR (23.0 kg $ha^{-1}$) and least total P uptake (20.7 kg $ha^{-1}$) in control (No-CR). Among various P fertilization treatments, the mean maximum total P uptake (26.6 kg $ha^{-1}$) was recorded in 50% RDP + PSB + AM, followed by 100% RDP (25.4 kg $ha^{-1}$) and 150% RDP (24.2 kg $ha^{-1}$) treatments. The maximum agronomic efficiency of P in maize (34.7 kg grain $kg^{-1}$ P) was recorded in crop residue retention @ 25% CR followed by crop residue retention @ 50% CR (33.3 kg grain $kg^{-1}$ P) and least agronomic efficiency (30.8 kg grain $kg^{-1}$ P) in control (No-CR). The mean maximum agronomic efficiency of P in maize (51.2 kg grain $kg^{-1}$ P) was recorded with 50% RDP+PSB + AM. Significant decrease in agronomic efficiency of P in maize was recorded with increasing rates of P fertilization rates. Crop residue retention rates increased the PUE of maize from 17.2 (control) to 18.1 per cent (75% CR). PUE increased up to 100% RDP, after that, PUE in maize decreased significantly at 150% RDP. It is concluded that P application at 50% of recommended rate along with AM+PSB inoculation proved superior over other P supply options, indicating that microbial inoculation could help in curtailing fertilizer P application in maize crop.

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# Fertility Management in Rice Maize Cropping System in Sandy Loam Soils of North Coastal Zone

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A field experiment was conducted at RARS, Anakapalle to study the effect of fertility management in rice maize cropping system on yield, soil fertility status and uptake pattern of nutrients in rice and maize during the year 2011-2013. The experiment was laid out in randomised block design for rice during Kharif and split plot design for zero tillage maize during *rabi* season with three main levels and four sub levels. The main levels consists of green manure incorporation +100% NPK (M1), application of FYM @ 10 t $ha^{-1}$ along with 100% NPK (M2) and recommended dose of fertilizers alone (M3). The four sub levels for zero tillage maize during *rabi* consists of 80 kg N (S1), 120 kg N (S2), 160 Kg N (S3), 200 kg N (S4) along with FYM @ 25 t $ha^{-1}$. The recommended dose of fertilisers for the *kharif* rice are N + $P_2O_5$ + $K_2O$ and 100 kg N, 32 kg $P_2O_5$, 32 kg $K_2O$ $ha^{-1}$ for *rabi* zero tillage maize. The experimental field had sandy loam soil neutral in reaction, normal in conductivity, low in available N, medium in available P and high in K. The results of the experiment revealed that the highest grain and straw yields of rice was with the application of FYM @ 10 t $ha^{-1}$ while the maximum maize yields were with the application of FYM @ 25 t $ha^{-1}$ along with 200 kg N while the significant lower yields were observed with the control. The soil pH and EC did not show any significant variation while the organic carbon increased in the treatment where combined application of organic source (FYM) and inorganic source of fertilisers but the significant difference was not found. The available nitrogen, phosphorus and potassium was highest with the application of FYM @ 10 t $ha^{-1}$ along with RDF in rice while in maize it was with combined application of FYM and with 200 kg N. The uptake of nutrients by the rice was the highest with the application of FYM @10 t $ha^{-1}$ along with 100% NPK while in maize crop the maximum nutrient uptake was with the combined application of FYM @ 25 t $ha^{-1}$ along with 200 kg N.

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# Influence of Sewage Sludge Application on Soil Properties, Plant Contents and Yield of Wheat and Maize

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In India, estimated 33212 million litter per day (MLD) of sewage water. This implies that a huge amount of sludge has been generated in our country. These waste waters carry appreciable amount of plant nutrients as well as trace toxic metals. Land application of the sewage sludge is also becoming popular due to possibility of recycling valuable components such as organic matter, N, P and other plant nutrients. However, long-term use of sewage, sludge and industrial effluents in agricultural lands is restricted as these non-conventional sources of plant nutrients often carry trace toxic metals. In view of increasing cost of fertilizers and declining availability of irrigation water, feasibility of recycling these non-conventional sources of plant nutrients on agricultural lands will merit investigation.To develop an appropriate sewage sludge based prescription for sustainable productivity of maize (*Zea maize*) - wheat (*Triticum aestivum* L.) system and without affect the soil health was initiated in the year 2014-15 at IARI, New Delhi with the following treatment combinations: T1, Control; T2, 100% NPK (150:60:50); T3, 25% N by SS + NPK; T4, 50% N by SS + NPK; T5, 100% N by SS + PK; T6, 200% N by SS ; T7, 300% N by SS and T8, T2 + 2.5 t sludge $ha^{-1}$. The experimental soil had pH 8.2, available N 171, available P 28.1 kg $ha^{-1}$, available K 265 kg $ha^{-1}$, DTPA-Zn 1.91 mg $kg^{-1}$, DTPA-Mn 3.39 mg $kg^{-1}$, DTPA-Fe 4.22 mg $kg^{-1}$ and DTPA-Cu 1.33 mg $kg^{-1}$. The Sewage sludge was applied 15 days before sowing of wheat as per treatments. Standard agronomic practices were followed for raising wheat (November to April).

Results showed that the maximum wheat yield was obtained with 100% NPK with 2.5 t $ha^{-1}$ sewage sludge which was more or less equal yield to others treatments except 100% NPK alone, 100% N by SS + PK and control treatments. The residual effect of 2.5 t $ha^{-1}$ sewage sludge with 100 NPK application was obtained maximum yield of maize but there is no significantly difference to 100% recommended NPK. Application of sewage sludge with and without inorganic fertilizers increased macronutrients (N, P and K), micronutrients (Zn, Fe, Mn and Cu) and heavy metals (Cr, Ni, Pb and Cd) in grain and straw of wheat in comparison to 100% NPK alone and control. Addition of sewage sludge also increased DTPA micronutrients (Zn, Fe, Mn and Cu) and heavy metals (Cd, Pb, Ni and Cr) under permissible limit in comparison to 100% NPK. The results suggest that conjunctive use of 50% N substituted by SS with NPK is extremely important for sustaining wheat yield and improving soil health.

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# Occurrence of Cr (VI) – Extent and Prospect of Remediation in Chromites Mine Areas at Sukinda, Odisha

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Chromite deposits in India are mostly localized in Sukinda belong to Jajpur district of Orissa. The open cast mining of chromite ore in India generates a huge amount of overburden dumps that along with mine drainage contaminate natural resources with hexavalent (VI) Cr, which is easily soluble, mobile and highly toxic in nature. To investigate the extent of occurrence of Cr(VI) soil and water samples were collected covering a radial distance of 3.1 to 20 Km from the surroundings of Chromites mine areas at Sukhinda, Odisha during April to October 2015. Analyses of the samples revealed that the waters were acidic to slightly alkaline in reaction, non-saline and contained K, Na, Ca, Mg, Cl and Mn at different proportions. In comparison with critical concentration of Cr and Fe, around 11 and 31% samples are found not suitable for crop irrigation respectively. While soils at 0 to 0.2 m depth from the surface are found acidic to neutral in reaction (pH, 4.44 to 6.43), low to moderate in organic carbon content (0.6 to 1.26 g 100 $g^{-1}$) and high in Cr 4.48 to 9.18 mg $kg^{-1}$ soil.

Growing water hyacinth (*Eichhornia crassipes*) in Cr(VI) enriched water for a period of 113 days has found to reduce Cr concentration by 52 to 85% from 0.8 to 3.8 mg $L^{-1}$ as initial levels within 16 days of plant growth. Accumulation of Cr(VI) was 5 to 44 times higher in root than its concentration obtained in plant shoot. It may attributed to root weight which was 1.32 to 2.5 times higher than its corresponding shoot weight of the plant. Besides an increase of P @ 1.08 to 1.58, Fe 3.11 to 8.72 and Mg 1.26 to 3.07 times in root over shoot are also evident. A decreasing trend in net photosynthesis (µmol $CO_2$ $m^2$ $S^1$) and plant growth rate by 17 to 20% is however vivid with increasing Cr concentration (>2.0 mg $L^{-1}$) in water. On the basis of bio-availability of Cr(VI) in natural resources site specific Cr (VI) removal by growing water hyacinth could have been initiated for remediation process for safe farming.

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# Effect of Continuous Fertilization on Sunflower Productivity and Soil Fertility under Sunflower–Maize Sequence

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Permanent manurial experiments are conducted to study the long term effect of continuous application of nutrients either singly or in combination and with or without organic manure on crop productivity and soil quality. In India, at Coimbatore permanent manurial experiment was started in the year 1909 and being maintained at Tamil Nadu Agricultural University, Coimbatore in red sandy loam soil (*Typic Haplustalf*). There are eighteen treatments *viz*., control, N alone, NK alone, NP alone, NPK, PK alone, K alone, P alone, NPK blanket, NPK+FYM, Farmers practice, No manure no crop, STCR-IPNS, FYM (NEB), poultry manure (NEB), Residue mulching, FYM every year, FYM even year and are being tested under non replicated trial. From 2008 onwards sunflower – maize cropping sequence was followed with high yielding varieties/ hybrids and fertilizer dose of 60:90:60 and 250:75:75 kg NPK $ha^{-1}$, respectively.

Sowing of 160th crop of sunflower (TNAU hybrid CO 2) was taken up during December 2014 and harvested during March 2015. Post-harvest soil and plant samples were analyzed for nutrient status. Crop yield data revealed that continuous application of 100% NPK along with FYM @ 12.5 t $ha^{-1}$ over 100 years recorded the highest seed yield (1683 kg $ha^{-1}$) over 100% NPK alone (1283 kg $ha^{-1}$) during 2015. The per cent yield increase over 100% NPK under INM was 30.0 followed by 26.2% under STCR-IPNS. Continuous application of single nutrients either N or P or K alone resulted in drastic decline in yield accounting for 42.7, 30.2 and 38.1%, respectively when compared to balanced nutrient application (100% NPK). Data on total nutrient uptake showed that the STCR-IPNS recorded the highest total N and K uptake (67.29 and 114.4 kg $ha^{-1}$) whereas the P uptake was higher under continuous application of 100% NPK along with FYM (10.01 kg $ha^{-1}$). Regarding soil nutrient status, continuous skipping of nutrient from fertilizer schedule resulted decline in availability of that nutrient in soil compared to balanced fertilization. No remarkable change was noticed with respect to soil pH and EC. Continuous adoption of INM or STCR-IPNS enhanced the soil OC status from 0.32% during 1974-79 to 0.62% during 2015. No specific trend was noticed with respect to micronutrients status over a period of continuous fertilization but in general, the soil was found to be sufficient in Mn and Cu and deficient in Fe and Zn. Balanced fertilization maintained the soil nutrient status whereas continuous addition of single nutrient alone depleted nutrients from soil.

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# Maize (*Zea mays*, L.) Productivity in Madhya Pradesh, Central India: Yield Gap Analysis using Simulation Modelling

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Quantifying the yield potential of maize at any given site is a key to understanding the existing yield gaps and identifying the most important constraints to achieving optimal yield and profit. Understanding the causes of these yield gaps allows farmers to prioritize their efforts in improving yield and profit in a sustainable and environmentally sound fashion. A well calibrated and validated APSIM model was used to assess the impact of climate change (change in temperature and rainfall patterns) on productivity of maize in the state Madhya Pradesh. The APSIM maize module was parameterised and validated for the maize cultivar Kanchan 101 from multiyear long-term and completed experiments. A total of 30 districts with 74 soil profiles were considered for the study. For the 30 selected sites in Madhya Pradesh, the potential yield of maize ranged from 3.3 to 5.2 t $ha^{-1}$ whereas the observed yields ranged from 0.7 to 3.1 t $ha^{-1}$ giving yield gaps ranging from 1.7 to 3.1 t $ha^{-1}$. From the long-term simulation study, it was revealed that there is a potential to improve the grain yield of maize crop by 3 t $ha^{-1}$ provided optimum dates of sowing and good management practices are followed.

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# Changes in Soil Quality Indicator and Productivity under Organic Farming vs Chemical Farming over a Period of 6 Years of Sugarcane Cultivation

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Present study on "Organic farming research in sugarcane" is being conducted from 2007 onwards at RARS, Anakapalle, Acharya N G Ranga Agricultural University, Andhra Pradesh in *Inceptisols* to study the feasibility of organic farming in sugarcane. Nutrient management through farmyard manure @ 25 t $ha^{-1}$ as basal dose and vermicompost @ 3 t $ha^{-1}$ at 60, 90 and 120 days after planting, insitu green manuring of sun hemp between sugarcane rows and incorporation, biofertilizer (azatobactor/ azospirillum, PSB) application in every alternate year, application of trash compost @ 5 t $ha^{-1}$ at cessation of monsoon rains was found optimum to stabilize the sugarcane yield to that of 100% recommended NPK through chemical fertilizers. As a check 100% chemical fertilizer treatment was also maintained in another field with same soil texture. Initial soils were neutral in reaction with normal conductivity. The soil organic carbon (0.52%) and available nitrogen (232 kg $ha^{-1}$) was low in status and available phosphorus (40.80 kg $ha^{-1}$) and potassium (269 kg $ha^{-1}$) status was in medium range. Results of the experiment revealed that organic farming is having positive effect on soil physical properties (*viz.*, bulk density, water holding capacity and per cent pore space), soil biology and soil nutrient status as it was improved from initial status to present status. Gradual yield improvement was observed in organic treated plots over the years and cane yields (plant crop) recorded after 4 years of initiation were 69.50 t $ha^{-1}$, where as in 100% chemical fertilizer treatment it was 77.56 t $ha^{-1}$. Number of milleable canes also followed the same trend as it was high in 100% chemical fertilizer treatment over chemical fertilizer treatment. Comparatively highest juice sucrose (18.83%) and brix (20.5%) was recorded in organic farming treatment when compared to 100% chemical fertilizer treatment (18.6 and 20.3%, respectively). Cane yields (ratoon crop) recorded after 5 years of initiation were 61.72 t $ha^{-1}$, where as in 100% chemical fertilizer treatment it was 66.35 t $ha^{-1}$. In case of shoot population and Number of Milleable Canes, a slight increase was observed in 100% chemical fertilizer treatment compared to organic farming plot. Cane and sugar yields (Plant crop) recorded after 6 years of organic farming were 74.6 and 10.45 t $ha^{-1}$, where as in 100% chemical fertilizer treatment it was 76.15 and 10.06 t $ha^{-1}$. Yield gap between organic and inorganic plots was reduced to 2% from 18.50% in initial with highest juice quality and sugar yields. One of the important soil quality indicator is organic carbon, it was increased to 0.69% from its initial value of 0.52%, where as in 100% chemical fertilizer treatment the organic carbon status was increased to 0.56% from its initial value. Significant improvement in soil organic carbon was observed in organic farming plot over 100% chemical fertilizer plot over a period of six years.

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# Validation of Soil Test Crop Response-based Fertilizer Recommendations for Targeted Yields of *Bt* Cotton in Semi-arid South-Western Zone of Haryana

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The suitability of soil test crop response (STCR) based fertilizer prescription equations under integrated plant nutrient supply (IPNS) for targeted yields of *Bt*. cotton were validated at eight farmers' fields in cotton growing areas of Haryana during 2013-14 and 2015-16. Seven fertilizer treatments were employed which included control; farmers practice (FP); generalised package recommendations (PR), STCR recommendations for 28 and 32 q $ha^{-1}$ (TY-28 and TY-32) seed cotton yield target with fertilizers alone; and with fertilizer and FYM (TY-28 FYM and TY32 FYM). The highest mean seed cotton yield was recorded in TY-32 FYM which decreased in the following order: TY-32 FYM > TY-32 > PR > TY-28 FYM > TY-28 > FP > control. The response to fertilizer application also followed the same trend. The mean response yardstick was 5.30, 5.08, 6.31, 5.32, 6.66 and 5.43 kg of seed cotton per kg of applied nutrients. The mean response yardstick was higher in TY-28/TY28 FYM (6.49) followed by TY-32 / TY32 FYM (5.38) as compared to PR (5.08) and FP (5.30). The yield targets of 28 and 32 q $ha^{-1}$ were achieved within deviations of -8.9 to +5.5 and -7.8 to +1.9 per cent, respectively, at different locations indicating the validity of STCR-IPNS fertilizer prescription for *Bt.* cotton.

The mean benefit of Rs 74602/- and 72862 $ha^{-1}$ was in TY-32 FYM and TY-32 treatments, respectively. Similarly, the mean net profit of Rs 66746 $ha^{-1}$ was the highest in targeted yield of 32 q $ha^{-1}$, followed by PR (Rs 58387), 28 q $ha^{-1}$ yield target (Rs 55892) and FP (Rs 41723) per hectare. Similarly, the mean marginal B:C ratio was higher under targeted yield treatments of STCR/ STCR-IPNS than other treatments. The results clearly revealed that the STCR based fertilizer recommendations for 32 q $ha^{-1}$ yield targets under irrigated conditions in cotton growing area of Haryana proved superior over generalised package recommendations due to higher productivity, response yardstick and benefit to farmers.

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# Effect of Long-term Application of Manures and Fertilizers on Organic Carbon Build-up and Enzyme Activities in a Coarse Loamy Soil

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An ongoing long-term field experiment started in 1995 on a coarse loamy, Typic Ustochrept soil at CCS Haryana Agricultural University, Hisar was selected to examine the impact of application of manures and fertilizers on organic carbon build up and soil enzyme activities after 19 years of fertilization. The seven treatments combinations viz. $T_1$ : 150 kg N + 60 kg $P_2O_5$ $ha^{-1}$, $T_2$ : 15 t FYM $ha^{-1}$, $T_3$ : 15 t FYM + 150 kg N + 30 kg $P_2O_5$ $ha^{-1}$, $T_4$ : 5 t poultry manure $ha^{-1}$, $T_5$ : 5 t poultry manure + 150 kg N + 30 kg $P_2O_5$ $ha^{-1}$, $T_6$ : 7.5 t pressmud $ha^{-1}$, $T_7$ : 7.5 t pressmud + 150 kg N +30 kg $P_2O_5$ $ha^{-1}$ were laid out in permanent plots and data were recorded in triplicate and analyzed using RBD design after harvesting of wheat crop in April 2014. The results showed that continuous application of organic manures alone or in combination with NP fertilizers decreased the soil pH. However, a reverse trend was obtained in case of EC of soil. Organic carbon content in soil increased significantly with application of manures (FYM, poultry manure, pressmud) alone or in conjunction with NP fertilizers. Among the organic manures applied, the highest build-up of organic carbon in soil was recorded with the application of FYM followed by pressmud and poultry manure however, lower content of MBC was observed in FYM treatments as compared to pressmud or poultry manure application. Application of organic manures alone or in combination with chemical fertilizers significantly increased enzymes activity as compared to application of fertilizers alone. Combined application of organic manures along with fertilizers significantly decreased dehydrogenase and urease activity as compared to application of organic manures alone, however alkaline phosphatase activity were found to be increased. Highest dehydrogenase (63.71 µg TPF $g^{-1}$ 24 $h^{-1}$), urease activity (97.60 µg $NH_4^+$-N $g^{-1}$ $h^{-1}$) and alkaline phosphatase (756.0 µg PNP $g^{-1}$ $hr^{-1}$) was reported with $FYM_{15}$, $Pressmud_{7.5}$ and Poultry $manure_5N_{150}P_{30}$, respectively. Among organic manures applied alone, dehydrogenase activity followed the order: FYM> Pressmud>Poultry manure, alkaline phosphatase followed the order: Poultry manure> FYM> Pressmud while urease enzyme follow the order Pressmud> FYM > Poultry manure.

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# Effect of Inorganics and Organic Sources on Soil Quality and Yield Performance of Elephant Foot Yam in Acid Alfisols

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A field experiment was conducted during *kharif* 2015 - 16 to study the effect of integrated use of lime, inorganics and organic manures on soil quality and yield performance of elephant foot yam *(Amorphophallus paenifolius* L.) in an acid Alfisol of Odisha. The experimental soil is fine-loamy, mixed, isohyperthermic, typic Haplustalf; sandy loam in texture, acidic (pH 5.16), non saline and having 0.256% organic C, 0.1344% total N, 218, 24.64 and 189 kg ha-' of available N, P and K, respectively. The soil also contains 33.44, 1.42, 112.8 and 0.52 mg $kg^{-1}$ of available Fe, Cu, Mn and Zn, respectively.

Integrated application of lime + FYM + NPK + $MgSO_4$ has recorded significantly highest corm yield (19.09 t $ha^{-1}$) with a yield response of 113% over control. Among the organic sources, incorporation of vermicompost has recorded significantly higher corm yield (11.30 t $ha^{-1}$) at par with FYM (10.86 t $ha^{-1}$) and neem cake (10.47 t ha') with a yield response of 21, 26 and 17 per cent over control, respectively. Highest dry matter (27.75%) was recorded due to combined application of lime + FYM + NPK + B followed by lime + FYM + NPK + $MgSO_4$. Highest starch content on fresh weight basis was recorded due to application of lime + FYM + NPK + $MgSO_4$ (17.17%) at par with 150% NPK (17.13%). Total sugars ranged from 1.32 to 1.88%, with highest being due to integrated application of lime + FYM + NPK + B. Integrated applickfion of soil test based NPK combined with lime, FYM and MgSO4 has shown highest dehydrogenase (1.52 µg TPF $h^{-1}$ $g^{-1}$) and fluorescein diacetate activities (1.62 $g^{-1}$ $h^{-1}$). Integrated use of lime + FYM + NPK + $MgSO_4$ has recorded highest acid and alkaline phosphatase activities (49.64 and 42.08 [µg PNP $h^{-1}$ $g^{-1}$, respectively). Soil bacteria showed positive and significant relationship with phosphatase and fungi had significant relationship with DHA and FDA, indicating that bacteria and fungi plays major role in enzyme mediated reactions in the soil. Long-term application of soil amendments, organic and inorganic chemical fertilizers at balanced proportion not only helps to augment the crop yields but also enhances the microbial activities of soil.

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# Geo-Referenced Soil Fertility Status of Baghchung Block of Jorhat District of Assam

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The management of soil fertility for maintaining soil health and sustaining crop production poses a great challenge in paddy growing areas of Assam. The state is subjected to continuous monocropping of paddy fields without proper fertility management which leads to decline in fertility status of the soil. To address this problem, an investigation was carried out with eight to ten geo-referenced surface soil samples (0 – 15 cm) collected from paddy fields of the villages of Baghchung block of Jorhat district in 2.5 km grid, to determine soil fertility status, to develop block level soil fertility maps and to issue Soil Health Card to the farmers for sustainable production of crops without deteriorating soil health. Total 484 samples were collected and analyzed for pH, OC, available N, P, K, S, Zn and B following standard methods. Soil fertility maps of the block were prepared for major (NPK), secondary (S) and micronutrients (Zn and B) using TNTmips software. Out of total samples analyzed, 2.7% samples of Baghchung block were found to be extremely acidic (pH < 4.5), 93.6% were very strongly acidic (pH 4.5-5.0), 3.5% were strongly acidic (pH 5.1-5.5), and 0.21% were medium acidic (pH 5.6 – 6.0), respectively. The soil organic carbon ranged from 0.12 to 1.83 (%). Available N, $P_2O_5$ and $K_2O$ ranged from 100.35 to 990.98, 14.92 to 88.40 and 26.07 to 493.7 (kg $ha^{-1}$), respectively. The highest area of Baghchung block were found to be under medium range of nutrient status for available N (77.1%) and $P_2O_5$ (87.4%) and low for $K_2O$ (84.2%). Available S ranged from 0.22 to 54.02 (mg $kg^{-1}$). Among the micronutrients 0.6% of the total samples were found to be deficient in Zinc and 50.8% were found to be deficient in Boron. There was a significant correlation between organic carbon with available N ($0.359^{**}$), $P_2O_5$ ($0.306^{**}$) and $K_2O$ ($0.107^{*}$).

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# Sulphur Fertilization for Increased Yield of Black Gram and Soil Fertility in an Inceptisol of Assam

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A field experiment was conducted at Instructional-cum-Research (ICR) Farm, Assam Agricultural University, Jorhat during *kharif* season 2013 -15 to assess the effect of sulphur fertilization on crop yield of blackgram and soil fertility in an Inceptisol of Assam. The experiment consisted of five levels of sulphur (0, 10, 20, 30 and 40 kg $ha^{-1}$) through gypsum and laid out in a randomised block design. Application of sulphur influenced the crop yield and nutrient uptake by black gram. Results revealed that application of 20 kg sulphur per hectare resulted the highest grain (10.16 q $ha^{-1}$) and stover yield (14.73 q $ha^{-1}$) of blackgram. The maximum uptake of nitrogen, phosphorus and potassium was recorded with sulphur rate of 20 kg $ha^{-1}$ while, the uptake of sulphur increased significantly with sulphur application upto 40 kg S $ha^{-1}$. Maximum gross income, net income and benefit: cost ratio (3.02) was also found with 20 kg S $ha^{-1}$ than other level of sulphur application. Pooled data revealed that application of 20 kg sulphur per hectare significantly recorded the highest content of organic carbon, available nitrogen, phosphorus and potassium in soil as compared to other levels of sulphur. In respect of available suphur and exchangeable calcium, significantly the highest content was obtained with application of 40 kg sulphur per hectare. Considering the improvement of soil fertility, crop yield and economic return, application of 20 kg S $ha^{-1}$ along with recommended dose of NPK was found to be superior compared to all other treatments.

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# Balanced Fertilizer Prescription through IPNS for Big Onion on an Inceptisol

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Big onion *(Allium cepa var.cepa)* is one of the most important commercial vegetable crops cultivated extensively in India and world. It is essential to adopt a strategy of integrated plant nutrition system (IPNS) to increase the yield of big onion and sustain soil health. Field experiments were conducted on a Typic Ustropept (Irugur soil series) soil of southern zone of Tamil Nadu by adopting the inductive cum targeted yield model and fertiliser requirements were quantified for big onion based on soil test and yield target. The basic parameters *viz.*, nutrient requirement (NR) and contribution of nutrients from soil ($C_s$), fertiliser ($C_f$) and farmyard manure ($C_{fym}$) were computed from the field experimental data. Fertilizer prescription equations (FPEs) were developed for big onion under IPNS on Irugur series (Typic Ustropept) of Tamil Nadu.

The results emanated from the present investigation revealed that big onion requires 0.33 kg of N, 0.20 kg of $P_2O_5$ and 0.39 kg of $K_2O$ for producing one quintal of fresh bulb. The per cent contribution of N from soil was 24.69 and fertilizer was 41.20. With regard to $P_2O_5$, the per cent contribution from soil was 32.05 and fertiliser was 34.99 while for $K_2O$, the per cent contribution from soil was 17.50 and from fertilizer was 64.12. The per cent contribution of N, $P_2O_5$ and $K_2O$ from FYM (CFYM) were 40.13, 19.58 and 32.98, respectively. The response yardstick recorded was 50.20 kg $kg^{-1}$. The data revealed that the order of NR was $K_2O$> N> $P_2O_5$; Cs was $P_2O_5$>N> $K_2O$; Cf: $K_2O$>N> $P_2O_5$; Co: N >$K_2O$>$P_2O_5$. Making use of the basic parameters, fertilizer prescription equations under IPNS were developed and are as follows. FN = 0.80 T - 0.60 SN - 0.84 ON; $FP_2O_5$ = 0.58 T - 2.10 SP -0.87 OP; $FK_2O$ = 0.61 T - 0.33 SK - 0.70 OK; where, FN, $FP_2O_5$ and $FK_2O$ are fertilizer N, $P_2O_5$ and $K_2O$ in kg $ha^{-1}$, respectively; T is the yield target of fresh bulb in q $ha^{-1}$; SN, SP and SK, respectively are alkaline $KMnO_4$-N, Olsen-P and $NH_4OAc$-K in kg $ha^{-1}$ and ON, OP and OK are the quantities of N, P and K in kg $ha^{-1}$ supplied through FYM. Using these equations, nomograms were formulated for a range of soil test values for desired yield target of big onion. The extent of saving of inorganic fertilisers for big onion was also computed using the fertiliser prescription equations under IPNS. The results showed that for the application of FYM @ 12.5 t $ha^{-1}$ with 28 per cent moisture and 0.528, 0.286 and 0.520 per cent of N, P and K respectively, the saving was 40, 20 and 33 kg of fertilizer N, $P_2O_5$ and $K_2O$, respectively.

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# Soil Fertility and Yield Limiting Nutrients in Oil Palm Plantations of North-Eastern State Mizoram, India

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A survey was conducted for assessment of soil fertility status, leaf nutrient concentration and finding yield limiting nutrients of oil palm (*Elaeis guineensis* Jacq.) plantations in Mizoram state situated in north-eastern part of India. Soil pH, electrical conductivity (EC), organic carbon (OC), available potassium (K) ($NH_4OAc$-K), available phosphorus (P) (Bray's-P), exchangeable calcium (Ca) (Exch. Ca) and magnesium (Mg) (Exch. Mg), available sulphur (S) ($CaCl_2$-S) and hot water soluble boron (B) (HWB) content in surface (0-20 cm depth) and subsurface (20-40 cm depth) soil layers varied widely. Diagnosis and recommendation integrated system (DRIS) norms were established for different nutrient expressions and DRIS indices were computed. As per DRIS indices, the order of requirement of nutrients was found to be B > K > Mg > P > nitrogen (N). Optimum leaf nutrient ranges as per DRIS norms varied from 1.91 to 2.95%, 0.46 to 0.65%, 0.63 to 1.00%, 0.48 to 0.88% and 9.41 to 31.0 mg $kg^{-1}$ for N, P, K, Mg and B, respectively. On the basis of DRIS derived optimum ranges, 32, 9, 27, 12 and 12 per cent leaf samples had less than optimum concentration of N, P, K, Mg and B, respectively. The optimum ranges developed could be used as a guide for routine diagnostic and advisory purpose for efficient fertilizer application.

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# Evaluation of Soybean Genotypes to Organic management practices under Rainfed Vertisols of Madhya Pradesh

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Soybean (*Glycine max* L. Merrill), also called as 'miracle crop', originated in China, had attracted the attention of the world because of its dual benefits of oil (20%) and protein (40%). With an average yield of about 1.0 t $ha^{-1}$ in India, it has potential to alleviate nutritional crisis in developing countries, however the productivity of the crop remained lower in India compared to other countries. For centuries, soybean has been used with meat, milk, cheese, bread and oil by the people of China, Japan, Korea, Manchuria, Philippines and Indonesia and so referred to as the 'Cow of the field', or 'Gold from soil'. There is a worldwide awareness on organic production systems due to various health concerns, including India. Despite interest in organic soybean production in India, little information is available on varietal suitability for commercial organic cultivation of soybean in the country. The soya food industry prefers selected soybean cultivars over others based on various parameters *viz.,* protein, oil content, physical traits of the seed *etc*. Although, protein and oil concentrations in the seed may be genetically controlled, these components are highly influenced by the environment and package of practices too. Present study was undertaken to assess the qualitative variation in seeds of soybean genotypes under rainfed cultivation in a semi-arid Vertisols at ICAR-Indian Institute of Soil Science, Bhopal. The experiment was laid out with randomized block design with four replications. Twelve cultivars of Soybean were evaluated (under soybean-wheat rotation) during the kharif season of 2014 with a common nutrient management practice. Manure dose of previously standardized experiment was utilized for supplying recommended dose of nutrient to the soybean crop irrespective of the genotype tested. Among the genotypes tested, JS 93-05 has registered the maximum seed protein content of 37.55 which was on par with JS 20-29 while RVS-2002-7 had registered the maximum seed oil content of 20.33 which was significantly superior over others. The significant variation for seed protein and oil content observed among the genotypes examined in this study indicated the potential for breeding management responsive high yielding soybean cultivars suitable for organic farming in the future.

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# Effect of Zinc and Silicon Fertilization on Growth and Yield of Rice

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Rice (*Oryza sativa*) the prince among cereals is the premier food crop not only in India but world too. Balanced fertilizers use in food grain crops including rice is one of the important considerations in providing food security to the burgeoning Indian population and promoting soil fertility in sustainable intensive agriculture. Balancing the micronutrients along with macronutrients for rice cultivation enhanced the quality and yield. Silicon is one of the most important micronutrients for sustainable rice production. Zinc plays an important role in the nutrition of rice. Field experiment was conducted at Annamalai university Experimental farm, Annamalainagar, Tamil Nadu, India during kharif 2015 to study the effect of zinc and silicon fertilization on growth and yield of rice var. ADT 36. The experiment consisted of sixteen treatments *viz*., zinc levels (0, 5, 7.5 and 10 kg $ha^{-1}$) and silicon levels (0, 75, 150 and 225 kg $ha^{-1}$) and their combinations. The results indicated that addition of graded dose of zinc or silicon or both significantly increased the growth and yield of rice in zinc and silicon deficient soil. Grain and straw yield increased with Zn levels and the highest grain yield (5178 kg $ha^{-1}$) and straw yield (6732 kg $ha^{-1}$) was noticed with 10 kg Zn $ha^{-1}$, respectively. Grain and straw yield decreased at rest of zinc levels. The percentage increase in grain yield (19.5) and straw yield (17.0) over no Zn was noticed at 10 kg Zn $ha^{-1}$ tried. With respect to silicon levels, maximum grain yield (4951 kg $ha^{-1}$) and straw yield (6477 kg $ha^{-1}$), respectively was noticed at 150 kg Si $ha^{-1}$. Further, increase in Si level caused reduction in grain and straw yield. This was comparable with 225 kg Si $ha^{-1}$ but superior to the rest of silicon levels. The per cent increase in grain and straw yield due to 150 kg Si $ha^{-1}$ over control was (11.0) and (10.0), respectively. With respect to interaction effect between zinc and silicon, the highest grain and straw yield was noticed with 150 kg Si $ha^{-1}$ and 10 kg Zn $ha^{-1}$. This treatment recorded the grain yield (5363 kg $ha^{-1}$) and straw yield (6970 kg $ha^{-1}$). Plant height progressively increased with zinc levels and the tallest plant was noticed with 10 kg Zn $ha^{-1}$, it was superior to rest of zinc levels. Similarly, plant height also progressively increased with Si levels and the tallest plant was noticed with 150 kg Si $ha^{-1}$ and declined at 225 kg Si $ha^{-1}$. Combined application of 150 kg Si $ha^{-1}$ and 10 kg Zn $ha^{-1}$ registered the tallest plant at all stages of crop growth compared to other combinations. Similarly the higher number of tillers $hill^{-1}$ and dry matter production was obtain with application of 150 kg Si $ha^{-1}$ and 10 kg Zn $ha^{-1}$ .The study revealed zinc and silicon fertilization as a suitable material for improving crop yield as well as soil fertility.

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# Effect of Conservation Agriculture Practices on Soil Organic Carbon and Nitrogen: A Case Study from a Rice-Wheat System on a Calcareous Soil of Eastern Indo-Gangetic Plains

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Improving soil organic carbon (SOC) and nitrogen (N) in arable soils is one of the important strategies to enhance soil quality for sustainable crop production. Hence, we investigated the changes in SOC and N under conservation agriculture (CA) in a calcareous soil of the eastern Indo-Gangetic Plains (IGP) after six years of rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) rotation. The treatments were: conventional-till transplanted rice followed by conventional-till wheat (CTR-CTW), CTR followed by zero-till wheat (CTR-ZTW), ZT direct dry-seeded rice followed by CTW (ZTDSR-CTW), ZTDSR followed by wheat both on permanent raised beds with residue retention (PBDSR-PBW+R), and ZTDSR followed by ZTW without residue retention (ZTDSR-ZTW), and ZTDSR-ZTW with residue retention (ZTDSR-ZTW+R). Results indicated that plots under CA (double ZT with residue retention; ZTDSR-ZTW+R plots) had highest total SOC concentrations in both 0-15 and 15-30 cm soil layers; the values being 20and 40% higher than CTR-CTW plots, respectively. Benefits of crop residue retention were maximum under complete ZT practices. Plots under ZTDSR-ZTW and PBDSR-PBW+R had similar SOC, whereas significant increment was registered under ZTDSR-ZTW+R compared with both of them. Similarly, Walkley-Black C (WBC), permanganate oxidizable C (POC), soil microbial biomass C (SMB-C) and particulate organic matter associated C (POM-C) were also found maximum under ZTDSR-ZTW+R across the sampling depths. On the other hand, total soil N(TSN) was nearly 26 and 34% higher as compared with CTR-CTW in 0-15 and 15-30 cm soil layers, respectively. Similar improvement in TSN was registered under PBDSR-PBW+R. There were no benefits of ZT alone as evident from similar TSN values under CTR-CTW and ZTDSR-ZTW. Alike POM-C, POM-N was also found maximum under ZTDSR-ZTW+R in both sampling depths. Similar values of SMB-C and SMB-N between CTR-CTW and ZTDSR-ZTW further revealed that ZT was beneficial only with residue retention. On the contrary, ZTDSR-ZTW+R and PBDSR-PBW+R registered significant improvement in SMB-C and SMB-N as compared to the above mentioned treatments. Apparently, CA practices caused a decrease in mineral-N. Except under PBDSR-PBW+R, all other CA treatments registered a significant decrease in the concentration of mineral-N as compared with CTR-CTW, in both 0-15 and 15-30 cm soil layers. Thus the study established the benefits of CA (ZT + crop residue retention) on SOC concentration, whereas effect of the same on mineral-N needs to be investigated in detail in further studies.

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# Evaluation of Fertilizer Prescriptions Equations under IPNS for Glory Lily on an Alfisol

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Fertilizer prescription equations (FPEs) were developed for glory lily under IPNS on Palaviduthi series (Typic Rhodustalf) of Tamil Nadu. FPEs under IPNS are FN = 41.45 T - 0.53 SN – 0.71 ON ; $FP_2O_5$ = 23.21T - 2.07 SP - 0.81 OP; $FK_2O$ = 30.45 T - 0.21 SK - 0.64 OK. where, FN, $FP_2O_5$ and $FK_2O$ are fertilizer N, $P_2O_5$ and $K_2O$ in kg $ha^{-1}$, respectively; T is the yield target in t $ha^{-1}$; SN, SP and SK, respectively are alkaline $KMnO_4$-N, Olsen-P and $NH_4OAc$-K in kg $ha^{-1}$ and ON, OP and OK are the quantities of N, P and K in kg $ha^{-1}$ supplied through FYM. To validate the FPEs, test verification trials were conducted at two locations during *Rabi* 2015-16 in Dindigul District, Tamil Nadu. There were nine treatments *viz.*, blanket, STCR-NPK alone for 5.5, 6.5 and 7.5 q $ha^{-1}$, STCR -IPNS for 5.5, 6.5 and 7.5 q $ha^{-1}$ and farmer's practice and control. Based on the initial soil test values of available N, P, K and yield targets aimed, fertilizer doses were calculated and applied for STCR treatments. For IPNS treatments, 12.5 tonnes of FYM were applied basally and fertilizer N, $P_2O_5$ and $K_2O$ doses were adjusted accordingly. Using the data on seed yield and fertilizer doses applied, per cent achievement and response ratio (RR) and B:C ratio were worked out. Post-harvest soil samples were collected and analyzed for available N, P and K status.

The results revealed that at both the locations, the targeted yield has been achieved within ±10 per cent variation proving the validity of the equations and the seed yield ranged from 396 to 764 kg $ha^{-1}$ and 402 to 758 kg $ha^{-1}$, respectively. Among the treatments, STCR-IPNS-7.5 q $ha^{-1}$ had recorded relatively higher seed yield (764 and 758 kg $ha^{-1}$). The mean increase in yield due to STCR-IPNS-7.5 q $ha^{-1}$ over blanket (RDF alone) and farmer's practice was 45.0 and 61.1 per cent, respectively. The increase in RR due to STCR-IPNS- 7.5 q $ha^{-1}$ over blanket and farmers practice were 0.20 and 0.32, respectively; corresponding increase in BCR were 0.31 and 0.44, respectively. Post harvest soil fertility values of $KMnO_4$-N, Olsen-P and $NH_4OAc$-K indicated the build up and maintenance of soil fertility due to soil test based fertilizer recommendation under IPNS. The targeted yield has been achieved within ±10 per cent variation proving the validity of the equations. Therefore, soil test crop response based fertiliser prescriptions under IPNS can be recommended for achieving the seed yield target of 7.5 q $ha^{-1}$ for third year crop of glory lily on Palaviduthi series (red non-calcareous) with sustained soil fertility.

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# Response of Silicate Fertilizer Effect on Physiological Traits and Rice Yield in Typical Ustfluvent Soil

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Extensive cultivation of rice in some regions of Asia and South East Asian countries has led to depletion of available silicons and warrants the application of silicate fertilizers for achieving sustainable rice yields. Rice is a silicon accumulating plant. Thus, it can increase productive yields, promoting various desirable physiological and biochemical processes of plant. Importance of silicon in Indian rice farming as well as in other crops is limited and gaining momentum at slow pace. The experiment was laid out in randomized block design. The experiment consisted of ten treatments. $T_1$ - NPK (RDF), $T_2$ - NPK + Potassium silicate (FS) - 0.25%, $T_3$- NPK + Potassium silicate (FS) - 0.50%, $T_4$ - NPK + Potassium silicate (FS) - 1%, $T_{5-}$ - NPK + Potassium silicate (FS) - 0.25%, $T_6$ - NPK + Potassium silicate (FS) - 0.50%, $T_{7-}$ - NPK + Potassium silicate (FS) - 1%, $T_8$ - NPK + Potassium silicate (SA) - 50 kg $ha^{-1}$, $T_9$ - NPK + Potassium silicate (SA) - 100 kg $ha^{-1}$ and $T_{10}$ - NPK + Potassium silicate (SA) - 150 kg $ha^{-1}$. From $T_2$ to $T_4$ foliar spray was done at tillering stage and from $T_{5\ to}$ $T_7$, foliar spray was done at tillering and panicle initiation stage. The results revealed that the highest LAI, chlorophyll, CGR, RGR, NAR was recorded with soil application of 50 kg Si $ha^{-1}$ and was comparable with foliar spray of 1% Si sprayed at tillering stage but superior to rest of the treatments. The grain and straw yield have significantly improved due to silicon application over control. The per cent increase in grain yield and straw ranged from 4.7 to 17 and 6.6 to 19.2, respectively. The grain and straw yield response ranged from 247 to 900 kg $ha^{-1}$ and 375 to 1087 kg $ha^{-1}$, respectively. The highest grain yield (6183.3 kg $ha^{-1}$) and straw yield (6740 kg $ha^{-1}$) was noticed with soil application of 50 kg Si $ha^{-1}$ and was comparable with foliar spray of 1% Si applied at tillering stage but superior to rest of the treatments. The rice yield declined with advancement of silicon rates. Similarly, rice yield increased with Si concentration (0.25% to 1%). But when foliar spray was applied twice, rice yield increased at lower concentration (0.25 and 0.5%), while rice yield decreased with 1% Si. Foliar application recorded higher Si use efficiency compared to soil application. Response ratio, physiological efficiency, agro physiological efficiency, apparent Si recovery and partial factor productivity decreased with Si levels and maximum was noticed with 50 kg Si $ha^{-1}$. While 0.5% Si applied at tillering stage recorded highest above use efficiency parameters and declined at 1% Si. Similarly, foliar spray at all concentration when applied twice reduced Si use efficiency compared to single spray. Silicon internal and translocation efficiency was lower in rice grain treated with silicon compared to control.

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# Improving Yield and Quality of Cowpea by Different Levels of $P_2O_5$ Enriched Organics on Vertisol

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To explore the effect of different levels of $P_2O_5$ enriched organics on cowpea, a pot experiment was carried out at the pot culture yard, Annamalai University with thirteen treatments and three replications in a CRD. The treatments were 50, 75 and 100% ($P_2O_5$) as SSP, EFYM, EPM and IRP. Cowpea (VBN 1) was grown as a test crop during January, 2010 with recommended dose of N:$P_2O_5$:$K_2O$ @ 25:50:25 kg $ha^{-1}$. Different levels of $P_2O_5$ enriched FYM, pressmud and incubated rock phosphate were prepared and used for this study. The results revealed that application of 100% $P_2O_5$ enriched pressmud (EPM) significantly increased the pod yield (16.4 g $pot^{-1}$), haulm yield (22.8 g $pot^{-1}$), dry matter produce (39.2 g $pot^{-1}$) and nodule number (16.42) of cowpea over other treatments. The best performing treatments screened from the first pot experiment were slightly modified for the second pot experiment. To optimize the level of $P_2O_5$ enriched organic composts, second pot experiment was conducted during *Kharif*, 2010 with seven treatments replicated thrice in CRD *i.e.* control, 100, 125 and 150% $P_2O_5$ enriched enriched pressmud (EPM) and incubated rock phosphate (IRP). Among the different treatments, application of 150% $P_2O_5$ EPM recorded the highest pod yield (24.11 g $pot^{-1}$), haulm yield (28.35 g $pot^{-1}$), dry matter produce (52.46 g $pot^{-1}$). However, this was statistically on par with 125% $P_2O_5$ enriched enriched pressmud (EPM). The study also concluded that the treatments were non-significant with post-harvest soil bulk density, porespace and water holding capacity but there were desirable changes in soil pH, EC (dS $m^{-1}$) and OC (g $kg^{-1}$). This might be due to greater response of cowpea to phosphorus nutrition, since P is involved in growth, development, photosynthesis, utilization of carbohydrate and enhancing the yield. Thus, P would have helped in the production of deeper, proliferation of root system. This might be due to higher rate of mineralization of pressmud, which would have resulted in the release of available nutrients *viz.,* N, P, K, Ca, Mg, S and micronutrients and its favorable effect in accelerating the growth and yield of cowpea.

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# Study of Organic Manures Enriched with Micronutrients on Tomato Crop in Salt Affected Soil

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Micronutrients are deficient in salt affected soils. In order to provide micronutrient to plant in a sustained manner, It is advocated to apply micronutrients in enriched form with organic manures. In this contest, a field experiment was conducted on salt affected soil (sandy loam) to evaluate study of organic manures enriched with micronutrients on tomato crop in salt affected soil. The treatments consisted of application of organic manures enriched with micronutrients. The experiment was laid out in randomized block design and replicated three times. The treatments were $T_1$- 20 kg of $ZnSO_4$ + 5.0 kg of borax as soil application. $T_2$-$T_1$+pressmud @ 12.5 t $ha^{-1}$. $T_3$- 10 kg of $ZnSO_4$+ 2.5 kg of borax as a soil application+ pressmud @ 12.5 t $ha^{-1}$ + 0.50% $ZnSO_4$ + 0.40% borax of F.S on 45 and 60 DAT. $T_4$- 10 kg of $ZnSO_4$ + 2.5 kg of borax as a soil application enriched with pressmud @ 12.5 t $ha^{-1}$ + 0.50% $ZnSO_4$+0.40% borax as F.S on 45 and 60 DAT. $T_5$-$T_1$+vermicompost @ 4 t $ha^{-1}$. $T_6$ - 10 kg of $ZnSO_4$ + 2.5 kg of borax as a soil application + vermicompost @ 4 t $ha^{-1}$ + 0.50% $ZnSO_4$ + 0.40% borax as F.S on 45 and 60 DAT. $T_7$- 10 kg of $ZnSO_4$ + 2.5 kg of borax as a soil application enriched with vermicompost @ 4 t $ha^{-1}$ + 0.50% $ZnSO_4$ + 0.40% borax as F.S on 45 and 60 DAT. The results of the experiment clearly revealed that the application of 10 kg of $ZnSO_4$ + 2.5 kg of borax as soil application enriched with vermicompost @ 4 t $ha^{-1}$ + 0.50% $ZnSO_4$+0.40% borax as F.S on 45and 60 DAT significantly influenced the growth, yield, quality and nutrient uptake. The treatment next in order were $T_4$ -10 kg of $ZnSO_4$ + 2.5 kg of borax as a soil application enriched with pressmud @ 12.5 t $ha^{-1}$ + 0.50% $ZnSO_4$ + 0.40% borax of F.S on 45 and60 DAT respectively.

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# Effect of Foliar Application of Micronutrients Enriched Humic Acid and Gibberellic Acid on the Fruit and Nut Yield of Cashew

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Micronutrient disorders were commonly observed during the early stage as well as the full grown stage of cashew. Application of micronutrients as foliar spray was very effective in cashew as compared to soil application. Addition of humic acid with micronutrients improves the effectiveness of micronutrient foliar spray in crops. GA3 foliar spray at pre blooming stage of cashew was established as a effective growth regulator in improving the yield of cashew The present investigation was carried out to study the effect of foliar application of micronutrients enriched humic acid on growth and yield of cashew cultivar 'VRI-3' with the objective to improve nut yield. This experiment was carried out in a farmer's field at periyakappankulam , Cuddalorer District of Tamil Nadu. The trial was laid out in randomized block design (RBD) with eight treatments and replicated thrice. The treatments consist of $T_1$-control (water spray),$T_2$-micronutrient mixture (0.5% $ZnSO_4$, 0.5% $FeSO_4$, 0.2% $CuSO_4$, 0.5% Borax, 0.2% $MnSO_4$) ,$T_3$-Humic acid (0.5%)$T_4$-$GA_3$ (50 mg $L^{-1}$),$T_5$-$T_2$+$T_3$, $T_6$-$T_2$+$T_4$,$T_7$-$T_3$+$T_4$,$T_8$-$T_2$+$T_3$+$T_4$. The present study revealed that the combined application of micronutrient mixtures along with humic acid and $GA_3$ as foliar spray($T_8$) recorded the highest value for the characters namely average apple weight (61.6 g), number of fruits per tree (2025.0), average nut weight (7.50 g), 100 nut weight (672.6 g), yield per tree (17.66 kg/tree) and nut yield (2.90 t $ha^{-1}$), followed by the treatment $T_5$, which recorded the average apple weight (59.86 g), number of fruits per tree (1956), average nut weight (7.38 g), 100 nut weight (666.6 g), yield per tree (16.57 kg $tree^{-1}$) and estimated yield per ha (2.78 t $ha^{-1}$). Based on the the nut yield the treatments are arranged in dissenting order as $T_8$>$T_5$>$T_6$>$T_2$>$T_7$>$T_4$>$T_3$>$T_1$. However, the control (water spray) recorded the lowest in all the traits.

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# Studies on Effect of Sea Water Intrusion on Salinization of Coastal Salt Affected Soils of Maharashtra

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Experiment was conducted during 2014-15 in coastal area of Maharashtra to study tidal water ingress through surface and capillary rise of salts thought ground water making soil saline. The tide height was raised up to 5.2 m during new moon and full moon days. During same months the ingress of tidal water through land surface is there if land is not protected by embankment, ingress is occurring through leakage of sluice gate or breakage of embankment. The observations from sea or creek side to land side were recorded for ground water and soil for salinity. The entry of tide water through creeks and sub-creeks to the land side is observed up to 3.0 km from sea or creek side developing the coastal saline soils. Salinity of the ground water (77.15 dS $m^{-1}$) some time which was more than creek water (69.0 dS $m^{-1}$). The salts exists in the ground water comes to surface of soil through capillary movement results in development of coastal saline soils. The intensity of salt present in the ground water depends on the distance from sea or creek and the strata existing in the area. Up to 500 m distance, ground water salinity was high from the creek or sea and then reduces as distance increases. The salinization through capillary rise and tidal ingress in the konkan region up to 2.5 to 3 kms from creekor sea side. The total coastal saline soil of Maharashtra is 65,000 ha.

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# Nitrogen Mineralization as Influenced by Integrated Use of Inorganic and Organic Manures with Variable C:N Ratios for Synchronizing and Increasing N Use Efficiency by Wheat

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Use of organic sources for supplying nitrogen (N) holds a prime importance in the recent past. The present investigation was carried out to study the release kinetics and mineralization of N for synchronizing crop demand from different organic sources with variable C:N ratios and to evaluate their effectiveness for crop productivity and maximizing N use efficiency using wheat as the test crop in an Inceptisol. Organic materials namely, sewage sludge from Okhla Sewage Plant, farmyard manure (FYM) and rock phosphate (RP) enriched compost were used for this study. All the sources of manures were neutral in reaction, had high content of N (1.24 to 1.64%) and P (0.67 to 2.31%), while K content ranged from 0.63 to 1.21%. The C/N ratio of the organic manures were in the order: FYM (23.8) > sewage sludge (19.1) > rock phosphate enriched compost (18.2). Data emanated from incubation experiment showed that all three organic sources followed similar pattern in releasing $NH_4^+$-N and $NO_3^-$-N in soil and they releases significantly higher amounts than that of control. During the first 15 days of incubation release of $NH_4^+$-N were slow, then it increased and reached its maximum around 45 days then again decreased. Maximum release of $NH_4^+$-N occurred from sewage sludge followed by enriched compost and FYM. In case of $NO_3^-$-N, it was observed that during first 15 days of incubation it released slowly then there was a sharp increase up to 45 days and thereafter the release slowed down. During initial days of incubation, the release of $NO_3^-$-N was greater in sewage sludge thereafter enriched compost resulted in greater amounts of release. Data on pot culture experiments revealed that the enriched compost performed better as a source of nutrient which showed 56 per cent increase over control, while treatment receiving FYM+100 mg N $kg^{-1}$ increased grain yield by 48 per cent over control. Results indicated that significant increase in available N ($NH_4^+$-N and $NO_3^-$-N) were maintained in soil throughout the crop growth namely, maximum tillering, flowering and after harvest of wheat due to addition of organic and inorganic sources of N over control. Similarly, significant improvements in biological properties like dehydrogenase, acid and alkaline phosphatase activities were observed in soil treated with organic and inorganic sources of N. In general, the biological activities declined from maximum tillering to maturity stages indicating greater microbial activities during active growth stages of crop. It can be concluded that application of organic manures along with inorganic N could be practiced in order to release mineralizable N for synchronizing the crop N demand and increased use efficiency.

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# Soil Fertility and *kharif* Marigold (*Tagetes erecta* Linn.) Productivity with Growth Regulators and Enhanced Fertilizer Doses

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A field experiment was carried out at Assam Agricultural University, Jorhat, Assam research farm to evaluate growth and yield of African marigold (*Tagetes erecta* Linn.) Cv. 'Siracole', and soil fertility with recommended doses (RD) of N, P and K fertilizers or triple RD of N, K and RD of P, with or without foliar spray of auxin + cytokinin or vermiwash during 2013-14 and 2014-15 *kharif* seasons. An unfertilized plot was kept as control and the mineral and organic (2500 kg/ha vermicompost) fertilizers were either applied separately or as mixture (*comlizer*) in two equal splits at the time of planting and at 30 days after planting (DAP). Each *comlizer* treatment (RD or 3 × RD) was supplemented with spraying either vermiwash 10% solution on second and third weeks and 20% solution on fourth and fifth weeks after planting, or spraying of auxin + cytokinin (laboratory grade) 0.01% solution on second and third weeks and 0.02% solution fourth and fifth weeks after planting. The treatments were replicated thrice in a randomized block design with individual plot size of 3.6 m × 3.0 m on a sandy loam soil with pH 5.5, organic carbon 6.4 g $kg^{-1}$, available N 248.3 kg $ha^{-1}$, P 19.6 kg $ha^{-1}$, K 88.2 kg $ha^{-1}$, $NH_4$-N 46.4 mg $kg^{-1}$ and $NO_3$-N 22.6 mg $kg^{-1}$. Seedlings of African marigold (*Tagetes erecta* Linn.) Cv. 'Siracole' were planted on 25th September in 2013 and 1st October in 2014 at a uniform spacing of 30 cm between plants and rows. Application of *comlizer* did not produce significant difference in growth and yield of marigold compared to separate applications of compost and mineral fertilizer. However, *comlizer* of enhanced RD of N and K (30 kg $ha^{-1}$) with vermiwash spray produced significantly higher flower yield, quality and growth parameters of marigold. *Comlizer* significantly enhanced mineralization of nitrogen at different growth stages of marigold in terms of $NH_4$-N and $NO_3$-N, but the available K content of soil as a whole and differences among the *comlizer* treatments were not significant. The soil fertility status after harvest of the crop significantly improved in comlizer treatments, irrespective of N and K levels. Vermiwash performed better in terms of few growth parameters and flower yield, compared to auxin and cytokinin, but was not cost effective.

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# Efficient Use of Soil Nitrogen for Sustainable Crop Production

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The availability of the mineral forms of nitrogen (N) is a key factor determining the productivity of crops for food, feed, fibre and bio-energy. Soil is the principal source of N for most field crops, and rice usually obtains 50-80% of its N requirement from the soil even in cases where fertilizer N is applied at high rates. N supplied by the soil is sufficient for rice grain yields of 2-4 t $ha^{-1}$ in most situations. The limited fossil fuel reserve available for manufacturing fertilizer N and the adverse effects of continued use of high fertilizer N doses on the environment call for a more efficient use of indigenous soil N.

Total N content of almost 80% of rice growing soils surveyed in tropical Asia ranged from 0.08 to 0.15%. Considering a thickness of the plough layer as 15-20 cm and bulk density of the soil as 1.25-1.35 Mg $m^{-3}$, the plough layer soil contains about 2000 to 3000 kg total N $ha^{-1}$. About 3 to 8% of total soil N is mineralized during a cropping season and made available to the crop. Total N uptake by a rice crop was found to be 1.7 to 3.7% of total N content present in the plough layer soil, since a fraction of mineralized soil N (about 50%) is lost by denitrification, ammonia volatilization and/or leaching. Any management practice that would even slightly increase the plant availability of soil N would result in significant benefits. There are several ways of enhancing soil N use in crop production. These involve: (i) utilizing N present in subsoil layers, (ii) increasing soil N mineralization rate, (iii) decreasing the loss of mineralized N from the rooting zone, and (iv) growing of efficient crop varieties.

Our research results have shown the impact of field water regimes on N mineralization in soils of varying reactions. It was also found that more than 40% of the total mineralized N in a soil profile remained below the surface/plough-layer. By adjusting tillage depth for land preparation, mineral N present in subsoil layers could be made available to the growing crops. Considerable amount of N mineralized and accumulated in the soil (30 to 60 kg $ha^{-1}$) during a dry fallow period, which commonly get lost from the soil profile by leaching and denitrification during soil puddling and land preparation for wet season rice, could be conserved by raising fast growing and drought tolerant legumes like horsegram and recycled to soil by incorporating their biomass/residues during land preparation for the following crop. Crop varieties have been found to significantly differ in their ability to use subsoil N and also in their influence on soil N mineralization. Selection of the efficient crop varieties could thus be another important way of making efficient use of soil N. To sustain N fertility and productivity of croplands, however, the original soil N levels must be maintained through natural resources like recycled crop residues and enhanced biological $N_2$ fixation.

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# Effect of Water Soluble Fertilizers and Conventional Fertilizers through Fertigation in Banana on Growth, Yield, Nutrient Distribution in Soil and Plant

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Use of water soluble fertilizers is increasing in India as practice of fertigation is becoming popular especially in commercial and high value horticultural crops. However the high cost of water soluble or speciality fertilizers is a hurdle for small and marginal farmers to adopt drip fertigation which increases not only water use efficiency , but also nutrient use efficiency by 30-40%. A field Investigation was carried out at IIHR in banana cv. Grandnaine to study the efficiency of conventional fertilizers in comparison to water soluble fertilizers in drip fertigation on growth, yield, nutrient distribution in different soil depths and on leaf NPK status. Speciality fertilizers in fertigation significantly improved growth of banana in terms of height and girth. Number of leaves did not vary much , though there was increase in number of leaves compared to basal application of fertilizers. Fruit yield was significantly affected by use of speciality fertilizers. These fertilizers in fertigation gave highest yield of 41.28 kg/bunch. This yield is about 33% more than the control treatment where 100% NPK given as basal and 20% more than the treatment where NPK was given through conventional fertilizers in fertigation. There was no significant variation in number of hands/ bunch and number of fingers/hand. The increase in bunch size was mainly due to increase in number of fingers and individual fruit weight. The individual fruit weight ranged from 178.4 g in control plots where NPK was given through conventional fertilizers as basal application to 225.4 g in the treatments where NPK was given through water soluble fertilizers in drip fertigation.

The status of soil N,P,K in different soil depths viz 0-20 cms and 20-40 cms showed that soil NPK contents were more in 0-20 cms depth in the treatments of conventional fertilizer application where as these increased in 20-40 cms depth in the treatments where speciality fertilizers were given through fertigation .This was due to increased solubility of water soluble fertilizers and consequent leaching to lower depth where majority of root growth of banana was observed. The distribution of NPK at different soil depths showed that soil N ranged from 254.7-283.9 ppm in 0-20 cm and 209.0—285.4 ppm in 20-40 cm depth. Soil P ranged from 6.89-8.83 in 0-20 cms and 5.22-9.76 ppm in 20-40 cms depth. Soil K ranged from 184.9-294.6 ppm in 0-20 cm and 195.0-320.9 ppm in 20-40 cm depth. Leaf NPK status also showed that their contents were higher in the treatments of speciality fertilizers .This study showed that growth and yield were significantly improved by use of water soluble fertilizers in banana due to better availability of NPK at 20-40 cm depth due to higher solubility of water soluble fertilizers.

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# Effect of Rate and Methods of Zinc and Iron Application on Mustard in Salt Affected Soil

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The abiotic stresses, such as soil salinity and sodicity are largely responsible for the low productivity of crops resulting from low availability of micro-nutrients such as Zn and Fe. Therefore, the importance of judicious management of plant nutrients in these soils is as important as that of their reclamation. Hence, a field experiment was conducted to evaluate the effect of rate and methods of zinc and iron application on mustard under pearlmillet-mustard cropping system with 12 treatments replicated thrice in RBD. The treatments were $T_i$- Control, $T_2$- 5 kg Zn $ha^{-1}$, $T_3$- 6.25 kg Zn $ha^{-1}$, $T_4$- 7.5 kg Zn $ha^{-1}$, $T_5$- 7.5 kg Fe $ha^{-1}$, T6- 10 kg Fe $ha^{-1}$, $T_7$-12.5 kg Fe $ha^{-1}$, Tg- 5 kg Zn+10 kg Fe $ha^{-1}$, $T_9$- 5 kg Zn $ha^{-1}$+10 kg Fe $ha^{-1}$ + 10 t FYM $ha^{-1}$, Tlo-Foliar sprays of 0.5% $ZnSO_4$ (twice), $T_{11}$- Foliar sprays of 1% $FeSO_4$ (twice at 30 and 45 DAS) and $T_12$- Combined foliar sprays (0.5% $ZnSO_4$+1% $FeSO_4$; twice). Zinc and iron were applied through soil in the form of $ZnSO_4.7H_2O$ and $FeSO_4.7H_2O$, respectively at the time of sowing. Foliar sprays of respective nutrients were also applied with same chemicals as soil application at 30 and 45 days after sowing. The soil had initial $EC_e$ 10.71 dS $m^{-1}$ and pH 8.45 for 0-15 cm soil depth. Results showed that soil application alone with 12.5 kg Fe $ha^{-1}$ significantly decreased Na content by 32% and chloride by 28% over control in the leaves of mustard at flowering stage. Among the foliar applications of Zn and Fe, highest total chlorophyll content was recorded under combined foliar sprays as in T12 (2.73 jag/g) than control (2.47 1.1 mg $g^{-1}$), whereas, lowest proline content (12.1 mg $g^{-1}$) was observed under 1% sprays of Fe ($T_{11}$) than control (13.1 mg $g^{-1}$). Treatment with 5 kg Zn $ha^{-1}$ + 10 kg Fe $ha^{-1}$ along with 10 t FYM $ha^{-I}$ was able to decrease proline by 50%, increase total chlorophyll content by 39.7% and seed yield by 44% in mustard over control. The foliar application of 0.5% $ZnSO_4$ or 1% $FeSO_4$ was effective in increasing the seed yield of mustard similar to soil application of 5 and 7.5 kg $ha^{-1}$ of Zn and Fe, respectively, whereas combined application of Zn and Fe was better than single nutrient foliar sprays. Under the straight or alone application of Zn and Fe, highest seed yield was recorded under the treatment of 7.5 kg Zn $ha^{-1}$ (19.4 q $ha^{-1}$) and 12.5 kg $ha^{-I}$ Fe (18.4 q $ha^{-1}$).

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# Response of Maize Crop to Nitrogen Applied through Nano Clay Polymer Composites

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Nitrogen (N) is an essential element required for the growth and development of plants. Application of nitrogenous fertilizer is mandatory for higher crop production as N plays many important roles in the plant. Most of the applied nitrogenous fertilizer is lost in the environment through various processes *viz*., denitrification, leaching, volatilization which results into very low nitrogen use efficiency. Controlled release nitrogenous fertilizer is expected to release N slowly matching with crop demand at various crop growth stages. In this context, the use of nano clay polymer composites (NCPC) as a slow release carrier of nutrients and some other agrochemicals may be useful. In the present investigation, we have used NCPC as a slow release carrier of nitrogenous fertilizer, with the aim to enhance N uptake by maize. For this purpose, a field experiment was conducted with control, 100% N applied through urea, 50% N applied through NCPC, 75% N applied through NCPC and 100% N applied through NCPC. Each treatment was replicated three times using a randomised block design. Fertilizer N was applied in three equal splits *i.e.* basal, eight leaf stage and tasseling stage. The plants were harvested at maturity. Results indicate that highest available N in soil was associated with 100% N applied through NCPC. Available N content in 100% N applied through urea and 75% N applied through NCPC were statistically at par. Such impact of these two treatments was also reflected on N content and yield of maize. Nitrogen applied through NCPC was the most efficient in enhancing yield of maize over control. Highest yield (5.53 t $ha^{-1}$) and N content (1.65%) in maize grain were recorded under 100% N applied through NCPC treatment. Maize yield of 5.4 t $ha^{-1}$ was recorded in conventional urea applied plot which was found at par with 75% N through NCPC applied plots (5.27 t $ha^{-1}$). Therefore, at least 25% of recommended dose of N can be saved if N is applied through NCPC without compromising yield. Thus, nitrogen loaded NCPC has potential of enhancing use efficiency of applied N leading to curtailing the dose of costly nitrogenous fertilizers.

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# Boron Concentration and its Translocation at Different Growth Stages of Rice under Rice Wheat Sequence in Acid Alfisol of Jharkhand

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A field study was conducted to evaluate boron concentration and its translocation in rice at different growth stages in various plant parts during *kharif* 2012 and 13, at the Research Farm of Department of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Ranchi (Jharkhand). The recommended dose of N, P and K was applied at 80: 40: 30 kg $ha^{-1}$ in combination with (a) four levels of boron (0, 1, 1.5 and 1 kg B $ha^{-1}$ + 2 foliar sprays of Borax (0.2%) at tillering and before flowering).The concentration of boron was recorded at tillering, pre flowering, panicle initiation and maturity stages. At maturity; straw, brown rice and husk were considered for translocation study. From the pooled data of two years (2012-13), it is evident that each additional dose of B exhibited higher B content in all plant parts and at different growth stages. The highest B concentration was observed under 1 kg B $ha^{-1}$ + 2 foliar spray of borax (0.2% at tillering and pre flowering stage) in all the stages and all plant parts and the least was recorded in control. The B content observed at tillering stage (3.77 mg $kg^{-1}$) and at pre flowering 3.22 mg $kg^{-1}$ (upper leaf), 4.91 mg $kg^{-1}$ (lower leaf) and 6.01 mg $kg^{-1}$ (stem) under 1 kg B $ha^{-1}$ + 2 foliar spray of borax. The magnitude of B concentration (mg $kg^{-1}$) in different plant parts was found in order of upper leaf < lower leaf < stem at pre flowering stage whereas at panicle initiation stage the highest B concentration was recorded in lower leaf followed by stem, middle leaf, upper leaf and least was recorded in panicle. At maturity B concentration was recorded highest in straw (14.9 mg $kg^{-1}$), followed by husk (11.51 mg $kg^{-1}$) and brown rice (1.57 mg $kg^{-1}$). From the observed trend, it is inferred that the translocation of B remains maximum towards the lower most part of the plant and in a decreasing manner towards the sink (panicle/grain).

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# Direct and Residual Effect of Zinc and Boron on Growth Parameters and Yield of Rice–Wheat Sequence in Red and Alluvial Soils of Eastern Uttar Pradesh

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A pot experiment was conducted during *kharif* 2014 and *rabi* 2014-15 to evaluate the direct effect of increasing zinc (Zn) and boron (B) application on growth parameters and yield of rice and their residual effect on subsequent wheat crop grown in sequence in red and alluvial soils under greenhouse conditions. Four levels of Zn (0, 1, 2 and 4 mg kg$^{-}$) and four levels of B (0, 0.5, 1 and 2 mg kg$^{-1}$) were applied to rice only and NPK at the rate of 60.40, 30 mg kg$^{-1}$ soil, respectively. were applied to all the pots in both the crops. At the end of experiment, there were significant improvements in plant height. chlorophyll content, number of tillers pot$^{-1}$ and yield in both the crops. The highest grain yield (48.90 g pot$^{-I}$ ) in rice was obtained with the combined application of 4.0 mg zinc and 1.0 mg boron kg$^{-1}$. However, highest wheat yield (35.98 g pot$^{-1}$) was obtained with 4.0 mg zinc and 2.0 mg boron kg$^{-1}$. Application of micronutrients might have accelerated the uptake of micro- as well as macro-nutrients resulting in higher grain yield. High response from a combined application of B and Zn clearly demonstrated the necessity of micronutrients for improving production in the soil under study. On the basis of results obtained, it can be concluded that Zn or B had synergistic effect on the vegetative growth and yield of crops. It could be suggested to choose a regular dose of B for enhancing efficiency of applied Zn. Sometimes a high dose of Zn could be even more beneficial with a controlled application of B.

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# Effect of N, P, K, S and Zn in Mustard Varieties on Alluvial Soils of Madhya Pradesh

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Rapeseed-mustard oilseed crops are important sources of edible oil in Indian diet. The area under the crop is increasing progressively because of its high economic value, but the yield per unit area per unit time is still low because of use of traditional varieties and inadequate use of fertilizers. The yield and quality of Indian mustard may be increased by the use of high yielding varieties. N, P, K S and Zn are important and inevitable nutrients responsible for crop yield and its quality. A field experiment was conducted during *rabi* season of 2008-09 and 2010-11 at the farmers' field of Ambah tehsil of Morena district under supplemental irrigated conditions. The experimental soil had sandy loam to clay loam in texture having 0.42% organic carbon, $KMnO_4$ extractable N-195 kg $ha^{-1}$, Olsen's $P_2O_5$-22 kg $ha^{-1}$, 1*N* ammonium acetate extractable $K_2O$-390 kg $ha^{-1}$, Morgan S 16 kg $ha^{-1}$ and DTPA extractable Zn 40 mg $kg^{-1}$. Five promising varieties (Varuna, Kranti, Rohini, JM-2 and JM-1) and 4 levels of N:P:K:S:Zn (60:30:15:22.5:15, 80:40:20:30:20, 100:50:25:27.5:25 and 120:60:30:45:30 kg $ha^{-1}$) were evaluated in split plot design with three replications. Full dose of $P_2O_5$ and $K_2O$, S and Zn and half dose of N were given as basal dressing at the time of sowing and remaining half dose of N was top dressed in standing crop, 35 days after sowing.

Seed yield and uptake of N, P, K, S and Zn significantly influenced by different fertility levels and varieties. Mean value of three years data revealed that the variety Rohini produced considerably higher seed yield and oil content over other varieties. Seed yield and N, P, K, S and Zn in soil and plant increased significantly with increasing levels of N:P:K:S:Zn up to 120:60:30:45:30 kg $ha^{-1}$. Higher oil content was recorded under lower dose of fertility levels. The higher uptake of total N, P, K, S and Zn by Rohini may be attributed to the higher N, P, K, S and Zn content and higher biological yield. Application of N, $P_2O_5$, $K_2O$, S and Zn @ 120, 60, 30, 45 and 30 kg $ha^{-1}$, respectively recorded highest available status and balance sheet of N, $P_2O_5$, $K_2O$, S and Zn.

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# Studies on the Influence of Silicon for Sustaining the Rice Production

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Our present investigation aimed to evaluate the effect of Si fertilizer on the economic produce and pest and disease infestation of rice. For this, a field trial was conducted with different doses of Si through different sources (*viz.*, diatomaceous earth (DE), $CaSiO_3$ and charred rice husk (CRH)) during *kharif* season for consecutive two years (2013 and 2014) with two levels of organic matter and seven Si treatments on a popularly grown rice cultivar Swarna Masuri. Si application significantly influenced the grain and straw yield as well as it helped to reduce the pest and disease infestation of rice. Higher doses of Si showed better results than lover dose and among the sources $CaSiO_3$ was better than other sources. Irrespective of soil the magnitude of increase in grain and straw yield of the tested cultivar were 25.1 and 17.9% upon application of charred rice husk; 26.9 and 19.7% on application of diatomaceous earth and 32.0 and 21.5% on application of $CaSiO_3$, respectively when they were applied @ 40 kg $ha^{-1}$. Application of Si @ 20 kg $ha^{-1}$ through charred rice husk, diatomaceous earth and $CaSiO_3$ increased grain and straw yield by 14.8 and 8.9, 17.4 and 11.0 and 23.5 and 15.0%, respectively. The results also showed that application of Si through different sources significantly decreased green leaf hopper (GLH), brown plant hopper (BPH), grasshopper, blast, brown spot and sheath blight infestation of rice over the control. Application of Si @ 40 kg $ha^{-1}$ through charred rice husk, diatomaceous earth and $CaSiO_3$, decrease GLH infestation 18.5, 21.6 and 25.9%, BPH infestation 27.2, 31.3 and 35.6%, grasshopper 49.3, 51.7 and 55.7%, blast 29.9, 34.8 and 41.7%, brown spot 34.0, 38.6 and 41.9%, sheath blight 39.2, 44.8 and 48.0%, over control respectively. The results, therefore, revealed that Si fertilizer application is very effective for sustaining the rice production.

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# Effect of Zinc Oxide Nanoparticles on Growth and Yiled of Groundnut (*Arachis hypogaea* L.)

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A micro-plot study was conducted to examine the effects of zinc oxide nanoparticles on growth and yield of groundnut. The soil utilized in the micro plot study was marginal in available Zn status. The study included four experiments in a sequence. The synthesis of ZnO nanoparticles was carried out in laboratory using oxalate decomposition and mean particle size was estimated by using different microscopic analysis *viz.*, XRD, TEM, SEM, DLS and UV-VIS Spectroscopy. Before conducting micro plot study, effect of Zn nanoparticles at different concentrations on germination of groundnut seeds was evaluated in laboratory. Based on the germination study different concentrations *viz.*, 500, 1000 and 2000 ppm were selected to treat the groundnut seeds as seed treatment as against standard seed treatment of bulk ZnO (30% Zn) suspension. The effect of foliar application of Zn nanoparticles keeping similar concentration was also conducted in groundnut in *kharif* and *summer* season 2013-14. The experiments were conducted in completely randomized design keeping three replications.

The effect of the treatments was studied on seed germination, seedling vigor, plant growth, chlorophyll content, pod yield and root growth of groundnut. Treatment of nanoscale ZnO (70 nm mean particle size) at 500 ppm concentration promoted seed germination, root length and seedling vigour. The seed treatment of groundnut seeds with ZnO nanoparticles at 500 ppm recorded the maximum groundnut pod yield (222 g plot$^{-1}$) over control (128 g plot$^{-1}$) and kernel yield (154.1 g plot$^{-1}$) over control (88 g plot$^{-1}$). The foliar application of ZnO nanoparticles at similar concentration *i.e.* at 500 ppm also recorded the highest pod (225.7 g plot$^{-1}$) and kernel yield (155.7 g plot$^{-1}$) as compared to seed treatment with bulk ZnO suspension (pod yield 150.4 g plot$^{-1}$; kernel yield 104.1 g plot$^{-1}$) and control (134.3 g plot$^{-1}$ and 92.7 g plot$^{-1}$). The inhibitory effect with higher nanoparticle concentration (2000 ppm) was noticed which indicated the need for judicious use of these nanoparticles to supplement the Zn requirement of crops.

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# Permanent Manurial Experiment on Maize-Green Gram Cropping System in Red Sandy Loam Soil of Vagarai under Irrigated Condition

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The experiment on permanent manurial experiment was started in 2011 using maize green gram cropping system. So far four maize (TNAU hybrid maize Co-6) and four green gram (Co-6) crops were raised to study the changes in soil parameters and yield. The main objective of the trial is to study the effect of continuous addition of organics, inorganics and its integrated effect on yield attributes, yield and uptake of maize. Maize crop was raised during Rabi and green gram crop at summer. Treatments consisted of control, organic, inorganic and integrated nutrient management. In the inorganic treatment blanket recommendation of 250:75:75 kg NPK $ha^{-1}$ was applied. Organic plot received the application of farm yard manure on N equivalent basis, while INM plot received 12.5 t FYM $ha^{-1}$and blanket recommendation of fertilizer along with biofertilizer. The experiment was conducted in a non replicated trial.

The yield parameters such as grain yield and haulm yield were showed the highest in INM practice followed by inorganic and organic treatments. The grain yield varied significantly due to various treatments and ranged from 573 to 725 kg $ha^{-1}$. The control recorded the lowest grain yield. Similarly the nutrient uptake by the crop at time of harvest registered significant difference due to different treatment effects. The N and P uptakes were highest in grain when compared to haulm whereas K uptake was highest in stalk rather than grain. Among the treatments, INM practice recorded the highest uptake and available nutrients (NPK) followed by inorganic, organic, while the control recorded lowest.

The result indicated that the grain and stover yield ranged from 4131 to 7716 kg $ha^{-1}$ and 7588 to 10339 kg $ha^{-1}$, respectively. The highest grain yield was observed in INM practice (7716 kg $ha^{-1}$) which was significantly differed from other treatments. The control recorded the lowest grain yield. The highest stover yield was recorded in INM (10339 kg $ha^{-1}$) followed by inorganic, organic treatments. The change in available N showed increasing trend in all the treatments except control. In the case of available P, K there was a decline in all the treatments however the rate of decrease was lowest in the case of organic.

The INM practice-higher growth and yield parameters consequently the higher grain, haulm yield and nutrient uptakes of green gram when compared to others indicating the superiority of INM practice. The same trend was observed in the maize crop also Increase in OC and available N status were observed in INM practice while available P and K contents were slightly reduced. Soil biological properties were enhanced in the INM plot followed by the organic plot.

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# Effect of Boron on the Yield, Quality and Economics of Cauliflower

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Cauliflower is grown almost throughout the year. The crop is highly remunerative and farmers get high return. The crop suffers from boron deficiency (dead heart rot and hollow stem) in soils of the region specially during the rainy season. Application of boron significantly overcomes these problems and results in increased curd yield.

Trials on farmers' field were conducted during 2014 at the adopted villages of Krishi Vgyan Kendra, Dewas. The experimental soil had pH 7.8, electrical conductivity 0.40 dS $m^{-1}$, organic carbon 0.45%, alkaline $KMnO_4$ extractable N 180 kg $ha^{-1}$ and 1N ammonium acetate extractable K 395 kg $ha^{-1}$. There are two practices were adopted [Farmers practices (135:50:30 NPK kg $ha^{-1}$ and improved practices (120:80:60 NPK kg $ha^{-1}$ + 1 kg borax $ha^{-1}$) for experiment. All the doses were applied at the time of sowing. Six farmers' fields were selected for the experiment. A common package of practices and pest management practices were adopted for the experiment.

The quality and yield parameters were influenced by the treatment. Highest curd yield (143.60 q $ha^{-1}$) with white curd colour were recorded under improved practices. 13.83% increase in yield over farmer practices were obtained under improved practices against the farmers practices i.e. curd yield (126.20 q $ha^{-1}$). Highest cost of cultivation (Rs. 32510 $ha^{-1}$) gross return (Rs. 125641 $ha^{-1}$), net return (Rs. 93133 $ha^{-1}$) and B:C ratio (3.86) were recorded under improved practices. However, lowest cost of cultivation (Rs. 31046/ha) gross return (Rs. 110390 $ha^{-1}$), net return (Rs. 79344 $ha^{-1}$) and B:C ratio (3.56) were recorded under farmers practices.

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# Potassium Response in Mung Bean in Coarse Textured Soils of Southern Haryana

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A field study was carried out on a coarse textured medium potash status soil of CCS HAU Regional Research Station, Bawal (Haryana) at three different locations from 2012 to 2014 to study the effect of potassium fertilization in mung bean in terms of yield, total K uptake, K build/depletion in soil and economics returns. The experimental soil was loamy sand in texture, alkaline in reaction (pH 8.32 to 8.40) , EC ( 0.17 to 0.20 dS $m^{-1}$), low in organic carbon (1.9 to 2.0 g $kg^{-1}$), medium in available P (10.55 to 11.34 kg $ha^{-1}$) and medium in available $K_2O$ (169.0-170.0 kg $ha^{-1}$).The experiment was laid out in randomized block design with three replications. There were five graded levels of potassium application *viz.,* 0, 10, 20, 30, and 40 kg $K_2O$ $ha^{-1}$. Recommended dose of fertilizers for crop was applied @ 20 kg N $ha^{-1}$ and 40 kg $P_2O_5$ $ha^{-1}$. Irrigation and plant protection measures were taken as per recommended practices. Crop was harvested at physiological maturity, threshed and plot wise yield was recorded. Seed, straw and soil samples were taken and analyzed for K concentration in seed and straw and available K in soil, respectively. The data was statistically analyzed and economics of K application was worked out. The results revealed that mung bean cv. MH- 421 seed yield increased significantly with application of potassium up to 20 kg $K_2O$ $ha^{-1}$. The increase in mean seed yield was 5.87, 16.29, 19.23 and 22.36 per cent due to application of 10, 20, 30 and 40 kg $K_2O$ $ha^{-1}$, respectively over control. Potassium fertilization also significantly increased the total K uptake by mung bean. It increased from 22.21 kg $ha^{-1}$ (control) to 26.03, 33.05, 37.15 and 40.00 kg $ha^{-1}$ at 10, 20, 30 and 40 kg $K_2O$ $ha^{-1}$, respectively. The mean K use efficiency varied from 38.2 to 54.2 per cent and was maximum with application of 20 kg $K_2O$ $ha^{-1}$. The application of potassium fertilizer helped in preventing the depletion of available soil K and enhanced its content in the soil. The mean post harvest available K status was 166.40, 167.25, 169.35, 170.48 and 171.57 kg $ha^{-1}$ at 0, 10, 20, 30 and 40 kg $K_2O$ $ha^{-1}$, respectively. The mean economic data analysis revealed that benefit cost ratio also increased with potassium application and the additional returns per rupee invested on K at 10, 20, 30 and 40 kg $K_2O$ $ha^{-1}$ levels of potassium were Rs. 10.94, 15.63, 12.17 and 10.72, respectively. The finding of this study serve to demonstrate that in coarse textured medium potash status soil of Southern Haryana, application of 20 kg $K_2O$ $ha^{-1}$ was found to be optimum for mung bean in terms of crop yield, soil K fertility status and economics.

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# Effect of Different Sources of Nutrient on Nodulation, Nutrient Uptake and Yield of Soybean (*Glycine max* (L.) Merrill) in Vertisol

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A field experiment was undertaken to evaluate the "Effect of different sources of nutrient on nodulation, nutrient uptake and yield of soybean (*Glycine max* (L.)Merrill) in Vertisol.". during *kharif* seasons 2014 and 2015 on the Research farm of R.A.K. College of Agriculture, Sehore (M.P.) on soybean. Experiment consisted of 7 treatments, laid out in randomized block design with three replications with the plot size 4m × 2.8m.The treatments includes- Absolute control ($T_1$), RDF( $N:P_2O_5:K_2O:S$ @20:60:20:20 respectively, T2 ) , RDF + Biofertilizer (*Rhizobium*+PSB, T3 ) , 50%RDF +FYM (2.5 t $ha^{-1}$ +Biofertilizer, $T_4$), 50%RDF +FYM(5.0 t $ha^{-1}$, $T_5$) , 50%RDF + Vermicompost 1.5 t $ha^{-1}$ + Biofertilizer, $T_6$) and 50%RDF + Vermicompost (3.0 t $ha^{-1}$, $T_7$). The experiment was conducted in medium black soil ( vertisol) having normal pH (7.3), EC (0.33 dS $m^{-1}$) and low organic carbon (0.42%). The soil available N, P, K, S, Zn and Mo were 198.28 kg $ha^{-1}$, 13.46 kg $ha^{-1}$, 455.64 kg $ha^{-1}$, 9.09 $kg^{-1}$ soil, 0.05 $kg^{-1}$ soil and 0.01 $kg^{-1}$ soil, respectively.

The effect of deffirent sources of nutrient on nodulation, nutrient uptake and yield of soybean was found economical and beneficial with respect to nodulation traits, nutrients uptake (NPKS), seed yield and net return were noticed significantly higher with the application of 50%RDF + Vermicompost (1.5 t $ha^{-1}$ + Biofertilizers ($T_6$) over the absolute control and other treatments. The enhancement in these parameters could be ascribed due to better availability of nutrients in the soil with the application of organic, biofertilizers and inorganic sources. The increment in supply of essential elements through these sources, their mobilization and influx into the plant tissues get enhanced and hence such results.

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# Response of Sulphur to Chilli in Medium Black Soils of Madhya Pradesh

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In recent years, sulphur deficiency has been aggravated in Indian soils due to tremendous increase in cropping intensity and adoption of cultivation of high yielding varieties. Use of sulphur free high grade fertilizers is other important factor responsible to it. Vegetable crops particularly belonging to 'Solanacae' have relatively higher sulphur requirement owing to their high content of sulphur containing amino acids and essential oils.

Trials on farmers' field were conducted during 2015 at the adopted villages of Krishi Vgyan Kendra, Dewas. The experimental soil had pH 7.8, electrical conductivity 0.40 dS $m^{-1}$, organic carbon 0.45%, alkaline $KMnO_4$ extractable N 180 kg $ha^{-1}$ and 1N ammonium acetate extractable K 395 kg $ha^{-1}$. There are three practices were adopted [Farmers practices (90:80:60 NPK kg $ha^{-1}$] and two recommended and improved practices (120:80:100 NPK kg $ha^{-1}$ and 120:80:100 NPK kg $ha^{-1}$ + sulphur @ 40 kg $ha^{-1}$+500 mL $ha^{-1}$ PSB) for experiment. All the doses were applied at the time of sowing. Thirteen farmers' fields were selected for the experiment. A common package of practices and pest management practices were adopted for the experiment.

The growth and yield parameters were significantly influenced by the treatments. Highest plant height (84.3 cm) and crop yield (91.43 q $ha^{-1}$) were recorded under improved practices against the farmers and recommended practices i.e. plant height (78.2 and 82.3.3 cm) crop yield (75.58 and 83.82 q $ha^{-1}$), respectively. Highest cost of cultivation (Rs 80700 $ha^{-1}$) gross return (Rs 210289 $ha^{-1}$), net return (Rs 129589 $ha^{-1}$ and B:C ratio (2.61) were recorded under improved practices. However, lowest cost of cultivation (Rs 783135 $ha^{-1}$) gross return (Rs 173834 $ha^{-1}$), net return (Rs 95521 $ha^{-1}$) and B:C ratio (2.22) were recorded under farmers practices.

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# Nutrient Status of Seedling and Budwood Nurseries of Meghalaya

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Rubber cultivation was confined to the south western part of India, mostly Kerala state, Kanyakumari district of Tamilnadu and Andaman and Nicobar Islands located between 8 to $12^0$ N till 1960s. The commercial cultivation of rubber (*Hevea brasiliensis*) in the north eastern region of India began in the early part of 1960s. Increase in productivity alone was not enough to meet the increasing demand at global as well as local level and horizontal expansion of rubber plantation was only viable answer. Scope for expansion of this crop, in the traditional belt is little due to non-availability of land. The only practical solution, therefore, has been extending rubber cultivation to the non-traditional regions. Rubber cultivation in the non-traditional region is successful, in spite of the fact that in these areas the crop faced various stress conditions like cold temperature during cold season and high wind velocity together with hail-storm etc. The majority of planting materials in Non-traditional rubber growing areas are supplied from the regional nurseries under the Rubber Board, Regional office and the objective of the present study is to assess the fertility status of nursery soils of Meghalaya. Six permanent nurseries under Rubber Board in non-traditional areas were selected for the study. Composite soil samples were collected from both seedling and bud wood nurseries (Each location two composite soil samples at the depth of 0-30 and 30-60 cm) during 2003 and 2010 and the soil samples were analyzed for the various parameters.

Data on soil collected during 2010 indicated wide variation in organic carbon, available phosphorus (P), potassium (K), Calcium (Ca), Magnesium (Mg), Iron (Fe), Manganese (Mn), Zinc (Zn), cupper (Cu) and soil pH in different nurseries. Available Zn was found to be low in all the nurseries. Evaluation of change in fertility status of soil by the long term establishment of nurseries in the same soil indicated, decline in organic carbon (16.67%), available calcium (12.78%), magnesium (35.51%) content and soil pH (4.61) at the surface soil. An increase in available phosphorous (19.36%) and potassium (13.51%) were noticed in all nurseries in all locations at the surface soil. Same trend was noted in both seedling and bud wood nurseries of *Hevea brasiliensis* at the sub surface soil (30-60 cm) also.

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# Impact of Long-Term Organic Farming on Soil Health and Crop Yield of Certified Organic Farms

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The field investigation in relation to evaluation of soil properties of certified organic farms in Nagpur district was carried out during kharif-rabi season of 2014 - 2015 to assess the physicochemical, biological and micronutrients properties of soils. Soil samples of 0-20 cm depth were collected randomly after the harvest of crops from five locations *viz.* Chacher, Saoner, Selu, Gangner and Chichbhavan. The certified organic farmers applying the 2.5 to 10 t FYM $ha^{-1}$, ghanajivamrut 500 kg $ha^{-1}$ (Ghanajivamrut is mixture of 500 kg fresh FYM with 50 lit jivamrut prepared by properly mixing 3-4 times at an one week interval and ready for use within 40-45 days) and jivamrut 500 L $ha^{-1}$(Jivamrut was prepared by taking 10 kg cow dung+ 10 lit cow urine + 2 kg jaggary+2 kg gram flour with half kg of organic rich soil in a 200 lit capacity plastic drum and mixing a materials with wooden stick 2-3 times daily for 4-5 days. Jivamrut was applied @ 500 lit $ha^{-1}$ by diluting 10 times) from last 7-15 years continuously for fruits, cereals, pulses and vegetables crops.

The result revealed that, soil pH and bulk density of soil was reduced due to the continuous incorporation of various organic sources under different crops. However, EC (0.21 to 0.44 dS $m^{-1}$) of soil remained almost unchanged. Increased hydraulic conductivity of soil associated with decrease in bulk density due to long term effect of various organic sources. Organic carbon was recorded between 4.64 to 9.94 g $kg^{-1}$ under the study whereas an application of inorganic fertilizer alone(4.47 to 6.96. g $kg^{-1}$ ).The per cent increased of organic carbon by 13.12 to 103.80 per cent at different locations. Soil available N was highest at Gangner location (340.52 kg $ha^{-1}$), which an increased by 27.89 per cent with the application of jivamrut 500 lit $ha^{-1}$ to pigeonpea over inorganic fertilizer. Application of NPK fertilizer alone increased the availability of potassium in soil by 13 to 17 per cent and available S by 10.2 to 33.2 per cent. The use of different organic sources under different cropping system found useful in maintaining the available micronutrient status, SMBC and DHA of soil over inorganic fertilizer alone. The positive co-relation of organic carbon was recorded with hydraulic conductivity, N, SMBC and DHA and these properties had significant positive co-relation with the yield of Nagpur mandarin, pulses and vegetable crops. Amongst the organic sources the use of ghanajivamrut had outstanding results on yield of Nagpur Mandarin (17.0 t $ha^{-1}$), wheat, turmeric and vegetables. The addition of ghanajivamrut, jivamrut and FYM for 7-15 years sustained the crop yield. However, higher yield of pigeonpea and cotton were obtained with the application of inorganic fertilizers.

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# Micronutrient Status of Soils in South-West Districts of Punjab, India

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Management of plant nutrients is mainly governed by their status in soils. Analysis of more than 3 lakhs soil samples under the aegis of AICRP on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants showed that about 44, 15, 6 and 8 percent soils are deficient in Zn, Fe, Mn and Cu, respectively. Micronutrient deficiencies that appear to be localized presently may expand geographically in the near future posing threat to the production system. Keeping these view and lack of information on micronutrient status to identify the emerging micronutrient deficiency or toxicity in soils, a study on micronutrient status in soils of South-West Region of Punjab has been planned. Two hundred forty six (246) surface (0-15 cm) soil samples from Bathinda, Mansa, faridkot and Shri Muktsar Sahib District of this region were collected and analysed. Soils were neutral slightly alkaline in reaction (pH 6.5 -9.2) with organic carbon (OC) content ranging from low to high (0.3- 14.1 g $kg^{-1}$). DTPA extractable Zn, Fe, Mn and Cu varied from 0.17 to 65.24, 1.14 to 179.2, 0.30 to18.01, and 0.16 to 8.10 mg $kg^{-1}$, respectively. Zn deficiency was reported only in Bathinda district with 9% deficient samples; however other districts showed medium to high range of DTPA-extractable Zn. The Cu deficiencies were reported in Bathinda and Mansa district with 9 and 5% deficient samples, respectively. Among the four the soils of three districts namely Bathinda, Mansa and Faridkot were reported Mn deficient by 12, 5 and 6 per cent, respectively. Maximum Fe deficiency was reported in Faridkot (25%) followed by Bathinda / Muktsar (17%) and Mansa (10%). On the basis of these data it is concluded that in general, the soil of the region showed maximum deficiency of Fe followed by Mn, Cu and Zn.

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# Standardization of the Doses of Vermi-compost for Organic Cultivation of Kalmegh (*Andrographis paniculata* Wall. Ex Nees)

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Kalmegh (*Andrographis paniculata*) is a medicinal plant belongs to family Acanthaceae. It is used as antibiotics for treatments of many diseases like typhoid, controlling of fever, worms, dysentery, digestive system, gas, curing of lever *etc*. Due to highly bitter in taste, it is called as "king of bitters". The whole plant is used for the preparation of any drugs and decoction. The active compound Andrographolide is the chief compound of this plant which may be useful for inhibiting the tumor cells causing cancer. Only organically grown medicinal plant is acceptable for drug formation by the companies. So, it is required to develop a package of practices for organic cultivation of this plant.

Keeping these facts in views, a field experiment was carried out at Banthra Research Station of the CSIR-National Botanical Research Institute, Lucknow during 2014 and 2015. Treatments of the experiment were $T_1$- Control, $T_2$- 2.5 t ha$^{-1}$, $T_3$- 5 t ha$^{-1}$, $T_4$- 7.5 t ha$^{-1}$, $T_5$- 10 t ha$^{-1}$, $T_6$- 12.5 t ha$^{-1}$ and $T_7$- 15 t ha$^{-1}$ with four replications in the RBD. The vermicompost applied before 25 days of transplanting of the Kalmegh. The result indicated that plant height, the number of branches, stem diameter, plant spread, plant biomass increased with increasing doses of vermicompost up to 15 t ha$^{-1}$. However, all the parameters were significant up to 10 t ha$^{-1}$ ($T_5$). Plant biomass is the main component of the plat which increased with increasing levels of the doses of vermi-compost up to 15 t ha$^{-1}$ ($T_7$), however, it was significant up to 10 t ha$^{-1}$ ($T_5$) showing the value of 2.16 t ha$^{-1}$ and 2.03 t ha$^{-1}$, respectively. Soil microbial population such as total bacteria, fungi, actinomycetes and *Azotobacter* increased with increasing doses of vermicompost application up to 15 t ha$^{-1}$. Application of vermi-compost provided the favourable conditions for the growth of aerobic microbes for decomposition and providing the nutrient for plant growth. Soil enzymic activity such as dehydrogenase, β–glucosidase, urease, protease and acid phosphatase also increased with increasing levels of organic matter. However, alkaline phosphatase decreased in the order of increasing the doses of vermicompost.

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# Effect of Monocropping of *Bt* Cotton on Soil Properties and It's Nutrient Requirement in Adilabad District

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A study was taken up to understand the impact of mono- cropping of *Bt* cotton on soil properties, to reassess the various fertilizer practices in vogue for *Bt* cotton and finding out the optimum nutrient requirement of *Bt* cotton in black soils of Adilabad. To meet the objectives the study was made into two parts. Initially, a survey was carried out by collecting information from cotton cultivated farmer's in Adilabad district during pre *kharif* season, 2013. The survey revealed that the farmer's of the region are applying high doses of fertilizers with an average dose of 245-140-75 kg NPK $ha^{-1}$ as against to the recommended dose 150-60-60 kg NPK $ha^{-1}$. Seed cotton yield of farmer's ranged from 15-32 q $ha^{-1}$ with an average of 25.02 q $ha^{-1}$. Changes in soil properties of *Bt* cotton grown soils were assessed by collecting 30 geo-referenced representative soil samples (12 from fields under *Bt* cotton for more than 8 years, 12 from fields under *Bt* cotton for 2 to 5 years and 6 from non *Bt* cotton fields of Adilabad district) and characterized for physical (texture), physicochemical (pH, EC and CEC), chemical (organic carbon, available N, P, K, S and micronutrients) and biological properties (microbial biomass carbon, and population of total aerobic microbes, *Pseudomonas* and *Azotobacter*). Cultivation of *Bt* cotton for a long period of > 8 years did not bring out any significant change when compared to short term (2-5 year) or non *Bt* cotton grown soils in any of the properties studied.

To find out the optimum nutrient requirement of *Bt* cotton a field experiment was conducted at KVK, Adilabad during *kharif*, 2013 with 9 treatments *viz*., Control, Farmers Practice (245-140-75 kg NPK $ha^{-1}$), recommended dose of fertilizers (RDF) (150-60-60 kg NPK $ha^{-1}$), RDF + S @ 30 kg $ha^{-1}$, Soil test based recommendations for an yield target of 25 q $ha^{-1}$ (115-90-30 kg NPK $ha^{-1}$), 125% RDF, 125% RDF+ S @ 30 kg $ha^{-1}$, 150% RDF and 150% RDF + S @ 30 kg $ha^{-1}$ in completely randomised block design with three replications. Farmer's practice recorded significantly higher plant height and monopodial per plant over 100% RDF, 100% RDF + S @ 30 kg $ha^{-1}$. Increasing fertilizers doses from 100% RDF to 150% RDF resulted in increasing the number of sympodial branches, number of bolls per plant and dry matter production at harvest but were on par with 100% RDF. Farmer's was also found to be on par with 100% RDF+ S @ 30 kg $ha^{-1}$. Increasing fertilizers doses from 100% RDF to 150% RDF resulted in increasing kapas yield but it was on par with yield attained in 100% RDF+ @ 30 kg $ha^{-1}$ (3927 kg $ha^{-1}$) and soil test based recommendations (3911 kg $ha^{-1}$). Response to the addition of sulphur @ 30 kg $ha^{-1}$ with 100, 125 or 150 per cent RDF was not significant. The sulphur addition treatments recorded marginal increase in yield which was on par with the respective treatments without sulphur. The soil test based fertilizer recommendation (3911 kg $ha^{-1}$) produced higher yield than target yield of 25 q $ha^{-1}$, suggesting the need for revalidation of STCR equations in Adilabad district.

Economic analysis indicated that application of very high doses of fertilizers did not help in getting higher net returns or higher benefit cost ratio. All the treatments with increased doses of fertilizers (2.43 to 2.73) and farmer's practice (2.21) recorded lower B: C ratio. Maximum net returns and B: C ratio were obtained with 100% RDF + S @ 30 kg $ha^{-1}$ followed by soil test based recommendations and control recorded minimum net returns. It is rational to follow soil test based fertilizer application or to adopt the present recommendation of 150:60:60 kg NPK $ha^{-1}$ along with 30 kg sulphur for profitable cultivation of *Bt* cotton in Adilabad district of Telangana state.

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# Studies on Effect of Varied Nitrogen Levels on Yield and Quality of Sweet Sorghum Genotypes

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Sweet sorghums are genotypes of sorghum developed for bio-fuel production, as an alternative to fossil fuels. However, these sweet sorghums, owing to their high palatability at any stage of crop harvest are much preferred by dairy farmers as a promising fodder crop. They are found yielding green fodder better than maize. Nevertheless the quality of fodder at different stages of harvest and nitrogen requirements when harvested for fodder at different stages was less studied. Four released cultivars of sweet sorghum *viz.*, SSV84, CSV19SS, CSH22SS and CSV24SS were grown under three levels of nitrogen *viz.*, 80, 100 and 120 kg $ha^{-1}$. The fodder quality is studied at 50% flowering and at physiological maturity.

Variety CSV19SS recorded highest green fodder yield when harvested at flowering or at physiological maturity with 415.4 and 443.6 q $ha^{-1}$. This was followed by CVH22SS with commendable green fodder yields. The nitrogen levels influenced the yields and quality. At flowering though the effect of N levels on crude protein was non-significant, the crude protein% was highest in CSV19SS (10.04%) followed by that of CSH22SS (9.96%).The crude fiber content was not affected by the N levels. The sweetness of cane which is the reason for palatability of the fodder, i.e., brix was also highest in CSV19SS (9.03%).

At physiological maturity of crop the highest protein content was observed in CSV24SS (8.37%)though CSV19SS and SSV84SS were also on par with it. Lowest was recorded in CSH22SS (7.69%). The var. CSH22SS also recorded highest CF% *i.e.*, 38.1. The crude protein per cent decreased from flowering to harvest while the reverse was true with respect to CF per cent. Among all four cultivars studied the var. CSV19SS proved better closely followed by CSH24SS.

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# Direct and Residual Effect of Boron Application on Yield and Soil Properties under Cauliflower-Okra Cropping Sequence

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A field experiment was conducted during 2013-14 at the experimental farm of Department of Soil Science, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, to evaluate the direct and residual effect of different levels of boron (0, 0.75, 1.5, 2.5, 5, 10, 20 and 30 kg $ha^{-1}$along with 100% NPK + FYM @ 20 t $ha^{-1}$ fresh weight basis) on cauliflower-okra yield and soil properties. The experiment with 10 treatments including eight levels of boron, one treatment comprising of only FYM @ 20 t $ha^{-1}$ and one absolute control was laid out in a randomized block design replicated thrice. Boron (B) was applied as boric acid (17.5% B) once to the first crop (cauliflower) only along with recommended dose of nitrogen (N), phosphorus (P) and potassium (K). The residual effect of B was studied in okra. The results revealed that the curd yield of cauliflower was significantly affected by different levels of direct boron application. Curd yield varied from a minimum of 25.0 q $ha^{-1}$ in absolute control to maximum of 110.3 q $ha^{-1}$ in the treatment receiving B @ 1.5 kg $ha^{-1}$ + 100% NPK + FYM which was statistically at par with the treatment where B was applied @ 0.75 kg $ha^{-1}$ along with 100% NPK + FYM. The maximum increase of 29.3% in curd yield was recorded in the treatment receiving B @ 1.5 kg $ha^{-1}$ along with 100% NPK + FYM followed by application of B @ 2.5 kg $ha^{-1}$ + 100% NPK + FYM, where increase was to the tune of 23.2% as compared to treatment where no boron fertilizer was added. At higher rates of boron i.e. 10, 20 and 30 kg $ha^{-1}$, due to toxic effects, a reduction of 43.5% in curd yield was recorded at highest B level. The residual effect of boron applied to cauliflower was significant on the yield of succeeding okra crop. The highest okra yield (109.4 q $ha^{-1}$) was recorded in treatment where boron was applied @ 20 kg $ha^{-1}$ to the preceding crop, which was 28.6% higher over control where no boron was applied. Highest yield with boron application @ 20 kg $ha^{-1}$ was statistically at par with the treatment where B was applied @ 10 kg $ha^{-1}$ along with 100% NPK + FYM. Different treatments did not show any effect on soil organic carbon but had a significant effect on soil pH, available N, P and K content. There was a build- up of soil B after harvest with increased level of B from its lowest (100% NPK + FYM without boron) to highest level (B @ 30 kg $ha^{-1}$ along with 100% NPK + FYM) applied to cauliflower crop. The highest value (1.53 ppm) of soil available boron was recorded with 30 kg B $ha^{-1}$.

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# Yield, Nutrient Content and Uptake by Wheat (*Triticum aestivum* L.) as Influenced by Integrated Nutrient Management in *Haplustepts*

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A field experiment was conducted at Agronomy Farm, Rajasthan College of Agriculture, Udaipur during *rabi* season in 2013-14 and 2014-15 to study the yield, nutrient content and uptake by Wheat (*Triticum aestivum* L.) as influenced by integrated nutrient management in *Haplustepts.* The experiment was laid out in a split plot design with 27 treatment combinations which consisted of 3 organic manures (FYM @ 10 t $ha^{-1}$, Vermicompost @ 4 t $ha^{-1}$ and Poultry manure @ 5 t $ha^{-1}$), 3 levels of inorganic fertilizers (50% RDF, 75% RDF and 100% RDF) and 3 levels of biofertilizers (*Azotobacter*, PSB and *Azotobacter* + PSB)were replicated three times. The results revealed that grain yield (5.04 t $ha^{-1}$), straw yield (9.69 t $ha^{-1}$) and biological yield (14.73 t $ha^{-1}$) significantly increased with the application of poultry manure @ 5 t $ha^{-1}$ over other organic manures. Further results showed that the application of 75% RDF significantly increased the grain yield (4.84 t $ha^{-1}$) straw yield (9.24 t $ha^{-1}$) and biological yield (14.07 t $ha^{-1}$) over 50% RDF and statistically at par with 100% RDF and inoculations of seed with *Azotobacter* + PSB significantly increased the grain yield (5.01 t $ha^{-1}$), straw yield (9.65 t $ha^{-1}$) and biological yield (14.67 t $ha^{-1}$) over single inoculation. However poultry manure @ 5 t $ha^{-1}$ significantly increased the N (1.538 and 0.535%), P (0.355 and 0.224%) and K (0.548 and 1.482%) content in grain and straw as well as N uptake (130.23 kg $ha^{-1}$), P uptake (39.93 kg $ha^{-1}$) and K uptake (171.69 kg $ha^{-1}$) by wheat over other organic treatments. Application of 75% RDF significantly enhance the N (1.519 and 0.530%), P (0.345 and 0.216%) and K (0.539 and 1.462%) content likewise N uptake (123.02 kg $ha^{-1}$), P uptake (37.05 kg $ha^{-1}$) and K uptake (162.06 kg $ha^{-1}$) over 50% RDF and at par with 100% RDF. N (1.547 and 0.537%), P (0.358 and 0.221%) and K (0.543 and 1.479%) content in grain and straw significantly increased due to the dual inoculation of seed with *Azotobacter* + PSB. This treatment also significantly improves N uptake (129.9 kg $ha^{-1}$), P uptake (39.6 kg $ha^{-1}$) and K uptake (170.5 kg $ha^{-1}$) by wheat crop over single inoculation. So results showed that wheat crop should be supplied with poultry manure @ 5 t $ha^{-1}$, 75% RDF and dual inoculation with *Azotobacter* + PSB for sustainable and higher productivity.

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# Effect of Seed Priming and S Application on the Yield and P Uptake of Gobhi Sarson (*Brassica napus* L.)

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Poor crop stand due to one or the other unfavourable agronomic and environmental conditions is one of the major causes of low yield. However, rapid germination of seedlings could emerge and produce deep roots before the upper layers of the soil are dried and crusted, which may result in better crop establishment and higher crop yield. Owing to use of straight fertilizers sulphur deficiency has been emerging fast and more so in oilseed crops which responds to application of S. Keeping these in view, a field study was conducted in split plot design to evaluate the effects of seed priming and S application on the yield and P uptake of gobhi sarson (*Brassica napus* L.) cultivar GSC-7. Seeds invigorated by traditional soaking (hydropriming), osmo-conditioning (soaking of seeds in aerated, low-water-potential solutions) with potassium di-hydrogen phosphate ($KH_2PO_4$), sodium molybdate dihydrate ($Na_2MoO_4.2H_2O$), seeds inoculated with *Pseudomonas argentinensis* (LPGPR1), RB-3 and untreated seeds as control were kept in the main plots and three levels of sulphur were kept in the sub plots. The highest seed (2535 kg $ha^{-1}$) and straw yield (5011 kg $ha^{-1}$) was observed in phosphorus (0.3%) primed seeds. The uptake of P (18.36 kg $ha^{-1}$) was also significantly higher in the plots where seeds were primed with 0.03 phosphorus. Application of up to 40 kg S $ha^{-1}$ significantly improved the dry matter and seed yield over no application of Sulphur. It may be concluded that priming of gobhi sarson seed with phosphorus (P @ 0.3%) and application of up to 40 kg S $ha^{-1}$ were effective in improving the dry matter and seed yield of gobhi sarson.

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# Evaluating Optimum Time of Application of Fertilizer N with Different Organic Sources for Increasing N Use Efficiency in Rice-Wheat System

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A field experiment was conducted during *kharif*, 2015 to evaluate optimum time of application of fertilizer N with different organic sources for increasing N use efficiency in transplanted rice on a sandy loam soil at Punjab Agricultural University, Ludhiana. The experiment was laid out in a split-plot design with four types of organic manures (press-mud and farmyard manure each at 15 t $ha^{-1}$, poultry manure and biogas slurry each at 6.25 t $ha^{-1}$ ) and no amendment treatment in the main plots along with three different timings of N application; three equal splits (one-third each at transplanting, 3 and 6 weeks after transplanting and one-fourth each at transplanting and 3 weeks after transplanting and one half at 6 weeks after transplanting) and two equal splits (one-half each at 3 and 6 weeks after transplanting) including no-N control. The fertilizer N to rice was applied at the rate of 60 kg $ha^{-1}$ with press-mud and poultry manure and 80 kg $ha^{-1}$ with farmyard manure and biogas slurry. Soil of the experimental field was sandy loam in texture, medium in organic carbon and high in available P and available K contents. The grain yield of rice obtained with different manures did not differ significantly. The treatment receiving nitrogen in two splits ie at 3 and 6 weeks after transplanting produced significantly higher grain yield of rice as compared to its application in 3 splits. However, application of N in three splits either by applying one-fourth each at transplanting and 3 weeks after transplanting and remaining half at 6 weeks after transplanting or one-third each at transplanting, 3 and 6 weeks after transplanting did not affect the grain yield of rice significantly. In the following wheat, the grain yield obtained was on a par with in all the treatments where organic manures were applied. Grain yield of wheat obtained on no manure plot was significantly lower than the plots receiving organic manures. Farmyard manure, poultry manure and biogas slurry applied to rice showed residual effect equivalent to 30 kg N + 30 kg $P_2O_5$ $ha^{-1}$ and press-mud saved 40 kg N + 30 kg $P_2O_5$ $ha^{-1}$ in the succeeding wheat.

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# Screening Basmati Rice Genotypes for Their Arsenic Accumulation

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Arsenic is a wide spread natural contaminant in drinking water in south and south-east Asia. Continuous irrigation with arsenic contaminated groundwater may lend to a build-up of this toxic element in soils which in turn may promote its entry into the food chain in lethal concentration depending upon soil type condition and plant species. Standard Institute of Industrial Research of Iran has disclosed that Indian and Pakistani rice is contaminated with chemicals including arsenic. Therefore, a greenhouse experiment was carried out with the objective to screen basmati rice genotypes for their accumulation of arsenic. Arsenic concentrations (0 to 800 ppb) were applied through irrigation water to four genotype of basmati rice viz. Pusa basmati-1121, Pusa Punjab basmati-1509, Punjab basmati-2 and Punjab basmati-3. After digestion, the grain and straw samples were analyzed simultaneously for As, P and Fe on inductively coupled argon plasma atomic emission spectrophotometer (ICAP-AES). Pusa Punjab basmati-1509 genotype accumulated highest concentration of arsenic in its root and straw, whereas lowest accumulation of arsenic was observed in Punjab basmati-2. In husk, highest arsenic concentration was found in Pusa basmati-1121 and lowest in Punjab basmati-2. In grain, highest arsenic concentration was found in Punjab basmati-3 and lowest in Pusa Punjab basmati-1509. In all genotypes, grain arsenic concentration was ranged from 0.038 to 0.288 mg $kg^{-1}$ which did not exceed the permissible limit of 1.0 mg $kg^{-1}$ in rice grain recommended by WHO. The distribution of arsenic in plant parts was found in order- roots > straw > husk > grain.

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# Assessment of Boron Status of Soils, Plants and Irrigation Water in Cotton Belt of Punjab

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Cotton is an important fibre crop sown in south-west Punjab. Boron (B) deficiency is one of the major constraints for crop production and has been reported in more than 80 countries and for 132 crops over the last 60 years. Soil applied B increased cotton yields even when B deficiency was not evident in the plants. In arid and semi-arid areas, B toxicity results from high levels of B in soils and from additions of B through the irrigation water. A soil survey was conducted during 2015-16 and geo-referenced soil samples were collected from seventy five sites from different villages in the districts of Bathinda, Mansa and Muktsar during the month of September at the pre-flowering stage to assess the boron concentration in soils, plants and irrigation water in cotton growing areas of Punjab. From the same locations, plant samples and irrigation water samples were also collected.

Soils were alkaline in nature and pH ranged from 7.2 to 9.2. The soils were neutral to saline in nature. The hot water soluble boron (HWS-B) content ranged from low (0.37 mg $kg^{-1}$ soil) to toxic (7.6 mg $kg^{-1}$ soil). Calcium carbonate is absent in some of the soils and is as high as 9.00 per cent. Simple correlation analysis showed that the boron availability is positively and significantly correlated with soil pH (r=0.230), soil organic matter (r=0.188), exchangeable sodium percentage (r=0.680) while it was significantly negatively correlated with calcium carbonate (r=0.210). The B concentration in cotton leaves ranged from 33.70 to 100.70 mg $kg^{-1}$ while in petioles, it ranged from 25.00 to 109.02 mg $kg^{-1}$. The concentration of B is higher in cotton leaves than the petiole. Higher boron content in soils has a significant effect on the uptake of boron in cotton. The native boron in soil is positively and significantly correlated with the boron uptake in cotton leaves (r = 0.259). The boron content ranged from absent to as high as 5.33 mg $kg^{-1}$ with a mean value of 2.13 mg $kg^{-1}$ which demonstrated that the B concentration in some of the tube well waters is invariably high. The boron in irrigation water showed a significant and positive correlation with pH (r = 0.246), EC (r = 0.728), chloride (r = 0.591) and calcium + magnesium (r = 0.495). The tube well water B is significantly and positively correlated with soil B content (r = 0.286) and B in cotton leaf (r = 0.316).

These results suggest that the ground water B exhibited a large effect on the B in soil and its uptake by plants. A considerable amount of B is added to cotton and wheat through irrigation water. Hence, its computation is necessary before applying it to the crop. Majority of these waters are saline, which further aggravates the soil problems for proper plant growth. This saline underground water amplified the B toxicity and B build up in soils. Therefore, under higher saline water conditions, B application should be carefully managed and should only be used for B loving crops like cotton and sunflower. Wheat is a boron sensitive crop. Therefore, B application should be based on chemical analysis of soil and water (especially soil extractable B analysis).

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# Influence of Zinc Application on Yield and Zinc Uptake in Sugarcane

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The present study was carried out at Research Farm of Punjab Agricultural University, Ludhiana during the year 2015 on a loamy sand soil. The soils of the experimental site are loamy sand in texture, neutral in reaction, non saline in nature, low in organic carbon, and low in available nitrogen, medium in available phosphorus and high in available potassium. The experiment was laid out in randomized complete block design (RBD) with five treatments replicated for three times. Five treatments *viz.*, T1: No zinc application (control); T2: $ZnSO_4$ @ 12.5 kg $ha^{-1}$; T3: $ZnSO_4$ @ 25 kg $ha^{-1}$; T4: $ZnSO_4$ @ 37.5 kg $ha^{-1}$; and T5: $ZnSO_4$ @ 50 kg $ha^{-1}$. Recommended dose of fertilizers *viz.*, 150 kg N $ha^{-1}$ and $P_2O_5$ was applied on soil test basis. In Punjab Sugarcane crop does not respond to K application. Entire dose of phosphorus and potash were applied at the time of planting through SSP and MOP, respectively. Nitrogen was applied in the form of urea in two equal splits *i.e.* one at 45 days after planting and other at 90 days after planting. Different levels of Zn were applied as per the treatments. All other agronomic practices like irrigation, weeding, earthing up, propping and other cultural practices were carried out uniformly in all the treatments.

Cane yield increased positively with the application of Zn under all the treatments. Cane yield varied from 49.7 to 58.8 t $ha^{-1}$. Significantly highest cane yield was recorded with zinc sulphate application @ 37.5 kg $ha^{-1}$. Minimum cane yield was recorded with no zinc sulphate application (control). Application of Zn @ 37.5 kg $ha^{-1}$ increased the cane yield up to 15.6 per cent over the control. On the other hand Zn concentration in cane juice ranged from 2.47 to 3.52 mg $kg^{-1}$ under all Zn levels and maximum Zn concentration was reported by zinc sulphate application @ 50 kg $ha^{-1}$. Application of Zn @ 37.5 kg $ha^{-1}$ increased the Zn concentration up to 40.5 per cent over the control. Zinc uptake cane juice ranged from 123 to 205 g $ha^{-1}$ and the highest uptake was reported by Zn applied @ 50 kg $ha^{-1}$. Application of Zn @ 37.5 kg $ha^{-1}$ increased the Zn uptake up to 63.4 per cent over the control. Similar trends of yield, Zn concentration and Zn uptake were reported in tops (straw removed from the top of sugarcane plant) of sugarcane. The results of the study clearly indicated that yield of sugarcane were significantly influenced by the application of Zn. The response to Zn was significant over control. Highest response was obtained with Zn application to the soil @ 37.5 kg $ha^{-1}$. On the basis of study, it is recommended that application of $ZnSO_4$ to the soil @ 37.5 kg $ha^{-1}$, along with macronutrients for better cane yield and Zn uptake of sugarcane production.

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# Effect of Nutrient Management Practices on Build-up of DTPA-extractable Micronutrients and Organic Carbon under Basmati-Wheat Sequence

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Soil samples were collected from an ongoing field experiment (since *rabi* 2006-07) on basmati-wheat sequence, at Research Farm, Punjab Agricultural University, Ludhiana in 2013. The experimental soil was sandy loam in texture and tested near neutral in pH (7.5), non-saline (0.2 dS $m^{-1}$) and low in organic carbon (0.37%) at the time of start of experiment in 2006-07. The experiment was planned in RBD with ten treatments.

The highest pH was observed in control plots and lowest in plots receiving 400 kg N $ha^{-1}$ through FYM. In the surface soil, organic carbon concentration ranged from 0.29% in control to 0.63% in treatments receiving 400 kg N $ha^{-1}$ through FYM. Integrated nutrient management through application of fertilizers and organic manure addition significantly increased the soil organic carbon content over control and recommended fertilizer treatment. The increase in SOC in integrated nutrient treatment plots may be due to addition of carbon through FYM and addition of more root biomass resulting from higher crop production under these treatments. DTPA-extractable Zn under various treatments ranged between 0.48 and7.55 mg $kg^{-1}$.The lowest content of Zn was recorded in control plots (0.48 mg $kg^{-1}$) and the highest (7.55 mg $kg^{-1}$) in plots receiving 400 kg N $ha^{-1}$ from VC. Organic manures either alone or in combination with inorganic fertilizers significantly improved Zn concentration over control as well as recommended fertilizer treatment. Available Fe ranged between 50.8 and 156.7 mg $kg^{-1}$ in surface soils. Minimum concentration of Fe (50.81 mg $kg^{-1}$) was recorded in control while maximum (156.6 mg $kg^{-1}$) in plots receiving 400 kg N $ha^{-1}$ from FYM.

Application of recommended dose of fertilizer significantly improved DTPA-extractable Fe over control plots. It was found that application of 200 kg N $ha^{-1}$ from FYM along with recommended fertilizer significantly increased the concentration of Fe over control while Fe content was significantly lower than that found in recommended fertilizer plots. However, application of organic treatments significantly improved Fe concentration over control. Concentration of Fe decreased with depth in all the treatments and it ranged between 10.5 and 155.7 mg $kg^{-1}$ at different depths. Under different treatments, DTPA-extractable Mn in surface soils ranged between 8.5 mg $kg^{-1}$ in plots receiving 300 kg N $ha^{-1}$ from VC and 22.6 mg $kg^{-1}$ in plots receiving 400 kg N $ha^{-1}$ from FYM. Hence, in the surface layer, DTPA-extractable Mn variation appeared to be more related to movement of water in the soil profile. Mn concentration was generally more in the sub-surface layer (15-30 cm) as compared to surface layer in almost all the treatments. It indicated movement of soluble Mn in the sub-soil. Availability of Cu ranged between 1.35 and 3.30 mg $kg^{-1}$ in surface soils. Lowest concentration of Cu (1.35 mg $kg^{-1}$) was recorded in control plots while highest (3.30 mg $kg^{-1}$) in plot receiving 300 kg N $ha^{-1}$ from FYM. With application of recommended dose of fertilizer, Cu concentration increased significantly over control. Integrated nutrient management significantly increased DTPA-extractable Cu over control but the effect was non-significant with respect to recommended fertilizer management treatment. Organic treatments had significantly higher Cu content than other treatments at all the depths and lowest amount of Cu was observed in rice straw compost treatment as compared to other treatments of organic manures.

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# Spatial Variability of Soil Quality Parameter in Peri-urban Areas of NCR as Influenced by Quality of Irrigation.

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Unplanned urbanization and industrialization in taking a heavy toll on the natural resources, namely, soil and water. Peri-urban agriculture is impacting the soil ecology in particular because of indiscriminate waste water usage. A study was carried out in the eastern part of the National Capital Region (NCR) of Delhi to assess the impact of irrigation from different sources, namely, waste waters, rain water and deep tube well water on the soil quality. Geo-referenced soil samples were analyzed from thirty five locations for various soil physical and chemical parameters viz., organic carbon content, texture, available NPK status, sulphur content and DTPA-extendable micronutrients Zn, Fe and B. The crops generally cultivated in the area were vegetables, barley, maize and wheat. The soil texture raised from sandy loam to clay and the soils were alkaline in nature with some sample having pH>8.5, The EC was generally within the safe category but there was a wide variation in the fertility status of the soil. DTPA-Zn varied from 0.82 to 16.94 mg $kg^{-1}$, DTPA-Fe from 12.42 to 58.52 mg $kg^{-1}$, Boron from 0.20 to 1.34 mg $kg^{-1}$ and sulphur from 3.45 to 49.00 mg $kg^{-1}$. The soil nutrient indexes varied with specific nutrients analyzed.

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# Long-term Effect of Fertilizer Application on Soil Fertility and Maize Productivity under Finger millet–Maize Sequence in Inceptisol

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Long-Term Manurial Experiments (LTFE) provide valuable information on the impact of long-term adoption of nutrient management systems with varying sources, types and combinations of plant nutrient inputs on soil fertility and productivity. With these views LTFE of Tamil Nadu Agricultural University was started during 1972 at Coimbatore under irrigated conditions in finger millet – maize cropping sequence. The experimental soil is calcareous, medium black, sandy clay loam in texture belonging to Prianaickenpalayam soil series (Vertic Ustropept) of Inceptisol.

There are ten treatments each replicated four times in randomized block design. The treatments are 50% NPK; 100% NPK; 150%NPK; 100% NPK + hand weeding (HW); 100% NPK + $ZnSO_4$ @ 25 kg $ha^{-1}$ (only for maize); 100% NP; 100% N; 100% NPK + FYM @ 10 t $ha^{-1}$; 100% NPK (S free) and absolute control. The doses of NPK applied were 90:45:17.5 kg NPK $ha^{-1}$ and 250:75:75 kg NPK $ha^{-1}$ for finger millet and maize hybrid crops respectively. Herbicides were applied as per the recommendation to all the treatments except 100% NPK + HW. Other cultural operations were carried out need based as per the recommended package of practices.

In LTFE, 103 crop of maize hybrid was raised during January 2015 and harvested during May 2015. Soil and plant samples were collected after harvest of maize crop and analyzed for nutrient status. The results revealed that application of 250:75:75 kg NPK $ha^{-1}$ along with FYM @ 10 t $ha^{-1}$ significantly increased the grain yield to the tune of 14.4% over 100% NPK. Non-inclusion of K in 100% NP also recorded the comparable yield with 100% NPK. Continuous addition of N alone resulted decline in yield up to 21.1% when compared to 100% NPK. No response to addition of $ZnSO_4$ in last 4 decades, however during 2015 response to added Zn is noticed. Organic carbon increased from 0.47% (1972-76) to 0.69% (2014-2015) under INM in maize crop. The acid phosphatase activity was higher in 100% NPK + FYM and lower activity was seen in control. The activity of both acid and alkaline phosphatase during monsoon fallow period showed a gradual decrease after rainfall followed by a slight increase during cropping period. The urease activity declined drastically as the crop reached harvest stage wherein the highest urease activity was registered in 100% NPK+ FYM. Further, 100% NPK+FYM also recorded significantly higher values of dehydrogenase in all the stages. Regarding nutrient balance, negative balance in available NPK was noticed under continuous cropping with finger millet whereas in maize hybrid build up was noticed for P and depletion was found in N and K.

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# Efficacy of Bio-nano Clay Polymer Composite as Slow Release Carrier of Phosphorus to Improve its Uptake by Wheat

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Our effort was to prepare economically viable nano clay polymer composites (NCPC) with clay and polymer which will act as slow release carrier of nutrients in soil. Therefore, starch based bio-NCPC was prepared using varying concentration of clay, where 50% of acrylic acid was replaced by starch. Soluble source of P and oxalic acid were loaded in bio-NCPC. As low molecular weight organic acids such as oxalic acid or citric acid are known to solubilise fixed P in soil, hence, oxalic acid was used to increase P availability in soil. A greenhouse experiment was conducted to evaluate the efficacy of bio-NCPC loaded with oxalic acid and P in increasing P availability in alluvial soil using wheat as a test crop. Treatment combination consisted of half of recommended dose of P (RDP) through bio-NCPC, half RDP along with 40 ppm oxalic acid through bio-NCPC, RDP through bio-NCPC, RDP and 40 ppm oxalic acid through bio-NCPC, half RDP through di-ammonium phosphate (DAP) fertilizer and full RDP through DAP fertilizer. Results showed that available P content in soil increased from 2.63 mg $kg^{-1}$ (control) to 5.53 and 5.93 mg $kg^{-1}$ with application of half RDP through bio-NCPC and RDP through DAP fertilizer, respectively. This indicates that half RDP through bio-NCPC and RDP through DAP were equally effective in increasing available P content in soil. Application of half RDP through bio-NCPC was statistically at par with RDP through DAP in increasing dry matter yield (DMY) and P concentration in wheat. However, combined application of ½ RDP and oxalic acid through bio-NCPC (8.23 g $pot^{-1}$) was superior to ½ RDP through bio-NCPC (6.93 g $pot^{-1}$) in increasing DMY of wheat. The results of the present investigation suggest that a good potential exists in bio-NCPC loaded with P in enhancing P uptake by crop, and also use of bio-NCPC as slow release carrier of P can save costly phosphatic fertilizer.

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# Soil Test-based Fertilizer Prescriptions for Wheat in Alluvial Soils of Northwest India

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Fertilizer is one of the costlier inputs in agriculture and for attaining higher crop yields farmers tend to use excessive chemical fertilizers. Considerable economy in fertilizer use can be achieved by gathering knowledge of crop response to applied fertilizer, inherent supply of nutrients by the soil and its short or long term effects in the system. Therefore, a study was undertaken with the objective of developing soil test based fertilizer calibrations with desired yield targets for wheat at Research farm, Punjab Agricultural University, Ludhiana. Fertilizer prescriptions under integrated plant nutrient supply (IPNS) were formulated for wheat by following Ramamoorthy's "Inductive cum Targeted yield approach" which showed that the nutrient requirement for producing one ton of wheat was 1.46, 0.78 and 1.82 kg $q^{-1}$ of N, $P_2O_5$ and $K_2O$, respectively. The per cent contribution of nutrients from soil and fertilizer were found to be 42 and 24 for nitrogen, 14 and 42 for phosphorus and 13 and 21 for potassium, respectively. Similarly, the per cent contribution of nutrients from fertilizers in presence of FYM was 56 for nitrogen, 19 for phosphorus and 39 for potassium. Increased contribution of nutrients from fertilizer in the presence of FYM suggests more mineralization possibly caused due to higher soil microbial activity with addition of organic matter to the soil. In addition, field experiments were also conducted at farmer's fields to check the validity of the fertilizer adjustment equations of wheat by comparing farmers practice, general recommended dose, soil test based general recommended dose, and fertilizer requirements for specific yield target (4.5, 5.0 and 5.5 t $ha^{-1}$) for ascertaining the economics of each practice. The results of the study showed the superiority of the target yield concept over the other practices as it gives higher yields with optimal economic returns and thus establishing the utility of the adjustment equations for recommending soil test based fertilizer application to the farmers.

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# Interactive Effects of Rice Residue Biochar and Nitrogen Fertiliser on Crop Biomass and Soil Functions in Contrasting Soils

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Worldwide, there is an increasing interest in using biochar in agriculture to help mitigate global warming and improve crop productivity. However, little is known about the effects of rice straw biochar alone or when applied in combination with N fertilizer on soil fertility and crop productivity. A one-year pot experiment was established to examine the interactive effects of different rates of rice residue biochar (0, 10, 20 and 40 t $ha^{-1}$) and nitrogen (0, 60, 90, 120 and 150 kg N $ha^{-1}$) in soils with contrasting texture [loamy sand (LS) and sandy clay loam (SCL)]on selected soil properties and crop biomass in a wheat-maize cropping sequence. Addition of biochar alone or in combination with N had no direct favourable effect on wheat biomass (residue plus grain or individually) in both soils. However, the effect of residual biochar and in combination with N fertilizer on the residue biomass of the next crop (maize)was significantly beneficial. In both soils, EC and pH increased with increasing rate of biochar addition. However, addition of N with biochar (cf. biochar alone) did not change pH values but increased EC significantly in the various treatments. Compared to unamended control (B0N0), addition of biochar alone at different rates increased SOC, MBC and DOC by 20-59%, 6-61% and 12-34% in the LS, and by 17-27%, 25-53% and 31-41% in SCL, respectively. Addition of N along with biochar did not have a significant effect on SOC values in both soils except at higher rates of N addition (120 and 150 kg N $ha^{-1}$) in the SCL soil. Whereas MBC and DOC increased only upto 90 kg N $ha^{-1}$ in both soils at different rates of biochar. Compared to unamended treatments, availability of N, P and K were higher at higher rate of biochar application. However, compared to biochar alone treatments, addition of N with biochar increased available N more steadily in SCL than LS whereas increase in P and K was not consistent in both soils. It is concluded that application of biochar alone or in combination with N fertilizer showed positive impact on soil properties after one-year cropping sequence, which may have enhanced the maize biomass. Thus, conversion of surplus rice residue to biochar for its application to soils could help in reducing open field burning of straw in Northern India. In addition, the study also points towards the need to establish long-term field experiments to verify the findings of this pot-based study in different environments.

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# Evaluation of Response Surface Methods for optimizing Fertilizer Doses in Garlic

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A field experiment involving three fertility gradient strips was conducted on garlic-maize cropping system at the PAU Soil Science Research Farm, Ludhiana during Rabi 2015-16. The experimental design was Latin Square with three rates of farmyard manure (FYM; 0, 25 and 50 t $ha^{-1}$), three nitrogen (N) rates (90, 120, and 150 kg N $ha^{-1}$ both for garlic and maize), three P rates (45, 60 and 75 kg $P_2O_5$ $ha^{-1}$ for both the crops) and three K rates (20, 30, and 40 kg $K_2O$ $ha^{-1}$ for both garlic and maize). A control plot was kept with each rate of FYM application. Each fertility strip accommodated all the treatments. After the imposition of FYM and other treatments, garlic (var. PG-17) was raised. Evaluation of garlic yield average response to fertilizer N applied at different FYM levels indicated that with FYM rate of 50 t $ha^{-1}$, the crop did not respond to fertilizer N beyond 90 kg $ha^{-1}$. In high fertility strip, similar effect was observed even at 25 t $ha^{-1}$ FYM level. The FYM application also suggested a P fertilizer saving effect. In general, response to P application beyond 45 kg $ha^{-1}$ was not observed when FYM @ 25 t $ha^{-1}$ or higher rate was used. Likewise across all fertility levels and FYM application rates, response to fertilizer K application higher than 20 kg $ha^{-1}$ did not cause any yield increment. A quadratic response surface was fitted to the garlic yield data as affected by the factors of N, P, K, and FYM by using SAS 9.3. The response surface method analyzes the fitted response surface to determine the factor levels of optimum response. The optimum levels of N,P, K fertilizers and FYM identified by the method were 214.4, 29.6, 41.9 kg $ha^{-1}$, and 49.5 t $ha^{-1}$, respectively. Predicted bulb yield was 17.2 t $ha^{-1}$. However, high dose of N in the presence of high dose of FYM and lack of reflection of saving of N, P, and K fertilizers upon higher use of FYM indicated that a large number of observations across different fertility levels are required to fit suitable response surface that is in agreement with the general observations.

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# Effect of Foliar Feeding of 19:19:19 and Potassium Nitrate Water Soluble Fertilizers on Yield and Quality of Soybean [*Glycine max* (l). Merill] in a Vertisol

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A field experiment was conducted at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad during *kharif* 2015 to study the effect of foliar application of 19:19:19 and $KNO_3$ water soluble grade fertilizers on yield and quality of soybean. Experiment consisted of 10 treatments with three replications under RCBD. Results showed that, foliar applications of 1.0 per cent 19:19:19 at 40 and 60 DAS resulted in significantly higher seed yield (27.50 q $ha^{-1}$) which was 23 per cent higher than the control (22.36 q $ha^{-1}$) and was on par with urea spray (2.0%) at 40 DAS plus $KNO_3$ (1.0%) at 60 DAS (27.08 q $ha^{-1}$). All the foliar nutrition treatments were statistically superior to control except foliar spray only with urea (2.0%), $KNO_3$ (1.0%) and 19:19:19 (0.5%). The improvement in growth characters and yield contributing attributes contributed to the higher economic yield in the said treatments. The uptake of nutrients (N, P, K and S) in foliar applied treatments significantly increased over control due to 1.0 per cent spray of 19:19:19 at 40 and 60 DAS, urea (2.0% at 40 DAS) plus $KNO_3$ (1.0% at 60 DAS) as well as their individual applications. There was significant improvement in protein content of seeds due to the said treatments. Highest B: C ratio (2.45) was recorded due to twice foliar application of 19:19:19 and lowest value (1.84) in control. Hence, foliar application of 19:19:19 (1.0%) alone or combined application of urea (2.0%) plus $KNO_3$ (1.0%) improved soybean productivity and protein content in soybean seeds.

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# Direct, Cumulative and Residual Effects of Biochar on Soil Properties

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Biochar refers to biomass-derived charcoal, obtained when biomass is "baked" under low or no oxygen conditions (pyrolysis). It holds good as a tool for improving soil productivity and sequestering carbon (C) in soil among other potential benefits. The conversion of organic waste to produce biochar by pyrolysis process is one of the viable options that can enhance natural rates of carbon sequestration in the soil, reduce farm waste and improve soil quality. Recognizing benefits of biochar, field experiments were conducted during 2011 -12 to study the effect of biochar with/without FYM and inorganic fertilizers on soil productivity of cotton – maize – cowpea based cropping system and to examine the direct, cumulative and residual effects of biochar on soil properties at field No.36 B, Eastern block, TNAU, Coimbatore, on an Inceptisol which belongs to Periyanaickenpalayam series and Vertic Ustropept in USDA classification and in the Western zone of Tamil Nadu.

The application of biochar irrespective of levels, reduced the bulk density, increased both particle density and porosity thereby improved the hydraulic conductivity and available water content of the post harvest clay loam soil of cotton. Further, it also decreased the pH and increased EC, organic carbon content, CEC, available N, P and K of post harvest soil of cotton. Thus, biochar proved to be not only a water conservator but also a conditioner cum fertilizer. The effect was increased with corresponding increase in the rate of application. Significant improvement was found when biochar was applied in conjunction with fertilizers and FYM due to the complimentary effect of FYM and fertilizers.

Similar trend of direct effect was registered in the post harvest soil of maize grown under both cumulative (continuous application) and residual (one time application) studies. However, the effect was higher under cumulative study than the residual study. The continuous application of biochar @ 10 t + 100% NPK + FYM decreased the bulk density (5.04%) and increased the porosity (5.17%), hydraulic conductivity (2.30%), available water (2.65%) organic carbon (34.83%), CEC (7.07%), available N (5.50%), available P (19.05%) and available K (8.05%) compared to one time application in the corresponding treatment. Confirming the additional improvement in the soil physical, physicochemical and chemical properties owing to the synergistic effect of residual biochar and its fresh addition under continuous application of biochar.

The residual effect of biochar on soil properties were conspicuous in the succeeding post harvest soil of cowpea and it is on par with direct, cumulative and residual studies, similar trend of results were also registered in the post harvest soil of cowpea under both the cumulative residual (residual effect of continuous application) and second residual (second residual effect of one time application) studies. Comparing the residual effects of biochar, the impact was relatively greater in cumulative residual soil (residual effect of continuous application) as against second residual soil (second residual effect of one time application).

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# An Appraisal of Nutrient Status of Soil and Plant at Different Stage in Maize Grown under Alfisol (Ranchi, Jharkhand)

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The present investigation was aimed to study the nutrient concentration in maize and the changes in availability of N, P and K at different physiological stages of maize in alfisol of Ranchi.

A field experiment was conducted at BAU, research farm, Department of Soil Science, Ranchi, Jharkhand in the year (2011 and 2012) to study an appraisal of nutrient status of soil and plant at different stage in maize grown under Alfisol. The soil of experimental field was sandy loam Typic Paleustalf and the initial pH was 5.0, organic carbon 4.9 g $kg^{-1}$, available N 182.4 kg $ha^{-1}$, available P 13.4 kg $ha^{-1}$, available K 133.5 kg $ha^{-1}$,and available S 40.65 mg $kg^{-1}$.The treatments consisted of: $T_1$ (NPK, 250 : 120 : 120), $T_2$(PK, 0 : 120 : 120), $T_3$ (NK, 250 : 0 : 120), $T_4$ (NP, 250 : 120 : 0) and $T_5$ (SSNM, 200 : 90 : 100) for maize.

The pH value of soil at five different stage of maize crop ranged from 4.98 to 5.57. The soil pH value decreased at stage 2 and its value increased at stage 5 (after harvest). pH was maximum in N omission plots than the other treated plots.Howeve the organic carbon at different stages of maize varied from 3.10 to 5.60 g $kg^{-1}$. The soil organic carbon content decreased at advanced stages and was found minimum after harvest of the crop (stage5). Available N content of soil at different stages of maize crop ranged from 173.7 to 305.2 kg $ha^{-1}$. Absence of N in fertilization schedule caused a decline in available N content at all the stages . Available N content of soil increased at all the stages as compared to stage 1 and maximum value was at stage 4 ($V_{10}$ stage) except in (-N) and (-K) plot.

Available P of soil increased from stage 1 (8.98-17.32 kg $ha^{-1}$) to stage 2 (9.54-25.72 kg $ha^{-1}$) and was maximum at stage 5 (13.46-52.64 kg $ha^{-1}$). Due to absence of P fertilization, available P status of soil was declined whereas continuous application of P resulted in increased P status. Available K status exhibited a general decline in (-K) plot at all stages and it was minimum after harvest of maize (stage 5).

The concentration of N in maize varied between 0.60-3.31%. Maximum N concentration observed at V4 stage (2.37-3.31%), which decreased at later stage V10 (0.86-1.40% ) and minimum value of N concentration (0.6-0.86%) was found in maize straw (after harvest ). Whearas the P and K concentration in maize plant at different stages ranged between 0.02-0.34% and0.39-3.54%, respectively. Higher value of P and K concentration was found at V4 and V10 stage and lowest value was recorded in maize straw after harvest of the crop.

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# Nutrient Management in Zero Tillage Maize in North Coastal Zone

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A field experiment was conducted on sandy loam soil to study the effect of nutrient management in zero tillage maize on yield, soil fertility status and uptake pattern of nutrients in maize under tropical conditions at RARS, Anakapalle during the year 2011-2013. The experimental soil had neutral in reaction, normal in conductivity, medium in available nitrogen, phosphorus and high in available potassium. The experiment was laid out as factorial randomised block design in three replications. Residue management under zero tillage using nutrient management with time of application of phosphorus as main plots with time and method of application of nitrogen and potassium as sub plots were applied. Results showed that the 100% recommended P through DAP at sowing by pocketing along with N as basal through foliar spray at 10 DAS and 100% Rec. K in two splits 1/2 as foliar spray at 10 DAS and remaining K at 50- 60 DAS as soil application had a significant effect on cob length, number of grains and number of rows per cob, 1000 grain weight, grain yield and stover yield. The uptake of nutrients and the nutrient use efficiency by the crop was also maximum with the application of 100% recommended P through DAP at sowing by pocketing along with N as basal through foliar spray at 10 DAS and 100% Rec. K in two splits 1/2 as foliar spray at 10 DAS and remaining K at 50- 60 DAS as soil application. The soil condition after the crop harvest showed significant variation among the available N, P and K but did not show any significant variation in soil reaction and electrical conductivity.

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# Long-term Effect of Manure and Fertilizers on Soil Physico-Chemical and Chemical Properties in Rainfed Groundnut-growing Alfisols

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A long-term field experiment was started at the Regional Agricultural Research Station, Tirupati of Acharya N.G. Ranga Agricultural University during *kharif* 1981. The present study was undertaken during *kharif*-2015 with a prime objective of monitoring the changes in concentration over a period of time. The soil of the experimental field was red sandy loam (Haplustalf). The experiment has eleven treatments each replicated four times in a randomized block design. The pH, EC and organic carbon of the soil were not significantly influenced by different treatments in both the surface and subsurface soil. The free calcium carbonate of surface soil was significantly influenced by different treatments whereas sub surface soil was not significantly influenced by different treatments. The available N of surface soil was ranged from 140.3 to 184.6 kg $ha^{-1}$ with a mean value of 165.0. However, highest significant value was recorded in FYM alone treated plot (T2) (184.6). The accumulation of considerable amount of available P in the treatment NPK + gypsum + $ZnSO_4$ both in the surface (46.5 kg $ha^{-1}$) and subsurface (41.6 kg $ha^{-1}$) soil was more as compared to the rest of the treatments. The buildup of soil available potassium in the K alone treated plot and K inclusive fertilizer combinationswas also recorded as compared to the rest of the treatments. The exchangeable calcium of surface soil was ranged from 2.32 to 4.39 cmol($p^+$)$kg^{-1}$ with a mean value of 3.37. The exchangeable magnesium in surface soil ranged from 1.80 to 2.74 cmol($p^+$)$kg^{-1}$ with the mean value of 2.24.

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# Influence of Organics and Graded Levels of NPK on Soil P Availability and Phosphatase Enzyme Activity during Monsoon Fallow and Cropping Period with Hybrid Maize

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Next to nitrogen (N), phosphorus (P) plays a major role in crop production. Most of the P in the plough layer of arable soils is present in a continuum of complex organic forms (phytin, phospholipids and nucleic acids). The phosphatase enzyme in soil serves as a biological catalyser in P transformation rendering its availability to crops. Biological and biochemical properties of the soil *viz.,* soil enzymes activity have often been influenced by intensive cropping, seasonal variation and fertility management practices. With this background, a field experiment was conducted at LTFE, TNAU, Coimbatore during monsoon fallow period followed by 101th crop of hybrid maize (2013-14) in order to evaluate the influence of organics and graded levels of NPK on soil available P, phosphatase enzyme activity, yield and P uptake by hybrid maize. There were ten treatments each replicated four times in randomized block design *viz.,* $T_1$- 50% NPK, $T_2$ - 100% NPK, $T_3$ - 150% NPK, $T_4$ - 100% NPK + hand weeding, $T_5$ - 100% NPK + $ZnSO_4$, $T_6$ - 100% NP, $T_7$ - 100% N alone, $T_8$ - 100% NPK + FYM, $T_9$ - 100% NPK (-S) and $T_{10}$ - Absolute control.

The results revealed thatthere was greater increase in the phosphatase enzyme activity (acid phosphatase, alkaline phosphatase) when FYM was applied along with inorganic fertilizers. In monsoon fallow period, acid and alkaline phosphatase activities recorded lower values after the rainfall stage. The continuous application of inorganic sources of nutrients either alone or in combination decreased the acid phosphatase activity. Further graded levels of NPK fertilizers from 50% NPK to 150% NPK also recorded a sharp decline in phosphatase activity when compared to control irrespective of all growth stages. The imposition of various treatments resulted in a highly significant variation in the soil available P. The overall available phosphorus content ranged between 8.2 and 18.6 kg $ha^{-1}$. Among the different treatments irrespective of the growth stages, the treatment which received FYM in addition to 100% NPK ($T_8$) recorded significantly higher available P followed by the treatment 150% NPK ($T_3$). Significantly lower available phosphorus was recorded in control in all the stages compared. Among different treatments, the grain and straw yieldas well as total uptake of P by maize were significantly higher in the treatment that received 100% NPK + FYM than inorganic fertilizer alone. An increase in grain yield of 12.62% was recorded in treatment receiving 100% NPK + FYM over application of 100% NPK alone.The apparent nutrient recovery of 11.3% and response ratio of 139.5% for P was observed at harvest stage of maize in treatment with 100% NPK along with FYM. The results emanated from this study clearly ascertain that the soil phosphatase enzyme activities were closely related with the C inputsand the enhanced levels of phosphatase activity due to the conjoint use of manure and fertilizer which would have promoted the recycling and transformation of added P fertilizers into different labile P pools in soil under continuous intensive cropping system. Further, the present investigation stresses the vital importance of including organic manure in the fertilizer schedule for enhancing yield and maintaining the soil fertility in order to sustain soil productivity over a long run.

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# Impact of Integrated Nutrient Management Strategy to Enhance Soil Fertility and Nutrient Uptake of Ratoon Sugarcane

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Soil test based application of plant nutrients helps to realize higher response ratio as the nutrients are applied in proportion to the magnitude of the deficiency of a particular nutrient and the correction of the nutrient imbalance in soil helps to harness the synergistic effects of balanced fertilization. Hence, it is necessary to have information on the optimum doses of fertilisers and organic manures based on soil testing, nutrient uptake and efficiency of added nutrients by the crop to develop a guideline for judicious application of fertiliser under integrated nutrient management system. The productivity of ratoon sugarcane crop is 10 to 30 per cent less than the plant crop of sugarcane. Thus, even a small improvement in ratoon crop would add considerably to overall sugarcane production and ratoon crop often gives better yield, quality and sugar recovery than plant cane.

A field experiment was conducted in Palani Chettipatti (P.C.Patti) village of Theni district, Tamil Nadu with test crop of Sugarcane (*var*. CO 86032) during 2013-2014 to study the impact of integrated nutrient management on soil fertility and nutrient uptake of ratoon sugarcane with ten treatments replicated thrice with randomized block design with the following set of treatments *viz.,* RSCL-recommended dose of fertilizers $T_1$ (350:150:150 kg N, $P_2O_5$ and $K_2O$ $ha^{-1}$); $T_2$ (125% N + 100% $P_2O_5$ and $K_2O$); $T_3$ (100% N + 75% $P_2O_5$ and $K_2O$); $T_4$ (100% N + 50% $P_2O_5$ and $K_2O$); $T_5$ (125% N + 75% $P_2O_5$+ 100% $K_2O$); $T_6$ (STCR based fertiliser recommendation); $T_7$ ($T_1$+ Zn); $T_8$ ($T_7$+S); $T_9$ (RSCL package) and $T_{10}$ (TNAU package). In all the treatments, 10 per cent recommended N and 50 per cent P were applied basally remaining 90 per cent N was applied in three equal splits @ 30 per cent with K @ 20, 40 and 40 per cent at 30, 60 and 90days after ratoon. The remaining 50 per cent of P was applied in 2 equal splits at 60 and 90days after ratoon.

Among the treatment The soil test based fertiliser application recorded the highest soil available N (298 kg $ha^{-1}$ and 250 kg $ha^{-1}$), P (58.6 $ha^{-1}$ and 49 kg $ha^{-1}$) and K (250 kg $ha^{-1}$ and 213 kg $ha^{-1}$) at grand growth stage and post-harvest stage of ratoon sugarcane and also recorded the highest nitrogen (487 kg $ha^{-1}$) and potassium (357 kg $ha^{-1}$) uptake at harvest stage. The rajshree sugars and chemicals Ltd. package and soil test based fertiliser application recorded the maximum total P uptake of 114.7 and 111.5 kg $ha^{-1}$, respectively. Combination of fertilisers along with other input like bio-compost and bio-fertilisers for ratoon sugarcane is suggested to improve both soil fertility and nutrient uptake.

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# Effect of Integrated Nutrient Management on Distribution of DTPA-Extractable Micronutrient Cations in Inceptisol under Rice-Wheat System

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A field experiment has been in progress since *kharif* 2009 on the experimental farm of the Department of Soil Science, Punjab Agricultural University, Ludhiana.It has been conducted in a fixed layout since its beginning with different treatment combinations. Each treatment is replicated thrice in a plot size of 11×6 $m^2$. The experiment has been laid out in a split plot design with four main and three sub-plot treatments. The organic manure through biogas slurry (BGS) @ 6 t $ha^{-1}$ is incorporated along with nitrogen fertilizer (N @ 80 and 120 kg $ha^{-1}$), phosphorus fertilizer (30 kg $P_2O_5 ha^{-1}$) and potassium fertilizer (30 kg $K_2O$ $ha^{-1}$) to the rice crop. In wheat crop, nitrogen fertilizer (120 kg N $ha^{-1}$) with different levels of phosphatic fertilizer (30 and 60 kg $P_2O_5$ $ha^{-1}$) and potassium fertilizer (30 kg $K_2O$ $ha^{-1}$) were applied.

The data showed that DTPA-extractable Zn in surface (0-15 cm) soil samples collected before sowing of wheat in October 2012 ranged from 5.00 to 5.33 mg $kg^{-1}$ with the mean value of 4.82 and it varied from 3.85 to 5.57 mg $kg^{-1}$ with the mean value of 4.74 in the samples collected after harvesting of rice in October 2013 in all the treatment combinations. Significantly higher concentration of DTPA-extractable Zn has been observed in the treatments where organic manure @ 6 t $ha^{-1}$ has been incorporated along with N @ 80 kg $ha^{-1}$ and $P_2O_5$ @ 30 kg $ha^{-1}$ to the rice crop having mean value of 5.21 as compared to the treatments where no organic manure has been added and only N @ 120 kg $ha^{-1}$ and $P_2O_5$ @ 30 kg $ha^{-1}$ where the mean value is 3.77. This may be ascribed to the better supply of Zn from these organic sources.The concentration of DTPA-extractable Cu in surface (0-15 cm) soil samples collected before sowing of wheat varied from 1.28 to 1.32 mg $kg^{-1}$ with the mean value of 1.20 and in the samples collected after harvesting of rice ranged from 1.38 to 1.77 mg $kg^{-1}$ having mean value of 1.53 in different treatment combinations. Among the different treatments, slight increase in DTPA-extractable Cu has been noticed in the treatments where organic manure @ 6 t $ha^{-1}$ has been incorporated along with N @ 80 kg $ha^{-1}$ and $P_2O_5$ @ 30 kg $ha^{-1}$ to the rice crop as compared to the treatments where no organic manure has been added and only N (120 kg $ha^{-1}$) and $P_2O_5$ (30 kg $ha^{-1}$) fertilizers were applied to the rice crop. The increase in DTPA-extractable Cu may be attributed to the chelating action of organic compounds released during decomposition of organic manures, which increased the availability of micronutrients by preventing fixation, oxidation, precipitation and leaching. The data presented reported that DTPA-extractable Fe ranged from24.81 to 44.11 mg $kg^{-1}$ with mean value of 33.68 in the samples collected before sowing of wheat whereas it varied from 48.09 to 71.10 mg $kg^{-1}$where the mean value is 59.76 in samples collected after harvesting of rice. Significant increase in the concentration of DTPA-extractable Fe has been observed in the treatments where organic manure @ 6 t $ha^{-1}$was applied along with inorganic fertilizers to the rice crop as compared to the treatments where no organic manure has been added and no $P_2O_5$ was applied and only N @ 120 kg $ha^{-1}$ was applied to the rice crop. DTPA-extractable Mn ranged from 16.87 to 30.03 mg $kg^{-1}$in samples collected before sowing of wheat and from 9.97 to 15.85 mg $kg^{-1}$in soil samples collected after harvesting of rice in different treatments. Similarly, a significant increase in the concentration of DTPA-extractable Mn has been observed in the treatments where organic manure @ 6 t $ha^{-1}$ has been incorporated along with N @ 80 kg $ha^{-1}$ and $P_2O_5$ @ 30 kg $ha^{-1}$ applied to the rice crop with a mean value of 22.47 as compared to the treatments where N @ 120 kg $ha^{-1}$ and $P_2O_5$ @ 30 kg $ha^{-1}$ was applied to the rice crop and no organic manure has been added where the mean value is 18.03.

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# Foliar Nutrition of Finger millet (*Eleusine coracana*) Cultivated on Steep Hill Slopes

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Finger millet crop is widely grown on steep hill slopes under conditions of heavy rainfall during the *kharif* season. The crop remains to be starved of nutrition due to the constraints faced by the farmers for fertilizing the crop on steep slopes under conditions of heavy rainfall in the month of July-August. Considering the problems faced by farmers field experiments were conducted in the region located at Zonal Agricultural Research Station, Shenda Park Farm, Kolhapur on Entisol, Sub-Montane Zone of Maharashtra during the *kharif* seasons of 2014 and 2015 to study the response of finger millet crop to foliar nutrition of nitrogen, phosphorus and potassium. The response of of fertilizer application was studied through the conventional chemical fertilizers viz. urea and di-ammonium phosphate, muriate of potash, calcium nitrate and complex fertilizer 19-19-19. The finger millet crop was transplanted having spacing of 30-10 cm and fertilized through basal recommended dose of 60: 30 (kg N, $P_2O_5$ $ha^{-1}$). The crop was fertilized with foliar spray at 50 days after transplanting. The chemical fertilizers used were urea, di-ammonium phosphate, muriate of potash, complex 19-19-19 and calcium nitrate applied @ 2% foliar spray while combination treatment of urea, di-ammonium phosphate and muriate of potash @ 0.5% each was applied to the experimental plots.

The findings of the field experiments revealed that the application foliar spray to the increased the yields of finger millet crop. The highest yield was recorded by the treatment foliar spray 19-19-19 @ 2% (19.51 q $ha^{-1}$) over the recommended dose of fertilizer (15.02 q $ha^{-1}$). It was followed by the treatment calcium nitrate applied @ 2% (18.21 q $ha^{-1}$), combination treatment of urea, di-ammonium phosphate and muriate of potash @ 0.5% (17.28 q $ha^{-1}$) while the lowest yield was recorded by the treatment foliar spray of muriate of potash @ 2% (16.02 q $ha^{-1}$). The straw yields of the crop also revealed the similar trend. The soil analyses after harvest of the crop revealed that the nitrogen, phosphorus and potassium contents in the soil after harvest of the crop did not differ amongst the different treatments. The data on plant uptake revealed that the treatment foliar spray 19-19-19 @ 2% recorded higher uptake of N, P and K as compared to no foliar spray application. The B:C ratio revealed that application of foliar spray 19-19-19 @ 2% recorded significantly highest B:C (1.30).

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# Evaluating the Effect of Phosphatic Fertilisers on Micronutrient Content and Uptake of Rice

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Phosphatic fertilisers occupy an important place amongst the non-renewable inputs of modern agriculture and are frequently applied to improve the P nutrition of crops. The slow mobility of applied phosphorus and its marked fixation results in low crop recoveries to the order of 20 – 25 per cent which call for ways and means for its judicious use. Best management practices for P should aim in ensuring P availability in soil solution at appropriate time, at a reasonable cost, thus increasing P use efficiency (PUE) in sustaining crop productivity. This can be achieved by using suitable P source which minimises reaction with soil components and makes P pools available to crop. Hence, the present investigation was taken up to evaluate the effect of different sources of P fertilisers and also in combination with phosphate solubilising bacteria on micronutrient content and uptake of wetland rice in the predominant rice growing tracts of Vadipatti block of Madurai district of Tamil Nadu.

A field experiment was taken up in the farmer's field at Irumbadi village of Vadipatti block of Madurai district during *rabi* 2013 with rice (*var.* ADT 39). The experimental soil was neutral to slightly alkaline, non – saline with moderate status of organic carbon and available N and high status of available P and K. Ten treatments ($T_1$ : 100% recommended P as SSP (313 kg SSP $ha^{-1}$); $T_2$ : 50% recommended P as SSP (156.25 kg SSP $ha^{-1}$);$T_3$ : $T_1$ + PSB @ 2 kg $ha^{-1}$ ; $T_4$ : $T_2$ + PSB @ 2 kg $ha^{-1}$ ; $T_5$ : Complex fertiliser source 15:15:15 (On P equivalent basis); $T_6$ : Complex fertiliser source 20:20:0 @ 250 kg $ha^{-1}$ (On P equivalent basis); $T_7$ : $T_5$ + PSB @ 2 kg $ha^{-1}$ ; $T_8$ : $T_6$ + PSB @ 2 kg $ha^{-1}$ ; $T_9$ : Farmer's fertiliser practice (315 kg urea; 250 kg complex; 150 kg DAP as basal and 100 kg MOP $ha^{-1}$); $T_{10}$ : Control (No fertiliser)) were imposed with three replications in a randomized block.

Among the P sources, 20:20:0 and phosphate solubilising bacteria proved significantly superior to single super phosphate and farmer's fertiliser practice of di ammonium phosphate application in influencing the micronutrient status of the soil. Application of 100 per cent recommended P as single super phosphate and 50 per cent recommended P as single super phosphate were on par in influencing the available nutrient status and thus influencing the yield of crop. Hence in rice growing soils with high available P status, a maintenance dose of 50 per cent recommended P as single super phosphate is sufficient to sustain the fertility status of soil until the soil test values report moderate to low available P. It can be thus concluded that the use of complex fertiliser sources (20:20:0 or 15:15:15) along with phosphate solubilising bacteria @ 2 kg $ha^{-1}$ can be recommended for release and mobilization of insoluble and fixed forms of P.

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# Nitrogen Management in Rice through STCR-IPNS Approach

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Rice is the prime food of the world, occupying an area of 146.5 million hectare (Mha) with a total production of 534.7 Mt. In India, it occupies an area of 44 Mha, which represents 41 per cent of cereals cropped with production of 80 million tons Among the different management practices, fertilizers management alone could determine more than 50 per cent of the rice productivity. Hence, the present investigation was undertaken to study the effect of nitrogen and FYM application on yield of rice and saving of inorganic N. In order to reduce the fertilizer dose and also to monitor the fertility, the field experiment was conducted at farmer's holding of Sorapet village in Mannadipet commune of Puducherry district, U.T. of Puducherry during 2013 – 14 by using STCR approach. The study area comes under coastal alluvial plain, classified as fine, mixed isohyperthermic, Typic Ustropept. The fertility status of the soil was low in $KMnO_4$-N (238 kg $ha^{-1}$), high in Olsen-P (37.1 kg $ha^{-1}$) and medium in $NH_4OAc$-K (168 kg $ha^{-1}$).

Soil test data, rice grain yield and NPK uptake by rice crop were used for obtaining four important basic parameters *viz.*, nutrient requirement to produce one quintal of rice grain (NR), contribution of nutrients form fertilizers (Cf), contribution of nutrients from soil (Cs) and contribution of nutrients from organic matter (Cfym). Making use of these basic parameters the fertilizer prescription equation was developed for N in rice and is given below.

FN = 5.29 T - 0.71 SN - 0.97 ON

In the present investigation, the beneficial effect of combined use of N fertilizer with FYM was studied with two different levels of FYM *viz.*, 6.25 t $ha^{-1}$ and 12.5 t $ha^{-1}$. The nomogram were formulated for desired yield target of rice for a range of soil test values under NPK alone, NPK plus 6.25 t $ha^{-1}$ and NPK plus 12.5 t $ha^{-1}$. The perusal of the estimate showed that when NPK alone was applied for a soil test value of 200 kg $ha^{-1}$ of nitrogen, the doses of fertilizer N required for desired yield target of 7 and 8 t $ha^{-1}$ were 228 and 281 kg $ha^{-1}$, respectively. While the doses were 208 and 261 kg $ha^{-1}$ respectively for combined addition of NPK plus FYM applied @ 6.25 t $ha^{-1}$ recording 8.77 and 7.12 per cent reduction of fertilizer N doses over NPK alone. When NPK applies with FYM @12.5 t $ha^{-1}$ the doses were 188 and 240 kg $ha^{-1}$ with a per cent reduction of 17.54 and 14.59, respectively over NPK alone.

Using the fertilizer prescription equation under IPNS, the extent of saving of inorganic N fertilizer with the application of FYM @ 6.25 t $ha^{-1}$ with 28 per cent moisture and 0.45 per cent N was 21 kg $ha^{-1}$. If FYM @ 12.5 t $ha^{-1}$ was applied with same nutrient content the saving was 41 kg $ha^{-1}$.

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# Validation of Fertilizer Prescription Equation based on STCR-IPNS for Rice (Var.ADT 43) in Mannadipet Soil Series of Puducherry

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In view of increasing demand for the cultivation and commercialization of high value crops like rice, it is essential to adopt Soil Test Crop Response Based Integrated Plant Nutrient System (STCR-IPNS) to increase productivity. In this context, fertilizer prescription equations (FPEs) for rice were developed following the STCR-IPNS concept by adopting inductive cum targeted yield approach for Mannadipet soil series (Typic Ustropept) as follows:

FN = 4.70 T - 0.59 SN - 0.91 ON

$FP_2O_5$ = 1.61 T – 1.10 SP – 0.86 OP

$FK_2O$ = 2.10 T - 0.37 SK - 0.72 OK

The fertilizer prescription equations (FPEs) for rice under IPNS were test verified by conducting verification trail in farmers holing during May 2014. The experiment consisted of nine treatments, blanket recommendations, STCR-NPK alone for 5, 6 and 7 t $ha^{-1}$ yield targets, STCR-IPNS for 5, 6 and 7 t $ha^{-1}$ yield targets, farmers practice and absolute control in RBD with three replications.

The findings emanated from the test verification trial had clearly revealed that the per cent achievement of the aimed targets was within ± 10 per cent variation confirming the validity of the STCR-IPNS recommendations. The STCR treatments recorded significantly higher grain yield and response ratio (RR) over blanket, while STCR-IPNS treatments recorded relatively higher yield and Response ratio over STCR-NPK alone treatments. The yield targets of STCR-IPNS for 7 t $ha^{-1}$ of rice proved its superiority over all other treatments in terms of yield (6.77 t $ha^{-1}$) and response ratio (13.52). These treatments had recorded yield increases of 48.26 and 39.39 per cent respectively over blanket and farmers practice for rice. The post harvest soil test value of test verification trail revealed that, soil test based fertilization resulted in buildup of fertility and magnitude of build up was higher with STCR-IPNS as compared to STCR-NPK alone, blanket recommendation and farmers practice.

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# Validation of STCR-IPNS Fertilizer Recommendations for Rice (CR 1009) in Mannadipet Soil Series of Puducherry

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The soil test crop response based on fertilizer prescriptions under Integrated Plant Nutrient System (STCR-IPNS) recommendations developed for rice in Mannadipet soil series (Typic Ustropept) of U.T of Puducherry was validated at farmer's holding at Sorapet villages of Puducherry district during October 2014.

Fertilizer prescription equation

$FN = 5.29\ T - 0.71\ SN - 0.97\ ON$

$FP_2O_5 = 2.22\ T - 2.12\ SP - 1.27\ OP$

$FK_2O = 2.24\ T - 0.42\ SK - 0.67\ OK$

The experiment consisted of nine treatments, blanket recommendations, STCR-NPK alone for 6, 7 and 8 t $ha^{-1}$ yield targets, STCR-IPNS for 6, 7 and 8 t $ha^{-1}$ yield targets, Farmers practice and absolute control in RBD with three replications.

The findings emanated from the test verification trial clearly revealed that the per cent achievement of the aimed targets was within ± 10 per cent variation confirming the validity of the STCR-IPNS recommendations. The STCR treatments registered significantly higher grain yield and response ratio (RR) over blanket while STCR-IPNS treatments recorded relatively higher yield and Response ratio over STCR-NPK alone treatments. The yield targets of STCR-IPNS for 8 t $ha^{-1}$ of rice proved their superiority over all other treatments in terms of yield (7.55 t $ha^{-1}$) and response ratio (11.65). These treatments had registered yield increases of 52.05 and 47.68 per cent respectively over blanket and farmers practice for rice. The post harvest soil test value of test verification trails revealed that, soil test based fertilization resulted in buildup of fertility and magnitude of build up was higher with STCR-IPNS as compared to STCR-NPK alone, blanket recommendation and farmers practice.

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# Nutritional Survey of Vineyards around Hyderabad (var Thompson Seedless)

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Grape (*Vitis vinifera*) is the commercial fruit crop grown in Telangana region. Thompson Seedless is most popular variety cultivated in this region. Earlier it was raised mostly on own roots but due to increasing area under salinity and decreasing water quality many of the grape growers are grafting Thompson Seedless on Dogridge. Hence, nutrient survey was conducted in vineyards around Hyderabad for 4 years *i.e.* from 2006 to 2010 with an objective to understand the nutrient related problems of grafted and own rooted vineyards. During the 4 years of survey petiole samples were collected from 57 vineyards raising Thompson seedless on own roots and 63 vineyards grafted on Dogridge at bud differentiation stage (BDS) and from 49 and 61 vineyards respectively at full bloom stage (FBS). Soil and water samples were collected after the harvest of crop. At bud differentiation stage (BDS) many own rooted (85%) and grafted (89%) vineyards had optimum petiole N status while at full bloom stage (FBS) they (69 and 67% respectively) recorded hidden hunger. The mean petiole N content at BDS was slightly less on grafted vines (1.13%) when compared to own rooted vines (1.2%) while not much difference was observed at FBS (1.2%). At BDS the percentage of vineyards which recorded high to toxic petiole P status was higher on own roots (77%) when compared to grafts (51.0%). The remaining vineyards fell under optimum status (23 and 47% respectively). At FBS an almost equal percent of own rooted vineyards recorded optimum (44%) and high (45%) petiole P status. Most grafted vineyards recorded optimum (74%) and few hidden hunger (12%). The mean petiole P content was less when grafted on Dogridge (0.68 and 0.59%) when compared to own rooted vines (0.85 and 0.76%) at BDS and FBS, respectively.

At BDS many own rooted vineyards recorded optimum (51%) and hidden hunger (28%) while grafted ones recorded optimum (41%) and high (45%) petiole K status. At FBS high (28 and 11%) and toxic petiole K status (58 and 76%) was recorded in own rooted and grafted vineyards respectively. The mean K content was higher when grafted on Dogridge (3.3 and 2.9%) compared to own rooted vines (2.4 and 2.9%) at both BDS and FBS, respectively. At BDS in case of Cu, Zn and Fe most own rooted (86, 76 and 64% respectively) and grafted (83, 84 and 61% respectively) vineyards recorded optimum petiole status at BDS, except Mn where hidden hunger ( approx 72%) was recorded on both grafted and own rooted vineyards at both stages. With respect to Cu, Fe and Zn content not much difference was recorded between own root (26, 81 and 68 ppm, respectively) and rootstock (25, 88 and 61 ppm, respectively) while, the Mn content was higher on rootstock (94 ppm) when compared to own root (53 ppm). At FBS high Cu and optimum Fe status was recorded both on grafted (83 and 64%, respectively) and own rooted vineyards (80 and 61%, respectively). In case of Zn hidden hunger and optimum status was recorded in 25 and 64% of own rooted and 45 and 46% of grafted vineyards respectively. The irrigation water quality was safe with respect to pH, Na, SAR and RSC in most samples whereas, the Cl content was above the threshold limit in 40% of the samples. The soil analysis revealed that soil was neutral and non saline in most vineyards. However, very high residual soil P, high K and micronutrient status was recorded in these vineyards.

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# Influence of Major Nutrients on Growth and Nutrient Uptake of Foxtail Millet (*Setaria italica*) in Alfisol under Rainfed Condition

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A field experiment was conducted in farmer's field of Panamarathupatty block, Salem during *rabi* season of 2014 -2015 to study the effect of NPK levels on nutrient uptake and yield of Foxtail millet (*Setaria italica*) in Alfisol under rainfed condition. The experiment was laid out in a randomized block design with three replications. The experiment was carried out in clay loam soil texture. The treatments consisted of $T_1$ – Control, $T_2$ – NPK @ 30:20:10 kg/ha, $T_3$ – NPK @ 45:20:10 kg $ha^{-1}$, $T_4$ – NPK @ 60:20:10 kg $ha^{-1}$, $T_5$ – NPK @ 30:30:20 kg $ha^{-1}$, $T_6$ – NPK @ 45:30:20 kg $ha^{-1}$, $T_7$ – NPK @ 60:30:20 kg $ha^{-1}$, $T_8$ – NPK @ 44:0:0 kg $ha^{-1}$, $T_9$ – NPK @ 0:22:0 kg $ha^{-1}$, $T_{10}$ – NPK @ 44:22:0 kg $ha^{-1}$ (Recommended dose of fertilizer). Foxtail millet CO (T) 7 was used as a test variety. The nitrogen was applied as urea in two splits i.e., 50% basally and remaining 50% as top dressing at tillering stage. The entire dose of phosphorus and potassium were applied basally as single super phosphate and muriate of potash respectively.

Application of NPK @ 60:30:20 kg $ha^{-1}$ ($T_7$) recorded higher plant height, and dry matter production which was followed by NPK @ 60:20:10 kg $ha^{-1}$ ($T_4$). Among the different treatments, application of NPK @ 60:30:20 kg $ha^{-1}$ ($T_7$) recorded higher total biomass (root + straw + grain) production of 8749 kg $ha^{-1}$ followed by treatment receiving NPK @ 60:20:10 kg $ha^{-1}$ (8450 kg $ha^{-1}$) which were significant from each other. The total nitrogen uptake varied from 64 to 124 kg $ha^{-1}$. Application of NPK @ 60:30:20 kg $ha^{-1}$ ($T_7$) recorded higher total N uptake of 124 kg $ha^{-1}$ which were significantly superior over other treatments. It also recorded higher total phosphorus uptake (14.3 kg $ha^{-1}$), followed by NPK @ 45:30:20 kg $ha^{-1}$ ($T_6$) (12.7 kg $ha^{-1}$) and NPK @ 60:20:10 kg $ha^{-1}$ ($T_4$) (12.4 kg $ha^{-1}$) which were on par with each other. The higher potassium uptake (78 kg $ha^{-1}$) was observed for the treatment carrying NPK @ 60:30:20 kg $ha^{-1}$ .

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# Nitrogen Management under SRI Method

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A field experiment was conducted at Instructional Farm of Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.) during the *kharif*, 2012 to evaluate the effect of integration of nitrogen in rice under SRI (system of rice intensification) method. Seven treatments *viz.* control, 100% N through fertilizer, 75% N through fertilizer+25% N through FYM, 75% N through fertilizer + 25% N through Green manuring, 50% N through fertilizer+25% N through FYM+25% N through Green manure, 50% N through fertilizer+50% N through FYM and 100% N through FYM were comprised in Randomized Block Design replicated as thrice. The variety NDR-359 was taken as test crop. The experimental soil having pH (1:2.5) 8.3, EC 0.33 $dSm^{-1}$, organic carbon (2.4 mg $kg^{-1}$), Available N (149.32), P (13.05 ) and K (263.94 kg $ha^{-1}$). The maximum growth, yield attributes and yield ( grain 64.32 and straw 81.00 q $ha^{-1}$) were recorded with the application of 75% N through fertilizer+25% N through green manuring (Sesbania) which was significantly superior over $T_5$ (50% N through fertilizer + 25% N through FYM + 25% N through green manuring), $T_6$ (50% N through fertilizer + 50% N through FYM), $T_7$ (100% N through FYM) and $T_1$(Control) and statistically at par with $T_2$ (100% N through fertilizer) and $T_3$ (75% N through fertilizer + 25% N through FYM). The maximum uptake of nitrogen (122.81), phosphorus (37.09) and potassium (151.59 kg $ha^{-1}$) were also recorded by the treatment having 75% N through fertilizer+25% N through green manuring and minimum also with $T_1$ (Control). The maximum net income (Rs. 61357.60 $ha^{-1}$) and benefit cost ratio (1.92) were obtained with the treatment having 75% N through fertilizer+25% N through green manure followed by $T_2$, $T_3$, $T_1$ $T_5$ and $T_7$, respectively.

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# Fertilizer Phosphorus Prescription for Rice under STCR-IPNS in Inceptisol of Puducherry

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The soil test crop response based on fertilizer prescriptions under integrated plant nutrient system (STCR-IPNS) for rice crop provide a scientific yield levels of crops taking into account the contribution of NPK from soil, fertilizer and organic. Being a site and situation specific technology, STCR-IPNS along with entire improved package of practices for rice ensures balanced nutrition, increased productivity and efficiency of applied phosphorus with sustained soil health over long run.

The field experiment was conducted at farmer's holding of Sorapet village in Mannadipet commune of Puducherry district, U.T. of Puducherry during 2013 – 14 by using STCR approach. The study area comes under coastal alluvial plain, classified as fine, mixed isohyperthermic, Typic Ustropept. The surface soil sample (0 - 15 cm deep) of the experimental field revealed that the soil is sandy clay loam in texture. The soil is slightly alkaline and non -saline in nature with cation exchange capacity of 29.0 cmol ($p^+$) $kg^{-1}$. The fertility status of the soil was low in $KMnO_4$-N (238 kg $ha^{-1}$), high in Olsen-P (37.1 kg $ha^{-1}$) and medium in $NH_4OAc$-K (168 kg $ha^{-1}$).

Soil test data, rice grain yield and NPK uptake by rice crop were used for obtaining four important basic parameters *viz.*, nutrient requirement to produce one quintal of rice grain (NR), contribution of nutrients form fertilizers (Cf), contribution of nutrients from soil (Cs) and contribution of nutrients from organic matter (Cfym). Making use of these basic parameters the fertilizer prescription equation was developed for P in rice and is given below.

$FP_2O_5 = 2.22\ T - 2.12\ SP - 1.27\ OP$

In the present investigation, the beneficial effect of combined use of P fertilizer with FYM was studied at two different levels of FYM *viz.*, 6.25 t $ha^{-1}$ and 12.5 t $ha^{-1}$. The nomogram were formulated for desired yield target of rice for a range of soil test values under NPK alone, NPK plus 6.25 t $ha^{-1}$ and NPK plus 12.5 t $ha^{-1}$. The perusal of estimate showed that when NPK alone was applied for a soil test value of 20 kg $ha^{-1}$ of $P_2O_5$, the doses of fertilizer $P_2O_5$ required for desired yield target of 7 and 8 t $ha^{-1}$ were113 and 135 kg $ha^{-1}$, respectively. While the doses were 102 and 124 kg $ha^{-1}$, respectively for combined addition of NPK plus FYM applied @ 6.25 t $ha^{-1}$ recording 9.73 and 8.15 per cent reduction of fertilizer $P_2O_5$ doses over NPK alone. When NPK applied with FYM @12.5 t $ha^{-1}$ the doses were 91 and 113 kg $ha^{-1}$ with a per cent reduction of 19.47 and 16.30, respectively over NPK alone.

Using the fertilizer prescription equation under IPNS, the extent of saving of inorganic P fertilizer with the application of FYM @ 6.25 t $ha^{-1}$ with 28 per cent moisture and 0.24 per cent of $P_2O_5$ was 11 kg $ha^{-1}$. If FYM @ 12.5 t $ha^{-1}$ was applied with same nutrient content the saving was 22 kg $ha^{-1}$.

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# Maximization of Productivity in Pearl Millet by the Application of Organic Manure and Micronutrient

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Pearl millet is a common crop grown in *kharif* by marginal and small farmers in alluvial soil region of northern Madhya Pradesh under Pearl millet - mustard and Pearl millet - wheat cropping systems. Under intensive cultivation, the reduction in the yield is generally traced due to deficiency of micronutrients. Organic manures, particularly FYM and vermi-compost not only supply macronutrients but also meet the requirement of micronutrients besides improving soil health. Organic manure influence both yield and plant micronutrients need and thus help to sustain crop productivity. An investigation on "Studies on response of organic manure, zinc and iron on pearl millet crop grown on Inceptisol" was carried out in RBD with 12 treatments and three replications during *kharif* 2014 at Research farm of Department of Soil Science and Agricultural Chemistry, College of Agriculture, R.V.S.K.V.V., Gwalior. The climate of experimental site is semi-arid and sub-tropical dominated with extreme weather conditions having hot and dry summer and cold winter. The mean annual rainfall of area is about 751 mm. The soil of the experimental field was sandy clay loam in texture having 55.6% sand, 23.8% silt and 20.6% clay. Soil was under Pearlmillet-wheat land use system having sandy loam texture, slightly saline in nature low in Organic carbon and available nitrogen and available phosphorus and medium in potassium Available Zn and Fe in soil was insufficient. The pearl millet (Variety: Kaveri super boss) was sown @ 5 kg $ha^{-1}$ in last week of July.

The result of study revealed that total biomass yield above ground and grain yield is significantly increase in all treatments over recommended dose of NPK (100:60:40) fertilizers. The highest total biomass yield and grain yield obtained in the treatment NPK + 5t vermicompost followed by the NPK + 5t FYM. The data also reveals that the treatments receive the micronutrient i.e $ZnSO_4$ and $FeSO_4$ either by foliar application or by soil application as well as singly $ZnSO_4$ or $FeSO_4$ or both ($ZnSO_4$ + $FeSO_4$) influence significantly the grain yield and total biomass yield production over recommended dose of NPK fertilizer. Application of organic manure i.e (NPK + 5 t Vermicompost) recorded significantly highest in all nutrient uptake by pearl millet followed by (NPK + 5 t FYM). The results of experiment also showed that the application of inorganic source of micronutrient i.e. $ZnSO_4$ and $FeSO_4$ eigther singly or in combination eigther soil or foliar application increase the nutrient uptake.The results revealed that the micronutrient deficiency of $ZnSO_4$ and $FeSO_4$ may be corrected by the application of organic manure or inorganic source with recommended dose of NPK eigther by soil application or by foliar application and get the optimum yield. The maximum net balance of nitrogen phosphorus and potassium was recorded in the treatment (NPK+5 t Vermicompost), followed by treatment (NPK+5 t FYM).

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# Impact of One Time Cntrolled Application of Spentwash on Soil Fertility Status in Zone-9 of North Karnataka

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A study was conducted during 2014-15 to know the effect of one time controlled land application of treated post bio-methanated spentwash as liquid manure for the crops based on their recommended nutrients. Totally 20 soil samples were collected before and after application of bio-methanated spentwash from the fields of the consent villages namely Chimmad, Guralpura, Hidkal, Hosur, Nandganv, Palabanvi, and Yaragatti. The collected soil samples were analyzed for various chemical properties and available nutrient status including major and micronutrients. Similarly, 20 soil samples were also collected after harvest of kharif crops from bio-methanated spentwash applied fields. The pH of the treated spentwash was neutral to alkaline in reaction (7.70 to 7.80). The EC value of spentwash varied between 28 to 30 dS $m^{-1}$ indicating high load of dissolved salts in it. It was rich in biocarbonates (333 me $L^{-1}$) chlorides (338 me $L^{-1}$) and sodium (0.03%). It was also rich in potassium (0.62%), nitrogen (0.14%) with very small amounts of sulphur (0.05%) and phosphorus (0.04%). This waste water also contained very small amount of micronutrients (Cu (1.47 mg $kg^{-1}$), Fe (31.4 mg $kg^{-1}$), Mn (3.22 mg $kg^{-1}$) and Zn (2.76 mg $kg^{-1}$)). Periodical analysis of the spentwash indicated higher BOD and COD values (around 23,550 mg $L^{-1}$ and 7,000 mg $L^{-1}$, respectively).

It was observed that soils are grouped under the order of Alfisol and Inceptisol and texture of the soil samples under study area varied from sandy to sandy loam and clay. The dominant cropping pattern in this study area were maize, sugarcane, ginger, turmeric, chilli, sunflower, barley and wheat with a popular cropping sequence of maize-barely-wheat and mixed cropping of sugarcane and maize. The results revealed that there was an increasing in the total soluble salt content (0.49 to 3.29 dS $m^{-1}$), build-up in organic carbon (3.90 to 9.60 g $kg^{-1}$) and available potassium (201 to 462 kg $ha^{-1}$) in the soil due to spentwash application. Water soluble potassium and sodium slightly increased in the soil which received bio-methanated spentwash compared to soil with no spentwash application. Water soluble anions recorded increased values soon after application of bio-methanated spentwash respectively in bicarbonate, sulphide and chloride (1.10 to 3.40, 2.62 to 6.71 and 2.40 to 11.2 me $L^{-1}$) content. There was increase in water soluble cations contents in soils (Ca, Mg and Na). The economics of crops yield (maize, sugarcane, ginger) were also increased due to the application of bio-methanated spentwash when compared to the non applield spentwash.

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# Site Specific Nutrient Management for Soybean in Swell Shrink Soils

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The field experiments were conducted during 2013-14 on farmers' fields in intensive soybean growing areas of Akola district to study the effect of nutrient management on uptake, nutrient use efficiency and yield of soybean in Vertisols. The experiment comprised of four treatments in omission plot technique in randomized block design replicated on fifteen farmers' fields and each farmer's field treated as one replication.

The results revealed that the significant reduction in soil available N, P and K status was recorded under nutrient omission plots while it was highest under combined application of NPK.The omission of nitrogen caused 11.13 per cent reduction in the available nitrogen status of soil over NPK. The reduction in available phosphorus was 28.06 per cent due to omission of phosphorus over the combined NPK. The omission of potassium recorded 11.20 per cent reduction in the available potassium status of soil as compared to NPK.

Significant reduction in nitrogen uptake (29.73 per cent) was recorded due to omission of nitrogen while omission of phosphorus caused 20.93 per cent reduction in nitrogen uptake. Due to omission of phosphorus 23.75 per cent reduction in phosphorus uptake was recorded while omission of nitrogen caused 14.54 per cent reduction in phosphorus uptake. Similarly, 16.19 per cent reduction in potassium uptake was recorded due to omission of potassium while omission of nitrogen caused 14.86 per cent reduction in potassium uptake.

The number of pods in soybean was significantly reduced under omission of phosphorus and found lowest while they were also significantly reduced due to omission of nitrogen and potassium. The number of nodules per plant was also significantly reduced due to omission of NP and NK. However, highest reduction was recorded due to omission of phosphorus followed by omission of nitrogen and omission of potassium while highest no of nodules were recorded under combined NPK application.

The significant reduction in yield of soybean was recorded under omission of phosphorus followed by nitrogen and potassium. The omission of nitrogen, phosphorus and potassium showed 18.66, 25.84 and 9.69 per cent yield reduction in soybean, respectively, as compared to combined application of NPK. The highest (25.84%) yield reduction was recorded under omission of phosphorus indicating that phosphorus is most crucial and sensitive nutrient for soybean. Therefore, it could be inferred that the highest reduction in uptake of nutrients and residual soil fertility status was recorded due to omission of phosphorus followed by nitrogen and potassium. The nutrient use efficiency was found most sensitive to potassium followed by nitrogen and phosphorus.

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# Soil Fertility Status of Betel Vine Growing Regions of Tumkur District of South Interior Karnataka

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A study was conducted to assess the soil fertility status of major betel vine growing regions of Tumkur district of South Interior Karnataka. Thirty soil samples were collected at two different depths (0-30 and 31-60 cm) from betel vine plantations and analysed for their physicochemical and chemical properties. The soils were neutral to slightly alkaline in reaction, non-saline in nature (free of soluble salts) and high in organic carbon status. The organic carbon content ranged from 0.78 to 1.02 per cent with a mean of 0.84 per cent. The distribution of organic carbon in soils showed a decreasing trend with depth. The exchangeable Ca content of the soil varied from 3.2 to 4.6 cmol($p^+$)$kg^{-1}$ soil with a mean value of 3.87 cmol ($p^+$) $kg^{-1}$. The exchangeable Ca content of the betel vine plantations soil was above 1.5 cmol($p^+$) $kg^{-1}$ which is the critical value for ideal soils. Exchangeable Ca content of the soil showed irregular trend with depth. Exchangeable Mg content of the soils varied from 1.48 to 2.64 cmol($p^+$)$kg^{-1}$ with an average value of 2.01 cmol($p^+$)$kg^{-1}$. Exchangeable Mg content of all sites of betel vine plantations was higher than the critical value of 1.0 cmol($p^+$)$kg^{-1}$ soil. Depth wise distribution of Mg also followed a similar trend to that of exchangeable Ca. The available sulphur in the soils varied from 8.6 to 16.3 mg $kg^{-1}$. Based on the nutrient indexing in soils, the surface soil was medium in available N (289 to 328 kg $ha^{-1}$), medium in available P (11.6 to 14.8 kg $ha^{-1}$) and medium in available K (194 to 237 kg $ha^{-1}$). A consistent decrease in the concentration of available N, P and K with the increase in soil depth was noted. The DTPA extractable Fe, Mn, Zn and Cu contents in surface soils ranged from 15.1 to 22.3, 3.4 to 7.2, 0.70 to 2.3 and 0.2 to 0.9 mg $kg^{-1}$, respectively and were nearly sufficient in the surface soils. The contents of DTPA extractable Fe, Mn, Zn and Cu decreased with the increase in soil depth. Soil analysis up to 60 cm soil depth revealed that betel vine plantations was high in organic carbon, medium in available N, P, K and S, high in exchangeable Ca and Mg, and nearly sufficient in DTPA extractable Fe, Mn, Zn and Cu.

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# Response of Mungbean (*Vigna Radiata* L. Wilczek) to Application of Different Level of Boron and Sulphur in Red Soil of Mirzapur (Uttar Pradesh)

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A field experiment was conducted on red soil to study the effect of boron and sulphur on growth yield and quality of mungbean during *kharif* season of 2014 at the Agricultural Research Farm of Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur. The experiment was laid out in the factorial randomize block design with 3 levels of sulphur (0 kg $ha^{-1}$, 15 kg $ha^{-1}$, and 30 kg $ha^{-1}$) and 4 levels of boron ( 1.5 kg $ha^{-1}$, 1.0 kg $ha^{-1}$, 0.5 $ha^{-1}$ and 0 kg $ha^{-1}$) of boron and was replicated thrice. The growth and growth attributes of mungbean i.e. plant height, number of leaves per plant and total dry matter production at 20 DAS, 40 DAS and at harvest were significantly improved by different sulphur and boron levels. The highest plant height, number of branches $plant^{-1}$, number of trifoliate leaf $plant^{-1}$, number of root, number of nodule $plant^{-1}$ and total dry matter production were recorded with 1.5 kg $ha^{-1}$ boron and 30 kg $ha^{-1}$ sulphur. The yield attributes and yield of mungbean were recorded at harvest and it was significantly influenced by the treatments of boron and sulphur levels highest length of pod $plant^{-1}$, number of pods $plant^{-1}$, number of grain $pod^{-1}$, grain yield, test weight (100 seed weight), stover yield, biological yield and harvest index were obtained by application of 15 kg $ha^{-1}$ sulphur and 1.5 kg $ha^{-1}$ boron. The interaction of 1.5 kg $ha^{-1}$ boron with 30 kg sulphur per hectare produced significantly highest value of yield attributes and yields over other treatment. Nutrient content (N, P, K, S, B content in the grain and straw), were also influenced significantly by different treatment of boron and sulphur levels. The application of 30 kg sulphur $ha^{-1}$ gave better result over others. On the basis of the results, it can be concluded that application of 30 kg sulphur $ha^{-1}$ with 1.5 kg $ha^{-1}$ boron was found most suitable under rainfed condition for mungbean crop. Since the experiment was conducted for one year only and needs further repetition of experiments to confirm the results in same condition.

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# The Effect of Cd and FYM on Growth and Yield of Forage Sorghum and Forage Maize

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The presence of heavy metals in soils are likely to pose serious threat on animal-human health by their long term persistence in the environment. Therefore, heavy metals contaminated fields need appropriate cost effective and environmentally friendly remediation measure to eliminate or minimize the possible health hazards. With this background a pot trial was undertaken in order to generate location specific information on "Phytostabilization of Cadmium Through Forage Maize and Forage Sorghum in Presence of FYM" the study was conducted during *summer*, 2014 at pot house, modern laboratory, Micronutrient Research Project (I.C.A.R), Anand Agricultural University, Anand. The pot experiment was laid out in completely randomized design (factorial) with three repetation. Total twenty treatments comprising of five doses of Cd (0, 10, 20, 40 and 80 ppm) and two levels of FYM (0 and 20 t $ha^{-1}$) were tested in forage maize and forage sorghum crops.

The observations on germination days, plant height (30 DAS and at harvest), leaf number (30 DAS and at harvest), green forage yield (g $pot^{-1}$), total dry matter yield (g $pot^{-1}$) of forage maize and forage sorghum crop were recorded. The crops were grown up to flowering stage (60 DAS) and their yields were recorded.

The experimental results indicated that with increasing Cd level significantly decrease in the plant height (cm) and leaf number at 30 DAS and 60 DAS, green forage yield (g $pot^{-1}$) and Total dry matter yield (g $pot^{-1}$) of whole plant and plant components of maize and sorghum. The yield reduction started at lower Cd level and and reduction was increased when 80 ppm Cd ($Cd_{80}$) was applied to soil. The effect was mitigated by FYM application @ 20 t $ha^{-1}$. In absence of cadmium ($Cd_0$) maize and sorghum crop gave maximum plant height, leaf number at 30 and 60 DAS, green fodder yield (g $pot^{-1}$) and the dry matter yield of shoot, root and total dry matter yield (g $pot^{-1}$).

Maize ($C_1$) had taller plant height, more number of leaves, shoot weight, root weight and total dry matter yield as compared to sorghum ($C_2$) is mainly due to genetic makeup of crops. In maize and sorghum crops $Cd_0F_1$ treatment recorded significantly the highest yield. Under $Cd_{80}F_0$ treatment the minimum yield in both the crops were recorded.

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# Effect of Diatomiteas Siliconsource under Cropped and Non-cropped Condition of Wetland Rice

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A field experiment was carried out at V. C. Farm, Mandya during *summer* and *kharif* 2015 with and without application of Si under rice cropped and non-cropped condition. The soil of experimental plot was neutral in reaction with sandy loam in texture. Calcium chloride (CCSi) and Acetic acid (AASi) extractable Si was medium in range.Twenty one days old rice seedlings of *var.* Tanu were transplanted with a spacing of 20 cm ×10 cm and standing water was maintained to achieve submergence condition. Recommended dose of fertilizers were applied as per package of practice. Diatomite (DE) @ 300 kg $ha^{-1}$ used as Si source was applied as basal along with the fertilizers.There was a significant increase in grain yield with the application of DE compared to no DE application treatment during *summer* 2015 but not with other yield parameters. Application of DE recorded numerical increase in the Si content and uptake by the rice straw and grain but was statistically on par with no DE application treatment. The content of AASi in the soil increased significantly with application of DE where no rice was grown, whereas Si content decreased in the presence of crop even though the DE was applied because of crop Si uptake and was on par with control with and without rice crop. The content of CCSi was significantly higher in control where no crop was grown with and without added Si. However in the presence of rice crop, soil Si content decreased and was on par with the other treatments.Application of DE recorded significantly higher straw yield compared to controlduring *kharif* 2015. However, there was no significant difference in grain yield between treatments. There was significant increase in the straw Si content and its uptake with the application of DE over control but notwith grain Si content and its uptake between the treatments. Silicon extracted by $CaCl_2$ was significantly affected and found to be highest in control and decreased significantly in the presence of crop either with or without DE application. The content of AASi was not significantly differed among the treatments but found to be lower in plots where crop was grown. Si content extracted by acetic acid and calcium chloride was found to be higher during *kharif* season compared to *summer* season.

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# Effect of K Application on Yield and Yield Attributes in Bt Cotton

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The study was carried out at the farm of Krishi Vigyan Kendra, Sirsa. The experimental soil was sandy loam in texture, slightly alkaline in reactions, low in organic carbon and nitrogen, medium in phosphorus with medium to high available K levels. The experiment was laid out in two soils having medium and high available K with seven treatments and was replicated thrice using RBD. There were seven treatments *viz*. $T_1$ - $N_{175}P_{60}$, $T_2$ - $N_{175}P_{60}$ + Water Spray, $T_3$ - $N_{175}P_{60}$+ foliar spray of 1% $KNO_3$, $T_4$ - $N_{175}P_{60}$+ $K_{30}$, $T_5$ - $N_{175}P_{60}$+ $K_{30}$+ foliar spray of 1% $KNO_3$, $T_6$ - $N_{175}P_{60}$+$K_{60}$ and $T_7$ - $N_{175}P_{60}$+$K_{60}$+ foliar spray of 1% $KNO_3$. Two foliar sprays were done at the time of flowering and peak boll development stages. It was observed that the seed cotton yield increased up to the treatment $T_4$ ($N_{175}P_{60}$ + $K_{30}$) after that the yield did not significantly increase in the high K fertility soil over medium K fertility soil. The highest seed cotton yield (2801.52 kg $ha^{-1}$) was obtained in the treatment $T_7$ ($N_{175}P_{60}$ + $K_{60}$ + foliar spray of 1% $KNO_3$) in medium K fertility soil. Lint yield was significantly affected by the available K status and K application. Ginning over turn and harvest index was not affected by the available K status and K application. The number of bolls/plant was significantly more in high K fertility soil and also affected by the foliar and soil applied potassium. The highest mean number of boll/ plant (46.97) was obtained in treatment $T_7$ ($N_{175}P_{60}$ + $K_{60}$ + foliar spray of 1% $KNO_3$).

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# Studies on Sulphur Nutrition of Soybean-Wheat Cropping Sequence

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Sulfur nutrition is a constraint in the regions receiving continuous heavy rains during *kharif* season (27 to 32 MW). The effects of high mobility of sulphates along with low organic matter status in the soil affects the yield potential of legume oil producing crop. Considering the differential crop requirements of sulfur for soybean and wheat crop, the study was undertaken to evaluate the effects of direct and residual effect of elemental sulfur application to a sulfur deficient soil on the yields of soybean-wheat cropping sequence. The experiment was conducted with the objective to study the response of different levels of sulphur on soybean and its residual effect was studied on subsequent wheat crop. The experiments were conducted at Zonal Agricultural Research Station, Kolhapur on S deficient soil during the cropping seasons of 2012-15. The experiments were laid out in randomized block design having six treatments and four replications. The treatments consisted of four levels of S (10, 20, 30 and 40 kg S $ha^{-1}$) besides basal dose of 50 kg N and 75 kg $P_2O_5$ $ha^{-1}$ was applied through urea and diammonium phosphate (DAP) uniformly to all the plots at the time of sowing. The pooled soybean equivalent yield data revealed that application of elemental sulphur @ 20 kg $ha^{-1}$ recorded significantly higher soybean equivalent yield (51.3 q $ha^{-1}$) over 10 kg $ha^{-1}$ elemental sulphur (47.3 q $ha^{-1}$) and without sulphur application (44.4 q $ha^{-1}$) while it was at par with sulphur application at higher levels of 30 (52.8 q $ha^{-1}$) and 40 (53.4 q $ha^{-1}$) kg $ha^{-1}$ elemental sulphur. The pooled oil yields (table 1.11) revealed that the application of 20 kg S $ha^{-1}$ significantly increased the oil yields (537 kg $ha^{-1}$) as compared to without sulphur application (425 kg $ha^{-1}$) however, at higher levels of 30 (559 kg $ha^{-1}$) and 40 (567 kg $ha^{-1}$) kg $ha^{-1}$ elemental sulphur application the difference were not significant. The pH, EC and organic carbon did not differ due to different treatments after completion of the cropping sequence. Similarly the available nitrogen, phosphorus and potassium contents also did not differ among the different treatment whereas higher significant values of N, P and K were recorded over control. The available sulphur contents in the soil on completion of cropping sequence recorded significantly higher available sulphur contents over without sulphur application (8.4 mg $kg^{-1}$) while the highest values were recorded in treatment 40 kg S $ha^{-1}$ (12.8 mg $kg^{-1}$). The benefit cost ratio (B:C) for 20 kg S $ha^{-1}$ was 1.80 while the marginal increase in B:C ratio was observed at higher level of S application treatments.

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# Soil Properties as Influenced by Fortified Cow-Dung Slurry

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The present investigation was conducted with the objective of to assess the response of N and P enriched cow-dung slurry on soil properties and different forms of carbon in complete randomized design. The treatments comprises viz., : $T_1$ : absolute control, $T_2$ : Only cow-dung slurry + 50% RDF (100:50:50 $N:P_2O_5:K_2O$ kg $ha^{-1}$), $T_3$ : cow-dung slurry fortified with Neem cake + 50% RDF, $T_4$ : cow-dung slurry fortified with cotton cake + 50% RDF, $T_5$ : cow-dung slurry fortified with rock phosphate + 50% RDF, $T_6$ : cow-dung slurry fortified with urea + 50% RDF, $T_7$ : Cow-dung slurry fortified with neem cake + cotton cake + 50% RDF, $T_8$ : Cow-dung slurry fortified with rock phosphate + urea + 50% RDF, $T_9$ : RDF-urea, SSP, MOP + 10 t FYM $ha^{-1}$.

The chemical properties of soil in respect of pHs, ECe, per cent organic carbon, calcium carbonate, Available nitrogen, phosphorus and potassium were significantly affected by different fortified cow-dung slurry treatments. The highest pHs was observed in treatment $T_1$ and lowest in $T_7$ and with respect to ECe, lowest values in $T_7$ and higher in $T_1$ treatment. Highest organic carbon and Lowest Calcium carbonate percentage were recorded in $T_7$. The humic substances viz., humic and fulvic acid were highest (14.13 and 23.46 g 100 $g^{-1}$ soil) in $T_7$ and lowest (6.40 and 9.62 g 100 $g^{-1}$ soil) in $T_1$. The carbon fractions *viz*., water soluble carbon and labile carbon were highest (195 and 297.5 mg $kg^{-1}$) in $T_7$ and lowest (70 and 204 mg $kg^{-1}$) in $T_1$.

The availability of N content in soil was the highest (210 kg $ha^{-1}$) in $T_6$ and lowest (129.6 kg $ha^{-1}$) in $T_1$. The availability of K content in soil was highest (470.4 kg $ha^{-1}$) in $T_9$ and lowest (421.8 kg $ha^{-1}$) in $T_1$.

From the above study it can be concluded that the application of 50% nitrogen and phosphorous through enriched cow-dung slurry (5 t $ha^{-1}$) with neem cake (1 t $ha^{-1}$) + cottan cake (1.89 t $ha^{-1}$) and remaining 50% recommended dose through chemical fertilizer was useful for better soil properties and improving the soil health under saline condition.

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# Effect of N and P Enriched Cow Dung Slurry on Growth and Nutrient Uptake by Maize in Saline Soil

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The present investigation was conducted with the objective of to assess the response of N and P enriched cow-dung slurry on growth and nutrient uptake of maize in complete randomized design. The treatments comprise viz., : $T_1$ : Absolute control, $T_2$ : Only cow-dung slurry + 50% RDF (100:50:50 $N:P_2O_5:K_2O$ $kgha^{-1}$), $T_3$ : Cow-dung slurry fortified with neem cake + 50% RDF, $T_4$ : Cow-dung slurry fortified with cotton cake + 50% RDF, $T_5$ : Cow-dung slurry fortified with rock phosphate + 50% RDF, $T_6$ : Cow-dung slurry fortified with urea + 50% RDF, $T_7$ : Cow-dung slurry fortified with Neem cake + cotton cake + 50% RDF, $T_8$ : Cow-dung slurry fortified with rock phosphate + urea + 50% RDF, $T_9$ : RDF-urea, SSP, MOP + 10 t FYM $ha^{-1}$.

The result indicated that the growth parameters *viz.*, plant height (116 cm), number of leaves (12 Nos.) and green fodder yield and dry matter yield of maize showed significant results due to the treatment $T_7$ (cow-dung slurry + neem cake + cotton cake + 50% RDF) over all other treatments. The highest nitrogen uptake and phosphorus was observed under treatment $T_7$ (cow-dung slurry + neem cake + cotton cake + 50% RDF).

From the above study it can be concluded that the application of 50% nitrogen and phosphorous through enriched cow-dung slurry (5 t $ha^{-1}$) with neem cake (1 t $ha^{-1}$) + cottan cake (1.89 t $ha^{-1}$) and remaining 50% recommended dose through chemical fertilizer was useful for better plant growth, nutrient uptake, maize green fodder yield under saline condition.

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# Effect of Integrated Nutrient Management on Growth and Yield of Amaranthus (*Amaranthus tricolor*) cv. Arka Suguna

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The experiment was conducted at Department of Horticulture Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal during the year 2016 to study the effect of integrated nutrient management on growth and yield characters in Amaranthus (*Amaranthus tricolor*) cv. Arka Suguna. The experiment includes seven treatments $T_1$ - Full recommended dose of fertilizer (75 kg N and 25 kg K), $T_2$ - vermicompost 2 t ha$^{-1}$, $T_3$ - FYM @ 25 t ha$^{-1}$, $T_4$ - poultry manure @ 5 t ha$^{-1}$, $T_5$ - vermicompost 2 t ha$^{-1}$ + Phosphorus solubilizing bacteria @ 2 kg ha$^{-1}$ (PSB) + *Azospirillum* @ 2 kg ha$^{-1}$, $T_6$ - FYM @ 25 t ha$^{-1}$ + Phosphorus solubilizing bacteria @ 2 kg ha$^{-1}$ (PSB) + *Azospirillum* @ 2 kg ha$^{-1}$ $T_7$ - Poultry manure @ 5 t ha$^{-1}$ + phosphorous solubilizing bacteria @ 2 kg ha$^{-1}$ (PSB) + *Azospirillum* @ 2 kg ha$^{-1}$. The results revealed that application of FYM + Phosphorus solubilizing bacteria (PSB) + *Azospirillum* combinations was found to be superior in growth and yield of amaranthus when compared to other treatments. The maximum plant height (32.61 cm), number of branches (8.0), leaf weight plant $^{-1}$ (52 g), stem weight (27.32 g) and total leaf yield (19 t ha$^{-1}$) were recorded in $T_6$ (application of FYM @ 25 t ha$^{-1}$ + phosphorus solubilizing bacteria @ 2 kg ha$^{-1}$ (PSB) + *Azospirillum* @ 2 kg ha$^{-1}$). The lowest plant height (21.50 cm), number of branches (3.5), leaf weight plant $^{-1}$ (25 g) stem weight (19.50 g), total leaf yield (12 t ha$^{-1}$) were recorded in $T_3$ (FYM @ 25 t ha$^{-1}$). Application of FYM @ 25 t ha$^{-1}$ + Phosphorus solubilizing bacteria @ 2 kg ha$^{-1}$ (PSB) + *Azospirillum* @ 2 kg ha$^{-1}$ was found to be better on growth and yield parameters in amaranthus.

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# Effect of NPK and Vermiwash on Growth and Yield of Bhendi (*Abelmoshus esculantus*) Hybrid No.10

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The experiment was conducted at Department of Horticulture Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal during the year 2013 to study the effect of NPK and vermiwash on growth and yield characters in Bhendi. The experiment includes13 treatments *viz.,* $T_1$ – Recommended dose of NPK + Vermiwash 1 sprays 1 week interval after 30 DAS, $T_2$ – Recommended dose of NPK + vermiwash 2 sprays 1 week interval after 30 DAS, $T_3$ – Recommended dose of NPK + Vermiwash 3 sprays at 1 week interval after 30 DAS, $T_4$ – Recommended dose of NPK + Vermiwash 4 sprays at 1 week interval after 30 DAS, $T_5$ – Recommended dose of NPK + Vermiwash 5 sprays at 1 week interval after 30 days, $T_6$ – Vermicompost @ 5 t $ha^{-1}$ + Vermiwash 1 sprays at 1 week interval after 30 DAS, $T_7$ – Vermicompost @ 5 t $ha^{-1}$ + Vermiwash 2 sprays at 1 week interval after 30 DAT, $T_8$ - Vermicompost @ 5 t $ha^{-1}$ + Vermiwash 3 sprays at 1 week interval after 30 DAS, $T_9$ - Vermicompost @ 5 t $ha^{-1}$ + Vermiwash 4 sprays at 1 week interval after 30 DAS, $T_{10}$ - Vermicompost @ 5 t $ha^{-1}$ + Vermiwash 5 sprays at 1 week interval after 30 DAS, $T_{11}$ – Recommended NPK + Vermiwash (Soil treatment) + 3 foliar sprays, $T_{12}$ – Vermicompost @ 5 t $ha^{-1}$ + Vermiwash (Soil treatment) + 3 foliar sprays, $T_{13}$ – Recommended dose of NPK (N 20 kg+P 50 kg + K 30 kg $ha^{-1}$ as basal + another 20 kg of N on 30 DAS as top dressing while earthing up). The results revealed that application of vermicompost @ 5 t $ha^{-1}$ + vermiwash 5 sprays at 1 week interval after 30 DAS was found to be superior in growth and yield of bhendi when compared to other treatments. The maximum plant height (104.50 cm), fruit length (12.20 cm), fruit weight (15.40 g) and fruit yield (164.25 q $ha^{-1}$) with CB radio of 3.86 were recorded in $T_{10}$ (application of vermicompost @ 5 t $ha^{-1}$ + vermiwash 5 sprays at 1 week interval after 30 DAS). The lowest plant height (82.14 cm) was recorded in $T_1$ (Recommended dose of NPK + Vermiwash 1 sprays 1 week interval after 30 DAS) and the lowest fruit length (8.35 g), fruit weight (13.57 g) and fruit yield (126.20 q $ha^{-1}$) was recorded in $T_{13}$ (Recommended NPK (N 20 kg + P 50 kg + K 30 kg $ha^{-1}$ as basal + another 20 kg of N on 30 DAS as top dressing while earthing up).from the results, it concluded that the treatment $T_{10}$ (application of vermicompost @ 5 t $ha^{-1}$ + vermiwash 5 sprays at 1 week interval after 30 DAS) was found to be better on growth and yield traits of bhendi.

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# Effect of Agronomic Interventions on Crop Yield and Nitrogen Use Efficiency in Maize (*Zea mays* L.) in Vertisol

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A field experiment was conducted consecutively for 2 years at the research farm of ICAR-Indian Institute of Soil Science, Bhopal, Madhya Pradesh (23°18′N, 77°24′ E, 485 m above mean sea level) with the objective to evaluate best agronomic interventions for enhancing crop yield and nitrogen use efficiency (NUE) in maize–chickpea cropping sequence between 2013-14 and 2015-16. The experiment was laid out in a randomized block design (RBD) with 12 treatment combinations of skipping basal dose of nitrogen, soil-test crop response equation (STCR) based fertilizers, nitrogen (N) rate and method of application and biochar application as soil amendment and replicated thrice. The soil of experimental field was clayey in texture (Isohyperthermic, Typic haplustert) and slightly alkaline in reaction with pH 7.8 and low available N (206.8 kg $ha^{-1}$), high P (50.86 kg $ha^{-1}$) and high K (400.2 kg $ha^{-1}$). Variety 'Hybrid-4212' of maize and 'JG 315' of chickpea were used in this experiment. Maize was raised as a rainfed in kharif season (June to September), while chickpea crop was raised with pre-sowing irrigation plus one sprinkler irrigation at pod development stage and all other agronomic practices were followed as per standard protocol. The two year study showed that total dry matter yield of maize crop was higher with soil test crop response equation based (STCR) fertilizer application; probably due to higher amount of nutrient addition. While among the varying N rate and time of application, grain and stover yield of maize crop were significantly higher in the treatments where basal dose of N was skipped and total N was applied in two equal splits (60 kg N $ha^{-1}$) at 20 and 40 days after sowing (DAS), respectively. The total dry matter yield of maize crop was also improved in the treatments where addition of biochar (10 t/ha) was made. There was not much influence of the residual fertility on growth and yield attributing parameters and grain and straw yield of chickpea, but the magnitude of crop yield and it attributes were higher in plot treated with biochar. Nitrogen use efficiency also significantly differed with the varying rate and time of application. The N use efficiencies were higher in the treatment where basal dose of nitrogen was skipped and total nitrogen was applied into two equal split dose at 20 and 40 DAS, respectively. The use of biochar at large scale to field (10 t $ha^{-1}$) as soil amendment with recommended dose fertilizer (120 kg N $ha^{-1}$) significantly improved the grain yield and N use efficiencies in maize crop. Thus, skipping basal dose of N and using biochar as soil amendment may improve crop productivity and N use efficiency in maize -chickpea system in deep black soil.

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# Effect of FYM and Lime on Seed Yield and Micronutrient Composition of Indian Mustard (*Brassica juncea* (L.) *Czern*) Grown in a Pb Spiked Soil

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Trace metals can often accumulate in considerable amounts in plant tissues and exceed the levels that are toxic to human or animal population before visible phytotoxic effects are produced. This has caused increasing concern with respect to certain trace metals particularly Pb which is considered as a potentially hazardous contaminant in the biosphere. It is a common environmental contaminant introduced into the soil through anthropogenic activity and the danger of Pb is aggravated by its almost indefinite persistence in the environment. To prevent Pb movement to deeper soil layers and ground water aquifers identification of some viable remedial measures is necessary in developing cost effective and community acceptable technologies for chemical and biological immobilization of Pb in soil. We selected farm yard manure (FYM) and lime ($CaCO_3$) as amendments which are very economical and easily available to investigate the influence of theses applied alone or in combination on i) Seed yield of Indian mustard and ii) micronutrient composition of Indian mustard in relation to addition of amendments.

Indian mustard was grown for 60 days in a screen house using a loamy sand soil spiked with six levels of Pb varying from 0-800 mg $kg^{-1}$ soil. Amendments used were lime ($CaCO_3$), and farm yard manure (FYM) applied alone and in combinations at 2.5 and 5.0 per cent (w/w). Adequate application of nitrogen, phosphorus and potassium was made to Indian mustard. The results showed that there was a linear decrease in the seed yield of Indian mustard with increase in levels of added Pb but addition of amendments increased the seed yield of Indian mustard as compared to unamended soil. All amendments combinations significantly reduced Pb accumulation by Indian mustard and the reduction increased with increasing the rate of amendment application. The addition of amendments also increased the concentration of micronutrients in Indian mustard as compared to unamended soils.

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# Effect of Inorganic Fertilizers and Farmyard Manure Application on Nutrient Availability in Soil under Rice-Wheat System

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A field experiment was conducted for 5 years at Regional station, Gurdaspur (Punjab) to study the effect of inorganic fertilizers applied either alone or in combination with farmyard manure (FYM) on grain yield, nutrient uptake and availability of plant nutrients in soil under rice-wheat cropping system. Grain yield and nutrient (N, P and K) uptake of rice and wheat increased significantly with the application of both organic and inorganic fertilizers, compared with control. Significantly higher grain yield was recorded in plots receiving balanced fertilizer application with and without FYM (NPK and NPK+FYM), compared with imbalanced application of fertilizer nutrients (NP, PK and NK). The concentration of $NO_3^-$-N and $NH_4^+$-N in surface (0-7.5 cm) and sub-surface (7.5-15 cm) soil depths increased significantly with the application of fertilizers and organic manure. Conjoint application of NPK+FYM significantly increased $NO_3^-$-N and $NH_4^+$-N concentration compared with the application of NPK or FYM alone. Available P concentration was significantly higher in soils fertilized with inorganic fertilizers (NPK alone), compared with organic manure (FYM alone). The conjoint application of NPK+FYM however, resulted in greater increase in available P concentration at both the soil depths. The concentration of available K in soil did not differ significantly with FYM alone and control treatments. Conversely, NPK application resulted in a significant increase in available K concentration, compared with unfertilized control. The results showed that balanced application of fertilizers nutrients conjointly with and organic manure improved grain yield, nutrient uptake and availability of plant nutrients in soil under rice-wheat cropping system.

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# Influence of Boron Application on Yield and Uptake of Boron by Berseem (*Trifolium alexandrium* L.) in Boron-deficient Calcareous Soils of Punjab

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A pot experiment was conducted during rabi 2014 to study the response of berseem (*Trifolium alexandrium* L.) to boron application in boron deficient calcareous soils of Punjab. Three different soils with varying calcium carbonate content viz. 0.75 (Soil I), 2.60 (Soil II) and 5.70 per cent (Soil III) were collected from different sites of Ludhiana, Bathinda and Shri Muktsar sahib districts of Punjab, India. The initial pH, electrical conductivity (dS $m^{-1}$) and hot water soluble boron content (mg $kg^{-1}$) of the above soils were 7.62, 0.27, 0.46; 8.18, 0.28, 0.37 and 8.25, 0.29, 0.28, respectively. The treatments comprised seven levels of soil applied boron *viz*. 0, 0.5, 0.75, 1.0, 1.25, 1.5 and 2.0 mg B $kg^{-1}$, which were applied through borax before sowing of the crop (Cv. BL-42). The experiment was laid out in CRD factorial design with three replications. Four fodder cuttings were taken at different timings of the crop during the period of the experiment. The mean green fodder yield, dry matter yield, B content and its uptake increased significantly at 0.75 mg B $kg^{-1}$ soil treatment level in the first cutting while these were significant at 1.0 mg B $kg^{-1}$ soil treatment level in all soils at second, third and fourth cuttings. The mean dry root biomass, root B content and its uptake also showed significant increase at 1.0 mg B $kg^{-1}$ soil treatment level in all soils. Among all calcareous soils, the mean green fodder yield, dry matter yield, B content and its uptake decreased significantly for the different soils having 0.75, 2.6 and 5.7 per cent calcium carbonate levels in each fodder cutting irrespective of boron levels. Soil I with lowest calcium carbonate was the best soil in respect of yield, B content and its uptake in comparison to Soil II and Soil III. Interaction between two factors (B application levels and soils) affected yield, B content and its uptake significantly at 0.75 mg B $kg^{-1}$ treatment level over control for all soils in first cutting while these were significant at 1.0 mg B $kg^{-1}$ level over control in second, third and fourth cuttings. Both boron application and soils interacted with each other synergistically and antagonistically at lower and higher levels, respectively and thus the interaction seemed to be rate dependent. Available boron content increased significantly with increasing boron levels in soils.

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# Development of Integrated Nutrient Management (INM) Modules for Improving Crop Productivity and Soil Health in a Deep Black Soil

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A long term field experiment was conducted consecutively for 4 years at the research farm of ICAR–Indian Institute of Soil Science, Bhopal on a fixed site to assess the effect of different integrated nutrient management (INM) modules on crop yield of maize-chickpea cropping sequence and soil health. In this study, 12 INM combinations of fertilizers, farmyard manure (FYM), poultry manures (PM), urban compost (UC) and *Glyricidia* loppings (Gly) and soil test based fertilizer (STCR) dose on target yield 5.0 and 1.50 t $ha^{-1}$ in maize and chickpea, respectively have been investigated between 2011-12 and 2015-16. Different treatment modules were laid out in a randomized block design (RBD) with 3 replications. The mean of 4 years data revealed that maize grain yield was significantly higher with the soil–test crop response equation (STCR) based INM module (75% NPK of STCR based dose with 5 t FYM) and followed by STCR based dose (target yield– 5 tonnes) over the years. All treatments irrespective of fresh application of fertilizer or organic sources of nutrients or residual effect of nutrients added in previous crop were at par in-terms of chickpea yield and significantly higher than control. However, the yields obtained on integration of NPK with poultry manures (PM), urban compost (UC) and *Glyricidia* loppings (Gly) were at par but inferior to FYM. The application of 5 t FYM every season improved the grain and straw yield of chickpea as compared to residue management (mulching by maize residues). FYM based INM modules (75% NPK of STCR dose +5 t FYM) gave significantly higher nutrients (N, P and K) uptake followed by GRD and STCR based fertilizers by maize and chickpea crops. The agronomic efficiency (AE), partial factor productivity (PFP) and recovery efficiency (RE) also improved by the FYM based INM modules over the years. Aaddition of organic manures increased N and P use efficiencies. Integration of organic and inorganic sources of nutrients in balanced proportion exhibited lower bulk density and increase in mean weight diameter (MWD), water stable aggregates (WSA) and porosity in soil. Soil microbial properties were influenced with application of INM modules. The highest FDA (39.5 µg fluroscein $g^{-1}$ soil $h^{-1}$) and dehydrogenase activity (105.8 µg TPF $g^{-1}$ soil $h^{-1}$) were recorded with the application of FYM (20 t $ha^{-1}$). Phosphatase enzyme activity plays an important role in the P cycle because it provides P for plant uptake by releasing $PO_4^{2-}$ ions in soil solution. Application of organics along with fertilizer has more pronounced effect on enzyme activities compared to supply of nutrient through fertilizer alone. Despite having maintained better soil fertility by improving physical and biological condition of soil through exclusive supply of organic sources of nutrients, crop yield was not sustainable in only organic treatments.

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# Productivity and Economics of Soybean-Wheat Cropping System under Different Levels of NPK at Farmer's Field in Different Blocks of Jhabua District of Madhya Pradesh

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A field experiment was conducted during two consecutive years of 2012-13 and 2013-14 at Farmer's Field in 5 blocks of Jhabua district of Madhya Pradesh to study the effect of different levels of NPK on productivity and economics in terms of net monetary return and B: C ratio in soybean-wheat cropping system. The application of recommended doses of NPK ($T_5$) exhibited their superiority by recording higher grain yield of both soybean and wheat crops over rest of the treatments during both years of study. The recommended doses of NPK ($T_5$) increased the soybean yield over control ($T_1$) by 71.2% and 48.6% in 2012-13 and 2013-14, respectively and wheat by 35.2% and 33.9% in 2012-13 and 2013-14, respectively. The mean wheat equivalent yield (WEY) was the highest (57.9 q $ha^{-1}$) with the application of recommended doses of NPK ($T_5$) in both soybean and wheat crops followed by $T_3$ (52.1 q $ha^{-1}$), $T_4$ (48.5 q $ha^{-1}$), $T_2$ (45.4 q $ha^{-1}$) and the lowest in $T_1$ (40.5 q $ha^{-1}$). Similarly, the highest NMR of Rs. 35475 $ha^{-1}$ and Rs. 50978 $ha^{-1}$ during 2012-13 and 2013-14 was recorded with application of recommended doses of NPK ($T_5$). The mean NMR per rupee invested (B:C) was higher (1.55) when crops were fertilized with recommended doses of NPK ($T_5$) and the lowest (1.16) was recorded when no fertilizers were applied to both the crops ($T_1$). Additional investment of Rs. 4854 $ha^{-1}$ in $T_5$ treatment, exhibited the additional NMR of Rs. 16567 $ha^{-1}$ over control ($T_1$). So the judicious use of money in right direction can pay positive results in terms of yield as well as additional NMR $ha^{-1}$.

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# Influence of Integrated Nutrient Management on Growth and Yield of Sesame Crop under Rainfed Conditions in Sub montane Punjab

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Sesame (*Sesamum indicum* L.) is one of the most ancient oil seed crop used by mankind. Sesame is considered to have both nutritional and medicinal values. The anti-photo-oxidant activity of sesamol for oil has been reported due to the scavenging of single singlet oxygen. Sesame seed contains two lignans, sesamin and sesamolin. After roasting sesame seeds, sesamolin is converted to sesamol. Sesamol has been found to have anti-oxidative effects and to induce growth arrest and apoptosis in cancer cells. Sesamol has a phenolic and a benzodioxide group in its molecular structure. The phenolic groups of molecules are generally responsible for the anti-oxidant activity of many natural products. benzodioxide derivatives are widely distributed in nature and have been shown to possess anti- tumor, anti-oxidant and many other biological activities. Integrated nutrient management aims at efficient and judicious use of all sources of plant nutrients to attain sustainable crop production with minimum deleterious effect on the soil health and least disturbance to plant soil environment

Field experiments were conducted during kharif 2014 and 2015 under rainfed conditions in sandy loam soil at Regional Research Station (Punjab Agricultural University), Ballowal Saunkhri, Punjab to study the effect of integrated nutrient management on growth and yield of sesame crop under rainfed conditions in sub montane region of Punjab. The experiment was laid out in randomized block design with 6 treatments *viz,* Control, 35:0:0 (N basal dose), 35:0:0(basal dose)+10 ton FYM $ha^{-1}$, 70:0:0 (2 N splits), 70:40:0 (2 N splits), 70:40:15 (2 N splits). Among the different treatments, application of NPK as 70:40:0 with nitrogen in two splits recorded the maximum values for growth parameters viz., plant height, number of branches per plant and yield attributes *viz*., number of capsules plant per plant and maximum number of seeds capsule per capsule and this treatment was at par with application of NPK as 70:0:0 treatment and 35:0:0+10 t $ha^{-1}$ treatment. Highest average seed yield of 852 kg $ha^{-1}$ was recorded with treatment 70:40:0 with nitrogen in two splits which was 44% per cent higher over the control treatment. The nitrogen, phosphorus and potassium uptake was also highest in the treatment NPK 70:40:0 followed by 70:0:0 and 35:0:0+10 t $ha^{-1}$ FYM, which was significantly higher over the control treatment. The net return and B:C ratio was also highest in the treatment 70:40:0 as compared to the other treatment.

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# Impact of Integrated Nutrient Management on Yield of Maize in Haplustepts through Front Line Demonstration

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Maize (*Zea mays* L.) is the third most widely distributed crop of the world and major crop of Chittorgarh district of Rajasthan. It is the basic important stable food of the mass consumption of Mewar area of Rajasthan The present study was carried out by soil scientist of Krishi Vigyan Kendra, Chittorgarh during *kharif* season from 2013-2014 and 2014-2015 in two adopted villages *viz.*, Tie and Laxmipura of two tehsils of district Chittorgarh. During these two years of study, an area of 06 ha were covered with plot size 0.2 ha under integrated nutrient management front line demonstrations with active participation of 30 farmer's in different two villages were conducted. Farmer's meeting, survey and field diagnostic visits each was targeted under taken during the cropping season. To manage the low yield problem, recommended package of practices of agro climatic zone IV a (Sub Humid Southern Plains) of Rajasthan were followed in integrated nutrient management front line demonstration programs. The recommended fertilizers, RDF (@100 kg $N_2$+30 kg $P_2O_5$+30 kg $K_2O$ $ha^{-1}$) package of practices involving use of ½ N, full dose of $P_2O_5$ and $K_2O$ as basal and remaining dose of nitrogen in two splits (at 30 and 60 DOS) were taken as intervention to manage the nutrient problem. Existing farmer's practices as control were taken for the comparison. Maize yield of demonstrated plot recorded 22.99 to 23.18% higher over farmers practice. On an average, technology gap was found 6.24 q $ha^{-1}$. Average extension gap and technology index were recorded 9.13 q $ha^{-1}$ and 12.58%, respectively. The yield gap analysis emphasizes on the need to educate the farmers through various extension programs for adoption of integrated nutrient management measures to revert the trend of wide extension gap.

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# Effect of Boron Application on Yield and Boron Content in Soybean-Wheat Cropping Sequance in a Vertisol

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Field experiment was conducted at JNKVV, Jabalpur during 2014-15 to evaluate the response of third cycle of soybean-wheat cropping system to boron (B) application in terms of productivity, B content in plant and soil. The experiment was laid out in split-plot design with three main treatments of periodicity (single, alternate and each year B application) and five sub-treatments of boron levels (0, 0.5, 1.0, 1.5 and 2.0 kg $ha^{-1}$) having four replications. The soil of the experimental field was clayey with pH 7.5, EC 0.20 dS $m^{-1}$, organic carbon 4.92 g $kg^{-1}$ and available B 0.47 mg $kg^{-1}$. The recommended doses of N, $P_2O_5$ and $K_2O$ $ha^{-1}$ were applied in soybean (20, 80 and 20 kg $ha^{-1}$) and wheat (120, 60, 40 kg $ha^{-1}$) as per recommended practice. Boron was applied through Borax in soybean crop and the treatments effect was studied in soybean and also the residual effect in succeeding wheat crop.

The results indicated that maximum yield of seed and stover yield (1.86 and 4.72 t $ha^{-1}$) recorded in alternate year B application which was significantly superior to single year and at par to each year B application treatment. It was also evident that application of 1.0, 1.5 and 2.0 kg B $ha^{-1}$ gave significantly higher seed yield over control and seed yield (1.80 t $ha^{-1}$) was obtained with the application of 1.5 kg B $ha^{-1}$. The B content in seed and stover progressively and significantly increased with the increasing levels of B over control and these levels were statistically different among themselves. Application of boron exerted significant positive influence on hot water extractable B in post-harvest soil samples.

The residual effect of the treatments on wheat crop showed that phasing effect of B on grain and straw yield of wheat was found non-significant. Maximum grain (4.40 t $ha^{-1}$) and straw (6.21 t $ha^{-1}$) yield was found under 1.0 kg B $ha^{-1}$ thereafter it was reduced with the application of higher levels. B content in grain and straw was found significantly higher under each year B application over single year but at par with alternate year. The increasing levels of B application significantly increased the B content in grain and straw over control. Maximum B content in grain (15.43 mg $kg^{-1}$) and straw (11.46 mg $kg^{-1}$) was obtained with 2.0 kg B $ha^{-1}$. From the present study alternate year application of 1.5 kg B $ha^{-1}$ in soybean-wheat system under a Vertisol was found more sustainable.

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# Performance of Basmati Rice as Influenced by Cropping Systems and N Levels

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India has established a monopoly in exporting Basmati rice, which fetches a price two to three times higher than that of regular rice. The cropping sequence Basmati rice-wheat is common but another crop of bajra as a fodder and summer moong can successfully be grown after wheat. To achieve high yield and to improve quality, N is a major factor considered in all types of environment. Low N may not lead to realization of maximum yield potential, and high N may lead to lodging, increased incidence of insect pest attack, and lower quality. Field studies were conducted at the PAU research farm to establish the optimum N requirement of Basmati rice(Punjab basmati-3) in different cropping sequences. The experiment, laid out in a split-plot design, studied three cropping systems (fallow-Basmati rice-wheat, summer moong-Basmati rice-wheat, and bajra(f)-Basmati rice-wheat [main plots] and four N levels (0, 20, 40, and 60 kg $ha^{-1}$) as subplots. The results revealed that the maximum mean seed yield of basmati was obtained in summer moong-Basmati rice-wheat cropping system and minimum was obtained under bajra(f)-Basmati rice-wheat. Significant response to applied N to basmati rice was obtained upto 20 kg N $ha^{-1}$ in the summer moong-basmati-wheat cropping system but upto 40 kg N $ha^{-1}$ was observed in the other two cropping systems. A significant increase in the organic carbon content was observed in the summer moong-basmati rice-wheat cropping system but a significant decrease in available K was observed in the bajra(f)-Basmati rice-wheat cropping system.

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# Integrated Phosphorus Management through STCR Approach for rice in Inceptisol of Puducherry

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The soil test crop response based on fertilizer prescriptions under integrated plant nutrient system (STCR-IPNS) for rice crop provide a scientific yield levels of crops taking into account the contribution of NPK from soil, fertilizer and organics. Being a site and situation specific technology, STCR-IPNS along with entire improved package of practices for rice ensures balanced nutrition, increased productivity and efficiency of applied phosphorus with sustained soil health over long run. The gradient crop (rice var.Kulla Ponni) and the test crop (rice var. White Ponni) experiments were conducted at farmer's field in Karikalampakkam village, U.T. of Puducherry, during 2015. The soil of the experimental field belongs to Bahour series, taxonomically Typic Ustropept; sandy clay loam in texture, pH 8.40, EC 0.778 dS $m^{-1}$, CEC 32.5 cmol($p^+$)$kg^{-1}$, $KMnO_4$-N 170.8 kg $ha^{-1}$, Olsen-P 65.4 kg $ha^{-1}$ and $NH_4OAc$-K 236 kg $ha^{-1}$. The treatments consisted of four levels of N (0, 50, 100, 150 kg $ha^{-1}$), four levels of $P_2O_5$ (0, 25, 50, 75 kg $ha^{-1}$), and four levels of $K_2O$ (0, 25, 50, 75 kg $ha^{-1}$) and three levels of farmyard manure (0, 6.25 and 12.5 t $ha^{-1}$). Each strip was divided into 24 sub-plots and pre sowing soil samples were collected from each sub plots. At maturity, the grain and straw yields were recorded plot wise. Plant and grain samples were collected and analyzed for their P content and uptake values were computed. Making use of the data on pre sowing soil test values, yields and uptake of $P_2O_5$ by rice and the levels of fertilizers nutrients and FYM, fertilizers prescription equation for $P_2O_5$ was developed and given below.

F $P_2O_5$ = 1.45 T – 0.69 SP – 1.54 OP

In the present investigation, the beneficial effect of combined use of NPK fertilizers with FYM was studied at two different levels of FYM *viz*; 6.25 and 12.5 t $ha^{-1}$. Nomograms was developed for desired yield target of rice for a range of soil test values under NPK alone, NPK plus 6.25 t $ha^{-1}$ FYM and NPK plus 12.5 t $ha^{-1}$ of FYM. The perusal of estimate showed that when NPK alone was applied for a soil test value of 20 kg $ha^{-1}$ of Olsen-P, the doses of fertilizers $P_2O_5$ required for 60 and 70 q $ha^{-1}$ were 73 and 88 kg $ha^{-1}$ respectively, while the doses were 59 and 73 kg $ha^{-1}$, respectively for the combined addition of NPK plus FYM @ 6.25 t $ha^{-1}$ recording 19.2 and 17.0 percent reduction of fertilizer $P_2O_5$ doses over NPK alone. When NPK is applied with FYM @ 12.5 t $ha^{-1}$ the doses were 44 and 54 kg $P_2O_5$ $ha^{-1}$ with a per cent reduction of 39.7 and 32.9 respectively over NPK alone. The percent contribution, were 12.13, 40.16 and 26.98 of $P_2O_5$ from soil, fertilizers and FYM respectively. Using the fertilizer prescription equation under IPNS, the extent of saving of inorganic P fertilizer with the application of FYM @ 6.25 t $ha^{-1}$ with 28 per cent moisture and 0.32 per cent of $P_2O_5$ was 14 kg $ha^{-1}$. If FYM @ 12.5 t $ha^{-1}$ was applied with same nutrient content the saving was 29 kg $ha^{-1}$.

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# STCR- An Innovative Technology for Optimizing Nitrogen Fertilizer in Rice Crop (White Ponni)

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Intensive agriculture and escalating prices of industrial N fertilizers demand integrated use of organic manure and chemical fertilizer for maintaining soil health, resulting in sustained crop production. In addition use of recommended N management practices with FYM addition has shown the increased efficiency of applied N, which in turn could be related to the higher yield and soil N supply. In order to reduce the fertilizer dose and also to monitor the fertility, the field experiment was conducted at farmer's holding of Karikalampakkam village in Nettapakkam commune of Puducherry district, U.T. of Puducherry during 2014 – 15 by using STCR approach. The soil of the experimental field belongs to Bahour series, taxonomically Typic Ustropept; sandy clay loam in texture, pH 8.40, EC 0.778 dS $m^{-1}$, CEC 32.5 cmol($p^+$)$kg^{-1}$, $KMnO_4$-N 170.8 kg $ha^{-1}$, Olsen-P 65.4 kg $ha^{-1}$ and $NH_4OAc$-K 236 kg $ha^{-1}$. The treatments consisted of four levels of N (0, 50, 100, 150 kg $ha^{-1}$), four levels of $P_2O_5$ (0, 25, 50, 75 kg $ha^{-1}$), and four levels of $K_2O$ (0, 25, 50, 75 kg $ha^{-1}$) and three levels of farm yard manure (0, 6.25 and 12.5 t $ha^{-1}$). Soil test data, rice grain yield and NPK uptake by rice crop were used for obtaining four important basic parameters viz., nutrient requirement to produce one quintal of rice grain (NR), contribution of nutrients form fertilizers (Cf), contribution of nutrients from soil (Cs) and contribution of nutrients from organic matter (Cfym). Making use of these basic parameters the fertilizer prescription equation was developed for N in rice and is given below.

FN = 3.13 T - 0.42 SN - 0.51 ON

The nomogram were formulated for desired yield target of rice for a range of soil test values under NPK alone, NPK plus 6.25 t $ha^{-1}$ and NPK plus 12.5 t $ha^{-1}$. The perusal of the estimate showed that when NPK alone was applied for a soil test value of 200 kg $ha^{-1}$ of nitrogen, the doses of fertilizer N required for desired yield target of 6 and 7 t $ha^{-1}$ were 104 and 136 kg $ha^{-1}$, respectively. While the doses were 81 and 112 kg $ha^{-1}$, respectively for combined addition of NPK plus FYM applied @ 6.25 t $ha^{-1}$ recording 22.1 and 17.6 per cent reduction of fertilizer N doses over NPK alone. When NPK applies with FYM @12.5 t $ha^{-1}$ the doses were 58 and 89 kg $ha^{-1}$ with a per cent reduction of 44.2 and 34.6, respectively over NPK alone. Using the fertilizer prescription equation under IPNS, the extent of saving of inorganic N fertilizer with the application of FYM @ 6.25 t $ha^{-1}$ with 28 per cent moisture and 0.52 per cent N was 23 kg $ha^{-1}$. If FYM @ 12.5 t $ha^{-1}$ was applied with same nutrient content the saving was 47 kg $ha^{-1}$.

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# Available Nutrient Status in Soils of Gwalior District

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Gwalior district is situated in the gird agro climatic zones of Madhya Pradesh. The soils of the district are under the broad group of alluvial soils and medium black soils in patches. The farmers of districts grown pearlmillet/sesame/greengram/blackgram/paddy in kharif and mustard/chickpea/wheat in rabi season.

Soil fertility is one of the important factors controlling yield of the crops. Macronutrients (N, P and K) and micronutrients (Zn, Cu, Fe and Mn) are important soil elements that control its fertility. Soil characterization in relation to evaluation of fertility status of the soil of an area or region is an important aspect in context of sustainable agriculture production. Because of imbalanced and inadequate fertilizers use and coupled with low efficiency of other inputs, the response (production) efficiency of chemical fertilizers nutrients declined tremendously under intensive cultivation in recent years. Variation in nutrients supply is a natural phenomenon and some of them may be sufficient where others deficient. Keeping this view, one hundred fifty (150) GPS based soil samples were collected from different cultivator's fields of Gwalior district during 2015.

The soil of Gwalior district was normal in reaction and soluble salts. Surface soil samples were non calcareous with low organic carbon content. Available N, P, K and S varied from 161.5-256.8, 8.25-33.54, 162.4-442.4 and 11.28-48.30 kg ha $^{1}$ with the mean value of 213.1, 18.5, 242.0 and 21.16 kg ka$^{-1}$, respectively. Available Zn, Cu, Fe and Mn were observed in the range of 0.24-2.51, 0.22 to 4.55, 2.46-29.36 and 1.65-10.25 mg kg$^{-1}$ with the mean value of 0.80, 1.28, 9.20 and 6.40 mg kg$^{-1}$, respectively.

Regarding soil nutrient index, the mustard growing soils of Gwalior district were found in category of low fertility status for nitrogen and medium with respect to phosphorus, potassium and sulphur. The value of nutrient index for NPKS were 1.26,1.75, 1.92 and 1.58, respectively, against the values <1.50 for low, 1.50-2.50 for medium and >2.50 for high fertility status. Under different micronutrient cations, available zinc and iron were deficient to 47 and 18 per cent, whereas available Cu and Mn were sufficient.

The correlation study revealed that organic carbon had greater impact on availability of nutrients. It suggested that organic matter was main contributing factor affecting the nutrient availability in soil. Deficiency of available nutrients increased with an increase in pH and calcium carbonate content whereas it decreased with an increase in organic carbon content in soils of Gwalior district of northern Madhya Pradesh.

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# Mineral Composition of Tropical Fruits and Vegetables: A Comparative Study for Bio-nutritional Source

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The mineral composition of some selected cultivars of tropical major and minor fruits, and vegetable were investigated and evaluated for their nutritive value as bio-nutritional source. Tropical major fruits such as mango, banana, guava, papaya, sapota, pomegranate etc are domesticated popularly throughout India while minor fruits as karonda, avocado, jamun, rambutan, pomelo are grown as wild fruit species and consumes in south eastern hilly regions of India. Information on nutritional value of many of these fruit species is scanty and these fruits have been shown to possess valuable antioxidants of great nutritional and therapeutic values. Among the minor fruits, high concentration of sugar was noted in rambutan (Nephelium lappaceum) and ascorbic acid in pomelo (*Citrus maxima*). Potassium content in rambutan and avocado was found similar to major fruits *viz.* guava (1.45%, in inner pulp). Pomegranate (1.70% in aril), sapota (1.18% in pulp). Fresh pulp of jamun (*Syzygium cumini*) was found to be rich in carbohydrate (13.51%) and protein (3.14%) and remarkably higher contents of calcium and iron was observed in seed of Jamun which serves as best fruit bio-nutritional source. Maximum proportion of micronutrients especially iron and zinc content was seen in septum and agril portion of pomegranate. Banana and guava showed significant level of potassium and calcium content in pulp portion of the fruit. Among vegetable, capsicum (*Capsicum annum*) contained considerably higher contents of potassium and calcium and micronutrients and thus can be identified as promising vegetable for bio-nutritional source.

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# Effect of Single Super Phosphate on Soil Properties and Forage Yield of Cowpea (*Vigna unguiculata* (L.) Walp.) Entries

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The field experiment was conducted at GPB Farm of Narendra Nagar, Kumarganj, Faizabad (U.P.) during *Kharif* season of 2015 to evaluate the effect of single super phasphate (SSP) doses on soil properties and forage yield of cowpea (*Vigna unguiculata* L.) entries. Twelve treatments comprised of three SSP doses-F1: 190 kg SSP $ha^{-1}$ , $F_2$ : 375 kg SSP $ha^{-1}$ and $F_3$: 560 kg SSP $ha^{-1}$ and four entries-$E_1$: TNFC-0926, $E_2$: Bundel lobia-1, $E_3$: UPC-5286 and $E_4$: 622 were replicated thrice in randomized block design (factorial). The experimental soil having pH (1:2.5) 8.62, EC dS $m^{-1}$ 0.39, organic carbon 2.9 g $kg^{-1}$, B.D. 1.45 Mg $m^{-3}$. Available N 166.73, P 13.20, K 207.55 and S 12.73 kg $ha^{-1}$. The maximum growth yield, yield attributes and yield (green forage yield 175.91 and dry matter yield 27.27 q $ha^{-1}$) were recorded with application of $F_3$ : 560 kg SSP $ha^{-1}$ which was significantly superior over $F_1$ and statistically at par with $F_2$ among the entries maximum growth, yield attributes and yield (green forage yield 170 q $ha^{-1}$ and dry matter yield 22.67 q $ha^{-1}$) were recorded with $F_3$: UPC-5286 entry which was significantly superior over $E_1$ and $E_2$ and statistically at par with $E_4$. Same trend were also recorded in nutrients content, uptake and quality of forage crop of cowpea. The maximum gross income was calculated with $E_3F_3$: 28065 and net income with $E_3F_2$: 13289. However, highest benefit cost ratio (0.84) was obtained with treatment combinations $E_3F_2$: UPC-5286+375kg SSP $ha^{-1}$. Thus the recommendation of $F_2$ (375 kg SSP $ha^{-1}$) and $E_3$ (UPC-5286) be made to the farmers of eastern (U.P.) for successful cultivation of forage crop cowpea in *kharif* season.

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# Fertilizer Adjustment Equations Develop under Soil Test-based Targeted Yield of Chandrasur in a Medium Black Soil of Madhya Pradesh

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The field experiment was conducted to develop fertilizer adjustment equations for chandrasur crop during rabi season of 2008-09 to 2010-11 at the Soil Science Experimental Research farm, JNKVV, Jabalpur on medium black soil under soil rest crop response approach. The experimental soil was netural in soil reaction, normal in electrical conductivity, low in available nitrogen and medium in phosphorus and potassium. Soil fertility gradients of $L_{½}$, $L_1$ and $L_2$ were created by applying graded doses of N, $P_2O_5$ and $K_2O$; jowar was grown as an exhaustive crop during *kharif* for stabilizing fertility gradient. During *rabi*, each strip was divided into 3 blocks, each block were further divided into 10 plots of 5 m x 2 m size. Three blocks in each strip were allotted to 3 levels of FYM *viz.*, F0,F1 and F2 corresponding 1o 0.5 and 10t FYM $ha^{-1}$, respectively. A set of 30 treatment combinations were plotted out of which 24 treatments in combination with four levels of each nitrogen (0.25, 50 and 75 kg $ha^{-1}$), phosphorus (0.25, 50 and 75 kg $ha^{-1}$) and potash (0.15, 30 and 45 kg $ha^{-1}$) were applied with 6 controls. The data of available nutrients of soil, grain yield and NPK uptake by chandrasur were used for obtaining basic parameters viz., nutrients require to produce 1 q of chandrasur grain (NR), contribution of nutrients from soil (% CS), contribution of nutrients from fertilizers (% CF) and contribution of nutrients from FYM (% CFYM) for development fertilizer adjustment equations (FAEs) for attaining different yield targets of chandrasur. The average response ratios due to application of nitrogen, phosphorus and potash were 5.83, 5.80 and 6.35 kg per kg of nutrient applied under varying FYM LEVELS, RESPECTIVELY. The nutrient requirements of 4.31, 1.64 and 6.77 kg N, $P_2O_5$ and for $K_2O$ were required for producing one quintal of grain yield of chandrasur. The per cent contributions of nutrients from soil, fertilizers and FYM were 14.60, 39.26 and 8.76 for N: 56.86, 13.34 and 3.72 for $P_2O_5$ and 17.33, 36.62 and 9.22 for $K_2O$, respectively. By using these basic parameters, ready reckoner of fertilizer doses for varying soil test values and desired yield targets of chandrasur for NPK alone and NPK with FYM were formulated.

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# Interactive Effect of Zinc and Boron Application on the Yield, Quality and Their Uptake by Green Gram (*Vigna radiate* L.)

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Green gram is an important *kharif* pulse crop grown extensively in very poor productivity low in available Zn and B. In view of the lack of information on response of crops to added Zn and B. Green house experiment was conducted to investigate the impact of Zn and B application on yield and their enrichment in seed and straw of green gram, at CCS HAU, Hisar, during the year 2013. In pot experiment 4 kg light texture (sand) soil was filled up and 4 level of both Zn (0,5,10 and 15 mg $kg^{-1}$ ) and B (0, 0.25,0.5 and 1.0 mg $kg^{-1}$) were applied and replicated thrice the soil used in pot had pH 7.90, EC 0.17 dS $m^{-1}$, organic carbon 0.09%, DTPA-Zn 0.36 mg $kg^{-1}$ and hot water soluble B 0.5 mg $kg^{-1}$. Eight seeds of green grain was seeded in each pot and after thinning four plants were allowed to grow upto maturity. The result revealed that combined application of Zn and B have significant antagonistic effect on yield of seed and straw as well as their B and Zn concentration of green gram. Whereas, individual application of boron response positively for boron concentration whereas Zn application decreases the B concentration but increased zinc concentration in seed and straw of green gram. Highest seed yield and B and Zn concentration in seed and straw of green gram. Highest seed yield and B and Zn concentration was found at $Zn_{15}B_0$,$Zn_{0,}B_{1.0}$,and $Zn_{15}$,$B_0$ mg $kg^{-1}$, respectively. Zinc and B application also significantly improve seed protein content and highest protein content was found with the application 15 mg $kg^{-1}$ along with 0.5 mg B $kg^{-1}$. The uptake of B and Zn decreases significantly due to their antagonistic interaction where extermally applied zinc as well as B increased their uptake.

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# Yield and Chemical Composition of Black Gram as Influenced by Levels and Sources of Phosphorus

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Phosphorus is a key nutrient for increasing productivity of pulses and the most important single factor responsible for poor productivity of pulses. The adequate supply of phosphorus to legume is more important than that of nitrogen. Because it has been beneficial effect on root development, nodulation, growth and yield. It plays an important role in energy transfer reactions and in oxidation-reduction processes. Phosphorus application increase cell division, as a result of which growth is increased in legumes. Today diammonium phosphorus (DAP) is the most widely used phosphate fertilizer among growers. DAP itself is alkaline with a high pH, exceeding 7.5. Single supper phosphate (SSP) is a straight fertilizer and contains 16% $P_1O_5$ and 12% S and may prove a better source of P under the conditions where pH is rising due to some reasons. Keeping in view the presents experiment was conducted for suitability and efficiency of P in black gram on alluvial soil.

The results revealed that seed yield significantly affected by different P sources and increased with the increasing level of P. The maximum seed yield (677.6 kg $ha^{-1}$) recorded with 60 kg $P_2O_5$ $ha^{-1}$ through SSP along with $N_{30}$ $K_{30}$. The increasing levels of $P_2O_5$ from 20 to 60 kg $ha^{-1}$ applied either DAP or SSP recorded significantly higher content and nutrient uptake of NPK and S as compared to without P applied treatment or control. Application of 60 kg $P_2O_5$ $ha^{-1}$ recorded highest content and uptake of NPK and S. Application of 60 kg $P_2O_5$ $ha^{-1}$ had higher net returns and B.C. ratio as compared to 30 kg $P_2O_5$ $ha^{-1}$. SSP applied treatments gave more net return and B.C. ratio as compared to same doses applied by DAP. Residual available N and P in soil was significantly increased to same doses applied by DAP. Residual available N and P in soil was significantly increased due to higher levels of P. Declining trend in available K over initial was observed in control and SSP applied treatments showed significantly higher S status in soil as compared to DAP applied treatments at the same doses of P.

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# Effect of Long-term Use of Fertilizer and Organic Amendments on Soil Properties under Rice-Wheat Cropping System

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The sustainability of the rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) rotation is important to Asia's food security. A long-term fertilizer experiment under rice-wheat crop rotation is in progress on Typic Haplustept soil at research farm, Department of Soil Science, Punjab Agricultural University, Ludhiana, since 1999. The site is located in the IndoGangetic alluvial tract at 3056'N7552'E and at an attitude of 274 m above mean sea level. The effects of fertilizer, manure and crop residue was studied through nine treatments comprises as $T_1$:100% N, $T_2$100% NP, $T_3$100% NPK, $T_4$:100% NPK (P to wheat only) $T_5$:150% NPK, $T_6$:100% NPK+farmyard manure (FYM), T7:100% NPK+green manure (*Sesbania aculeata*), $T_8$:100% NPK+straw incorporation and $T_9$: control. The soil samples were collected from various depths (0.15, 15-30, 30.45, 45-60 and 60.90 cm) after the harvesting of wheat during 2012-2013. The results indicated that the soil pH increased with increase in soil depth, irrespective to fertilizer treatments. However, the EC increased with the application of inorganic fertilizer as compared to control. There was decrease in EC of subsurface soil, irrespective to treatments. The application of integrated fertilizers recorded significantly higher soil organic carbon (SOC) than inorganic treatments. The available N decreased with increase in soil depth irrespective to fertilizer treatments. The were significant build-up in Olsen-P with P application. The application of inorganic and integrated fertilizers significantly improved available K content compared to control. The highest grain yield was obtained in T6 and it was significantly higher than all other treatments. Similarly maximum straw yield was recorded under $T_6$ treatment. The application of integrated fertilizers resulted in significantly highest N uptake as compared to inorganic fertilizer and control. The total P uptake ranged from 10.0 kg $ha^{-1}$ in control to 31.2 kg $ha^{-1}$ in T6. The total K uptake in rice ranged from 116.5 kg $ha^{-1}$ in control to 232.6 kg $ha^{-1}$ in $T_7$ treatment. The N,P and K uptake increased with the application of inorganic fertilizers along with organic manures. The grain yield of wheat increased significantly with P application of N from 1.6 t $ha^{-1}$ in control to 3.5 t $ha^{-1}$ in $T_1$ and further increased significantly with P application to 4.3 t $ha^{-1}$ in $T_2$. The residual effect of FYM application was found to be significant in wheat. The application of P increased the grain yield and P uptake by both rice-wheat crops.

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# Evaluation of Response of Applied-P to Soybean Grown in Vertisols and Influence of Rhizosphere on its Availability

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To carry out the investigation in-situ and ex-situ experiments were conducted in Vertisols. The on-station experiment was conducted during *kharif* season of 2015 at AICRP on Cropping System, College of Agriculture, Indore. The area has almost uniform topography with light to medium black Vertisols, formed from basaltic parent material. In the study an attempt has been made to evaluate the most suitable method for P availability in calcareous Vertisols for soybean crop considering the pH of rhizosphere. On the basis of studies carried out following conclusions of P management has been derived for soybean grown in Vertisols. Seed yield and dry matter yield of soybean was not affected significantly by different levels of applied P. The growth and yield attributes were not influenced significantly by the different applied P levels to soybean grown in calcareous Vertisols. From the study it is evident that both the P content and uptake of P was not significantly increased due to application of different levels P ranging from 0-180 kgha$^{-1}$. Application of two P doses in these soils did not give the significant increase in the dry matter yield of soybean. On the basis of 76 soil samples analysed the mean value of available-P by Olsen method was 19.69 kg ha$^{-1}$ while, in case of Bray-II method the average available –P was 154.26 kg ha$^{-1}$. The minimum and maximum values of available-P by Olsen and Bray-II method were 1.6, 65.2 and 15.7, 600.6 kg ha$^{-1}$, respectively. In case of Bray-II method the acid extractent extracted more P compared to Olsen. This means Vertisols have ability to supply P more than evaluated by Olsen. Rhizosphere of soybean crop plays a pivotal role in solubilizing the native P mainly Ca-P. The rhizosphere of soybean showed acidic pH (5.5 – 6.5). The most of the leguminous crops show acidic pH of the rhizosphere which plays a major role in enhancing P availability to crop. Our study emphasized that for P recommendations consideration of role of rhizophere is crucial and may help in reducing the application rates of P to leguminous crop specifically soybean. The on-station and on-farm studie reveled that there is a no response of P application in Vertisols to soybean crop. This is mainly due to root system pH which enhances P availability for soybean. The understanding of soybean rhizosphere and biogeochemical process associated with P uptake emphasized reduced application of P fertilizer to soybean up to 50%. of RDF when, grown in Vertisols.

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# Effect of Conservation Tillage Practices on Soil Properties under Jute Based Cropping Systems

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Field experiment conducted with conservation tillage (without tillage), conservation tillage with residue along with conventional tillage (control) under the most predominant cropping systems jute-rice-wheat/lentil/potato systems to study the effect of tillage and residue management on soil physicochemical properties and crop productivity. The initial soil sample characterized as sandy loam in texture, pH 7.83, medium in organic carbon content (0.59%), medium to high in available N content (296.8 kg $ha^{-1}$) and low in available P (25.1 kg $ha^{-1}$) and K (12.3 kg $ha^{-1}$) content. Results showed a gradual increase in SOC content under conservation agricultural practices maximum (0.80 and 0.77%, respectively) being in the soil samples collected after the harvest of rice crop as compared to conventional system. Soil organic carbon (SOC) content in conservation practices showed an increasing trend throughout the crop season whereas it is just reverse in case of conventional tillage practices wherein the SOC content gradually decreased from its initial value (0.59%). Significant difference in SOC among the tillage treatments may be ascribed due to crop residue management facilitating greater earthworm population and microbial activity under conservation tillage. However, the crop yield in conventional tillage practice was 15-18% higher against conservation tillage practice which is common during initial years of conservation tillage experiments.

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# Role of Cover Crops and their Time of Chopping on the Microclimatic and Root Structure of Baby Corn (*Zea mays* L.)

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Cover crops are often known to improve soil organic matter, reduce soil water evaporation and help to improve soil temperature variation. A field investigation on the role of cover crops and their time of chopping on the microclimatic properties and root structure of no-till baby corn (*Zea mays* L.) was conducted during *kharif* 2014 at research farm, Punjab Agricultural University, Ludhiana. The experiment was laid in a split plot design with four replications and nine treatments having three cover crops *i.e.* bajra, maize, sorghum and three different time of chopping of cover crops *i.e.* 25, 35, 45 days after sowing. The maximum baby corn and green fodder yields were recorded in treatment of bajra chopping 45 days after sowing. Differences in light interception after three cover crops were not found significant at 30 or 60 days after sowing. Photosynthetically active radiation interception (PARI) at 30 days after sowing of baby corn was equal in chopping of cover crops after 35 and 45 days. Higher value of PARI may be due to higher leaf area index of baby corn in different treatments. Soil temperature was not significantly affected at 30 and 60 days after sowing of baby corn in various cover crop treatments. However, soil temperature 30 days after sowing of baby corn was significantly affected by number of days to chopping of cover crop and it was lower for chopping after 45 days as compared to chopping after 25 and 35 days. This may be due to fact that 45 days of cover crops had more biomass which acts as mulch which have shown to decrease soil temperatures in summer months.

Cover crop biomass protects soil from incoming soil radiations which helps in retain soil moisture resulted in decrease soil temperature. The effect of various cover crops on root density of baby corn at different soil depths was insignificant, although root density decreased with the soil depth of soil profile. Time of chopping of cover crops had significant effect on root density and it was higher in 0-15 cm depth followed by 15-30 cm after chopping of 45 days cover crops. This was due to better moisture availability in upper layers of soil profile under heavy biomass, which reduces loss of water through evaporation resulted in higher root density. It can be concluded that cover crops provide opportunities to improve soil properties and microclimatic observations of subsequent crops.

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# Phytoremediation of Cadmium Contaminated Soil Using *Brassica Species*

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A screenhouse experiment was conducted on sandy loam soil having DTPA extractable cadmium (Cd) 0.086 mg $kg^{-1}$ to assess the effect of six levels of Cd (0, 5, 10, 20, 40 and 80 mg $kg^{-1}$) and three levels of EDTA (0, 1 and 2 g $kg^{-1}$) in a factorial randomized design on the growth of three *Brassica* species (*Brassica juncea, Brassica compestris and Brassica napus*). Five kg of this processed soil was taken in each pot, lined inside by polythene sheet to avoid contamination from the surface of the wall of pots. The required amounts of Cd and EDTA were applied as cadmium chloride and sodium ethylene diamine tetra acetic acid at the above rates in solution form. Each treatment was replicated four times. The pots were then kept for one month to attain equilibrium for Cd. The recommended doses of N, $P_2O_5$ and $K_2O$ were applied to three species. The crops were sown at field capacity moisture level. Twelve seeds of each of *Brassica* species were sown. After germination, the seedlings were thinned to six plants per pot. The pots were irrigated with water as and when required. The crops were harvested at grand growth stage. Dry weight of shoot of all the three crop species were noted and plant samples of shoot were analyzed for total Cd.

The mean Cd uptake in the shoot of all the crop species increased significantly with the increase in the level of Cd irrespective of EDTA application. The mean Cd uptake increased in the shoot of *Brassica juncea* by 21.4, 207.13, 427, 592, 608.5 and 611.8 mg $pot^{-1}$ with Cd application @ 0, 5, 10, 20, 40 and 80 mg $kg^{-1}$, respectively. Whereas, in case of *Brassica compestris*, mean Cd uptake increased by 31.4, 196, 344, 509, 479 and 479.56 mg $pot^{-1}$ with Cd application @ 0, 5, 10, 20, 40 and 80 mg $kg^{-1}$, respectively. Whereas in *Brassica napus* mean Cd uptake increased by 30, 177, 307, 447, 492 and 543 with Cd application @ 0, 5, 10, 20, 40 and 80 mg $kg^{-1}$, respectively. It shows that Cd was readily absorbed and translocated from root to above ground parts of the plant. Uptake was more in case of *Brassica juncea*, followed by *Brassica napus* and *Brassica compestris*. This was due to high dry weight in case of *Brassica juncea* followed by *Brassica napus* and *Brassica compestris*. The uptake of Cd by shoot followed the order *Brassica juncea* > *Brassica napus* > *Brassica compestris* at all rates of applied Cd. The increase in mean uptake of Cd in roots of *Brassica juncea* was about 8.43, 61.5, 122.7, 156.8, 144.5 and 188.7 mg $pot^{-1}$ at 5, 10, 20, 40 and 80 mg Cd $kg^{-1}$ soil application, respectively. However, the magnitude of increase in Cd uptake varied with crops species. Among the crop species, minimum uptake of Cd was recorded in the roots of *Brassica compestris* whereas maximum uptake of Cd was observed in *Brassica juncea.* It is concluded that though the higher levels of Cd in soils adversely affected the growth of the three *Brassica* species. The Cd concentration and Cd uptake in all three plant species were calculated and it was found that the amount of the metal accumulated in the shoots of *Brassica juncea* was higher on the basis of per unit biomass than that in *Brassica napus* and *Brassica compestris*. *Brassica juncea* showed the maximum tolerance and therefore, *Brassica juncea* holds potential towards detoxification of the Cd-contaminated soils and also an option to avoid the entry of heavy metals in food chain.

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# *In-situ* Evaluation of Underground Poor Quality Water Purifier cum Descaler for Irrigation to Field Crops in Light Textured Soil of S-W Punjab

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The dependence on the use of underground saline and/or sodic water seems inevitable due to ever shrinking good quality canal irrigation water supplies. The present study was conducted during 2010-16 on loamy sand soil at PAU Regional Research Station, Bathinda with an aim to test the performance of water purifier to change the underground poor quality water to reasonably good quality water for irrigation in cotton-wheat/*raya* cropping sequence in south-western zone of Punjab. The experiment comprised of four treatments *viz*. canal water (CW), raw tube well water (TW), purified tube well water (PTW) and alternate TW/PTW irrigations with four replications in randomized block design. The residual sodium carbonate (RSC) and electrical conductivity (EC) of the raw tubewell water and canal water used was 6.4 and 0.5 meq $L^{-1}$; and 2200 and 450 μmhos $cm^{-1}$, respectively. In water purifier treatment, the brackish water is passed through a pipe fitted with poor quality tubewell water delivery pipe. The water quality parameters (EC and RSC ) after passing the poor quality (saline-sodic) water through water purifier cum descaler and raw poor quality tubewell showed no variation or improvement in quality. The pooled mean of research data revealed that in cotton, application of poor quality TW, PTW and PTW/TW (alternately) irrigation produced statistically at par seed cotton yield which was significantly lower than CW alone. In wheat and *raya*, different qualities of irrigation water had non-significant effect on grain yield. Irrigation with saline-sodic TW, PTW and TW/PTW exerted similar influence on pH, EC, sodium adsorption ratio (SAR) and organic carbon content of the surface layer of soil, which was different from CW irrigation. It is concluded that water purifier cum descaler used in this experiment has no influence to effect changes in chemical composition of poor quality saline sodic water and hence soil properties.

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# Magnesium Deficiency Management for Enhancing Yield of Cotton under Rainfed Vertisol through Demonstrations by Farmers Participatory Approach

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Cotton is the most important commercial fibre crop in India. The *Bt* transgenic hybrids introduced for cultivation in 2002, now occupies more than 90% of the cotton area. Although, it contributed significantly to productivity and production increases, average productivity levels are still lower than the world average. Poor soil fertility is one major constraint in achieving potential yield levels. A deficiency of at least a single nutrient (N) is most common and in most of the cases it is a multiple nutrient (N, P, K, secondary nutrients - S and micronutrients - Zn, B) deficiency. Presence of high Ca may induce Mg deficiency leading to reddening of leaves in cotton. In contrast to Ca, deficiency symptoms are initially observed in the older leaves. The reddening occurs due to reduced photosynthetic activity of the plant, which may be due to immobilization of Mg in cotton. Sometimes the Mg deficiency is confused with natural ageing late in the season. Survey reports have also shown that secondary nutrients through fertilizers are not applied to cotton even in major cotton growing areas of Virudhunagar distrcit. Soil is slightly calcareous in nature with a pH of 8.4, and canker nodules present in the subsurface horizon. Magnesium defciency is predominant in all cotton growing areas of Virudhunagar district and the farmers usually practice application of fungicide due to misconception as disease (local name sevattai disease) which was not a normal recommendation practice for Mg deficiency. With this background, front line demonstrations (FLD) were conducted at ten locations of various villages covering Aruppukottai, Thiruzhuzhi and Kariyapatti blocks of Virudhunagar district during rabi 2011-12 to demonstrate reddening packages (combined spray of magnesium sulphate 2% and urea 1% during square formation and boll faormation stages) for the management of Mg deficiency in cotton under rainfed Vertisol conditions through farmers participatory approach. Seed cotton yield of an average of 1.44 t $ha^{-1}$ was recorded in demonstrated field than the yield of 0.81 t $ha^{-1}$ harvested in the local check plot with the yield increase of 23 per cent than in the control. There were 15 to 30 per cent improvements in yield parameters, which finally resulted in 70 per cent increase in net return. The results clearly indicated that in cotton, packages of combined spray of magnesium sulphate 2% and urea 1% during square formation and boll formation stages for the management of Mg deficiency recorded lower deficiency symptoms (rating score), maximum yield attributes and yield when compared to farmer's practice of without Mg application in a black calcareous soil of Virudhunagar district under rainfed conditions.

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# Effect of Conservation Agriculture Practices on Changes in Soil Quality Parameters

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To monitor changes in soil quality parameters under soybean, rice and maize based cropping systems, soil samples were collected (0-15 and 15-30 cm) from conservation agriculture (CA) experiments running since 2013 at Directorate of Weed Science, Jabalpur. The perusal of data from CA experiments of Jabalpur indicated that maximum build-up of soil organic carbon (SOC) (8.7 g $kg^{-1}$) was recorded from rice-based cropping system where zero tillage was practiced along with residue retention. This is significantly higher than the SOC content of conventional tilled plot with residue burnt and retained treatments. Similar observations were recorded in maize-based cropping system. The effect of residue retention along with zero tillage was also noticed in 15-30 cm of soil depth. We also measured $KMnO_4$ oxidisable C under different CA experiments of Jabalpur to measure management induced changes in soil quality parameters. It was observed that labile C content (0-15 cm soil depth) was significantly higher under zero tilled plots along with residue retained (519 mg $kg^{-1}$) in rice-based cropping system in comparison to conventionally tilled with residue retained (429 mg $kg^{-1}$). Similar trend was recorded in maize and soybean-based cropping systems. In both these experiments zero tilled plots with residue retained maintained higher level of labile C in comparison to conventional tilled plots with no residue retention. Available K content was found to be the maximum in zero tilled plots with either residue retained or burnt. It was significantly lower in plots which were conventionally tilled.

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# Interactive Effect of Zinc under Different Saline Condition on Germination and Straw Yield of Wheat

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Wheat (*Triticum aestivum*) is the world's most widely cultivated food crop. In India, wheat is the second most cultivated staple food crop and salinity in soil becomes a problem when the total amount of the salts which accumulate in the root zone is high enough to affect plant growth. Wheat is moderately tolerant to salinity and can perform well under saline conditions. Studies showed that there were positive effects between soil salinity and application of zinc (Zn) in improving plant functions. Thus, the present research work had been planned to study the relative tolerance of wheat (Var. KRL-210) and interactive effect of Zn and types of salinity on germination and straw yield of wheat. The experiment was laid out in screenhouse by taking two types ($Cl^-$ and $SO_4^{2-}$ dominated) and levels of salinity (0 and 12 dS $m^{-1}$) along with four levels of Zn (0, 5, 10 and 15 ppm) in completely randomized design having three replications.

Germination of wheat was delayed more in chloride dominated salinity at 8 and 12 dS $m^{-1}$ as compared to sulphate dominated salinity. No effect at 0 and 4 dS $m^{-1}$ in both types of salinity in germination. Germination percentage varied from 20 to 30 per cent in chloride dominated soils whereas, it ranged from 30 to 50 per cent in the sulphate dominated soils at 4 ECe (dS $m^{-1}$) on 7 days after sowing. In chloride dominated soils of 8 ECe (dS $m^{-1}$) 100 per cent germination were observed 13 days after sowing where 10 and 15 ppm Zn was applied and 15 days after sowing where 0 and 5 ppm Zn was applied and in case of 12 ECe (dS $m^{-1}$) 100 per cent germination reached up to 17 days after sowing. However, the magnitude of straw yield decrease in the wheat resulted from the increase in salinity. The experimental data clearly indicated that in the absence of Zn and salinities the mean straw yield was 10.2 g $pot^{-1}$. The mean straw yield increased from 10.2 to 13.94 g $pot^{-1}$ (36.7%) with the increasing application of Zn from 0 to 15 ppm soil in the absence of applied salinities. Therefore, germination and straw yield of wheat decreased with increasing levels of chloride and sulphate dominated salinity, whereas increasing levels of Zn application mitigates the adverse effect in both types of salinity.

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# Effect of Rice Establishment, Tillage and Rice Residue Management on Macro- and Micronutrient Uptakes in Wheat under Rice-Wheat System

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A field study entitled 'Effect of rice establishment, tillage and rice residue management on macro- and micronutrient uptakes in wheat under rice-wheat system' was conducted on third wheat (2012-13) crop in an on-going experiment initiated during rice 2010 at the experimental area of Department of Soil Science, PAU, Ludhiana. The experiment consisted of rice establishment methods, and tillage and rice straw management practices in wheat. These combinations comprised of four main plots of rice establishment methods dry direct seeded rice under zero tillage (DSR-ZT) and conventional tillage (CT), direct transplanted rice (DTR) and puddled transplanted rice (PTR) and three sub-plots in wheat conventional tillage, zero tillage without rice straw (ZT-R) and zero till wheat sown with Happy Seeder (HS) retaining rice straw as mulch (ZT+R) with three replications in split plot design. The results revealed that ZT wheat sown with HS significantly increased N, P and K uptake in grain and straw over ZT-R and CT. The interaction between rice establishment systems, and tillage and rice straw management practices was significant on straw N uptake. Highest straw N uptake was under ZT wheat sown with HS followed PTR and lowest was recorded under ZT-R followed PTR. The results revealed that 16 to 23 per cent N, 25 to 30 per cent P and 74 to 80 per cent K were retained in wheat straw. Grain Fe, Mn and Zn uptake was significantly higher under ZT wheat sown with HS than ZT-R. Micronutrient cations (Fe, Mn, Cu and Zn) uptake in wheat straw was significantly higher under ZT wheat sown with HS than ZT-R. Even micronutrient cations (Fe, Mn, Cu and Zn) uptake in wheat straw was significantly higher under CT wheat than ZT-R. The results revealed that 84 to 87 per cent Fe, 54 to 64 per cent Mn, 42 to 54 per cent Cu and 36 to 47 per cent Zn were retained in wheat straw. The overall results indicated that zero tillage with rice residue as mulch has positive effect on macro- and micronutrient uptakes in wheat crop and hence can be exploited as a sustainable approach to improve soil productivity.

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# Effect of Conservation Agricultural Practices on Crop Yield and Soil Properties in Vertisols of Central India

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Converting from conventional tillage practices to no-tillage/conservation agriculture (CA) is one of the main strategies to reduce farming cost and improve functional capacity of agricultural soils from sources to sink of atmospheric $CO_2$. The CA aims at raising crops in rotation without tilling the soil while retaining at least 30% crop residue on the soil surface. Thus, a long-term field experiment was initiated to study the effect of CA on soil properties and crop yield in Vertisols of central India. Soil samples (surface and sub-surface) were collected from experimental field after completion of three years of crop cycle. Results revealed that irrespective of soil depth, tillage had insignificant effect on soil pH and EC data. The mean weight diameter (MWD) at surface layer (0-15 cm) was significantly affected by the tillage treatments. Impact of tillage system on soil organic carbon (SOC) was found to significant only at surface layer (0-15 cm) and higher SOC value was observed under reduced tillage (RT) with residue retention as compared to conventional tillage (CT). Among carbon pools, very labile, labile and non-labile were found to be significant among tillage system. Reduced tillage (RT) practices resulted in increased carbon pools particularly very labile and non-labile pools over CT. However, cropping system does not have any significant effect on SOC and carbon pools at the end of 3rd crop cycle. Soil microbial biomass carbon (SMBC) data indicated significant difference was observed between tillage treatments. Among the cropping system, soybean+pigeon pea (2:1), soybean—wheat and soybean+cotton (2:1) cropping systems were significantly different over soybean-fallow system. Yield data indicated that tillage had no effect on soybean grain equivalent (SGE) after three years of crop cycle. Among the cropping systems studied, maize-gram recorded significantly higher soybean grain equivalent yield (4.57 t $ha^{-1}$) followed by soybean+pigeon pea (2:1) and soybean-wheat cropping system. Results indicated that there was a relative improvement of some soil properties like MWD, organic carbon and pools, and microbial biomass carbon under reduced tillage with residue retention as compared to conventional tillage after completion of three crop cycles.

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# Heavy Metals Accumulation in Post-harvest Soil of Rice and Wheat with Different Levels of Sewage Sludge

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Application of sewage sludge to agricultural field is gaining popularity over traditional method of manuring. In contrast to chemical fertilizers, sewage sludge is relatively inexpensive, in addition to nutrients, it provides organic matter to soil. It is also considered as a slow-release fertilizer. Sewage sludge (SS) is a good source of major as well as micronutrients, but it contains pollutant elements like Cd, Cr, Ni, Pb, As, Hg *etc*. Regular application of sewage sludge to soil may lead to soil pollution and heavy metals accumulation in plant. A study was conducted to assess direct and residual effect of sewage sludge on heavy metal accumulation in soils under rice-wheat system. Field experiments were conducted at Agricultural Research Farm, Banaras Hindu University, Varanasi for two consecutive years (2011-12 and 2012-13) under rice and wheat in a sequence. Three levels of sewage sludge (15, 30 and 45 t $ha^{-1}$) were applied along with 50 and 100% recommended dose of fertilizers (RDF). The experiment was conducted in randomized block design with 10 treatments taking three replications. Sewage sludge was applied only in first crop (rice) and its residual effect was studied in next three successive crops. Rice variety PRH 10 and wheat variety HUW 234 were chosen as test crops.

The initial soil (0–15 cm) had pH 8.49 (1:2.5), EC 0.149 dS $m^{-1}$, organic carbon 4.7 g $kg^{-1}$ and available N, P and K as 132.7, 18.3 and 127.7 kg $ha^{-1}$, respectively. The DTPA extractable Cd, Cr, Ni and Pb contents of soil were 0.25, 0.37, 2.38 and 0.13 mg $kg^{-1}$, respectively. The SS was collected from Sewage Treatment Plant, Bhagwanpur, Varanasi in the month of May 2011. The SS had pH 6.57, EC 2.57 dS $m^{-1}$, organic C 9.65%, total N, P, K and S content as 1.4, 1.2, 0.87 and 0.96%, respectively. The contents of DTPA extractable Cd, Cr, Ni and Pb in SS were 4.62, 9.67, 13.6 and 8.87 mg $kg^{-1}$ and the total were 24.4, 51.3, 65.9 and 44.6 mg $kg^{"1}$, respectively. The direct and residual effect of sewage sludge significantly increased the DTPA-extractable Cd, Cr, Ni and Pb content over control in post harvest soil of both rice and wheat. The highest content of Cd, Cr and Ni were recorded in Ist rice and decreased in soils of subsequent crops. However, the highest content of Pb in soil was recorded in 4th crop of study (IInd wheat) followed by third crop (IInd rice). A progressive increase in DTPA extractable Pb content with year of cultivation was recorded in soils. The highest total content of Cd, Cr, Ni and Pb in post harvest soils were 2.43, 8.95, 18.9 and 17.0 mg $kg^{-1}$, respectively at the end of the experiment which showed a significant build-up of 4.1 times, 3.2 times, 59% and 93% over their respective controls. The maximum content of DTPA and total Cd, Cr, Ni and Pb in soils was recorded in treatments where 45 t $ha^{-1}$ sewage sludge was applied. Application of sewage sludge to agricultural soils may cause heavy metal accumulation in soil. The sewage sludge used in the present study had high amount of heavy metals which caused a considerable increase in total content of heavy metal content in soil. With progressive cultivation, the content of heavy metals decreased except Pb.

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# Liming Influence on Fenugreek Productivity including Disease Incidence and Nutritional Parameters of Plant and Soil under Typic Haplustalfs

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Based on the recent estimates, 60 per cent land area on earth occupied by the acid soil. In India acidification (pH < 4.5 -5.5) was estimated as 16.03 Mha. In the Jharkhand state, soil acidity problem is acute in 4 lakh hectare of cultivated area. Liming in these soils play a crucial role for enhancing their productivity, however liming is an expensive management measure and some time it does not work properly. Selection of crops tolerant to acidity is an effective tool to encounter the soil problem. Therefore, field experiments were carried out consecutively three years in acid soils of Ranchi, Jharkhand on fenugreek (*Trigonella foenumgraecum*) with various fractions of recommended dose of lime (RDL) *i.e.* 25%, 50%, 75% and 100% and these were compared with control (No lime) and neutral soil conditions too. Results revealed that growth and yield parameters of fenugreek variety Ajmer methi-1 positively influenced by applied fractions of RDL. Growth and yield was more pronounced at 100% use of RDL. Per cent yield increase with corresponding fractions of lime was 15.0, 17.5, 18.1 and 37.4, respectively. Seed yield was directly correlated with soil available N, P, K and seed N content, and their corresponding $r^2$ values were 0.90, 0.97, 0.89 and 0.94, respectively. Impact of lime was wide at early growth stages than later. The N, P, K and protein content increased with lime and Fe, Mn and Zn content was lower. Phosphorus translocated highest from haulm to seed followed by K and N. Uptake of all the nutrients was more with lime. Moreover, N, P and K content was many fold lower in acid soil than the origin of variety *i.e.* neutral pH, whereas micronutrient content was higher in fenugreek under acid soil than neural. Soil available nutrients were influenced marginally with lime. However, soil EC and pH increased and soil organic carbon (SOC) decreased. Per cent disease index (PDI) was more with liming/soil pH ($r^2$ = 0.97), soil available Mn ($r^2$ = -0.94) and leaf Mn content ($r^2$ = -0.88). Due to high humidity, it was persistently higher at Ranchi than the Ajmer; a place of origin of variety. The combine effect of soil acidity and disease, in reduction of yield was accounted about 50-60% as compared to neutral soil. Hence, liming improved soil properties and fenugreek productivity but adversely affect the SOC and encouraged disease incidence.

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# Spatial Variation of Groundwater Quality of Kaithal Block of Kaithal District

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The present study examined the quality of groundwater in a Kaithal, the north eastern district of Haryana State with a total geographical area of 2317 sq. km is located between 29°31′- 30°12′ north latitudes and 76°10'- 76°42' east longitudes. It is surrounded by Jind, Kurukshetra and Ambala district of Haryana and Patiala district of Punjab in north, respectively. 132 groundwater samples from running tubewells in the block have been analyzed for ionic concentrations of $CO_3^{2-}$, $HCO_3^-$, $Cl^-$, $SO_4^{2-}$, $Ca^{2+}$, $Mg^{2+}$, $Na^+$ and $K^+$. Parameters such as electrical conductivity (EC), sodium absorption ratio (SAR) and residual sodium carbonate (RSC) have been evaluated. According to AICRP classification, it was found that 31.1% water samples were of good quality, 34.8% saline and 34.1% alkali in nature. Out of the saline water, 26.5 and 8.3% were marginally saline and high SAR saline, respectively. In alkali group, 8.3, 9.9 and 15.9% were maginally alkali, alkali and high alkali, respectively. The study revealed that out of 132 samples 121 of the samples showed EC upto 4 dS $m^{-1}$ and the maximum value of EC (6.06 dS $m^{-1}$) was found in village Sajuma. Residual sodium carbonate (RSC) and sodium adsorption ratio (SAR) varied from nil to 5.70 me $L^{-1}$ and 3.69 to 28.59 (mmol $L^{-1})^{½}$, respectively. Spatial variable maps of EC, SAR, RSC and water quality of groundwater used for irrigation in the block were prepared through GIS to study spatial variability.

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# Effect of Wastewater Irrigation on Heavy Metal Accumulation in Vegetable Crops

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Heavy metal contents of wastewater is a cause of serious concern for its reuse in irrigationdue to the potential health impacts of consuming contaminated produce. In this study an assessment is made of the impact of wastewater irrigation on heavy metal accumulation in vegetable crops of Haroti region of Rajasthan. The major crops grown with wastewater irrigation are vegetable crops like cauliflower, cabbage, spinach and garlic *etc*. Thirty four locations were selected for soil and wastewater sampling in the study area and then most polluted sites were selected on the basis of quality parameters and heavy metal contents.The wastewater of Bundi and Kota is of high to very high salinity but the salt load at Anta and Jhalawar city was found comparatively low. Mn, Zn, Cd, Pb, Cr and Ni and were found beyond the maximum permissible limit in wastewater used for irrigation at Bundi and Kota. Wastewater irrigated spinach, cabbage, cauliflower and garlic at selected sites of Bundi and Kota found to accumulate the copper, zinc, cadmium, lead and chromium more than the maximum permissible limits. The wastewater quality of Anta and Jhalawar cities are good enough to reuse in irrigating the vegetable crops with a very little extent of heavy metal problems. The leafy vegetables *viz*. spinach and cabbage irrigated with wastewater were found most unsafe for human consumption.

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# Behaviour of Sewage Water in Soil

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The sewage water, sewage irrigated soil were collected from farmers field in village Ghusar near Akola city. It was observed that sewage water was alkaline in reaction (pH 8.25 and 7.91) with high EC *i.e.* 2.60-2.85 dS $m^{-1}$, COD was 840 and 820 mg $L^{-1}$, BOD was 160 and 180 mg $L^{-1}$ and TDS (1664 and 1824 mg $L^{-1}$) which was higher than the permissible limit. The concentration of calcium was below permissible limit (280 and 320 mg $L^{-1}$) where as the concentration of $Mg^{2+}$ ( 96 and 72 mg $L^{-1}$), $Na^{+}$ ( 230 and 322 mg $L^{-1}$), K ( 54.99 and 39 mg $L^{-1}$), $HCO_3^{-}$ ( 976 and 1280 mg $L^{-1}$), $Cl^{-}$ (140 and 280 mg $L^{-1}$), $NH_4$-N (27.7 and 66.8 mg $L^{-1}$) and $NO_3$-N (5.6 and 8.6 mg $L^{-1}$) which exceeds permissible limit. The concentration of Fe (2.12 and 2.66 mg $L^{-1}$) Mn (1.22 and 2.94 mg $L^{-1}$), Zn (2.24 and 7.88 mg $L^{-1}$), Cu (0.44 and 0.56 mg $L^{-1}$) and B (4.0 and 6.2 mg $L^{-1}$) was higher than critical limit where as concentration of Cd (0.15 and 0.12 mg$L^{-1}$), Cr (0.20 and 0.30 mg $L^{-1}$), Pb (3.6 and 1.6 mg $L^{-1}$) and Co (0.38 and 0.51 mg $L^{-1}$) was higher. The bulk density of sewage irrigated soil was 1.28 and 1.2 Mg $m^{-3}$ during year 2011 and 12, respectively. The bulk density of sewage free soil was 1.30 Mg $m^{-3}$ which was higher than sewage irrigated soils while hydraulic conductivity and aggregate stability was increased as compared to sewage free soil. The sewage water at Ghusar district Akola contains macro and micronutrients and also found beneficial in improving physical, chemical and biological properties of soil. However, it also has high EC, BOD, COD and heavy metals which warrants its use with caution.

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# Phytostabilization of Lead in Soil through FYM under Fodder Maize

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A pot experiment was conducted to carry out the study on phytostabilization of lead (Pb) in soil through FYM under fodder maize. The pot experiment was laid out in a factorial completely randomized design with three replications, comprising of four levels of Pb (0, 50, 100, 150 and 200 mg $kg^{-1}$) and two levels of FYM (0 and 20 t $ha^{-1}$) and two varieties (GM-3 and African tall) of fodder maize.

The plant height (cm) at 15, 30, 45 and 60 DAS, green forage yield and dry matter yield of whole plant of maize was significant decrease with increasing levels of Pb. The yield reduction started at lower level of Pb (50 mg $kg^{-1}$ soil) and reduction was maximum when 200 mg $kg^{-1}$ Pb was applied to soil. Significantly the highest green forage yield (71.03 g $pot^{-1}$) was recorded under $Pb_0 \times F_1$ treatment. Among all treatment combinations, $Pb_0F_1$ recorded maximum dry matter yield (15.97 g $pot^{-1}$), whereas the minimum yield (6.24 g $pot^{-1}$) was noted under $Pb_{200}F_0$ treatment combination. With increasing rates of Pb application, Pb content in shoot and root of maize was found to increase at 30 DAS and 60 DAS, whereas P, S, Fe, Mn, Zn and Cu were decreased in shoot and root of both the varieties at 60 DAS. The application of Pb from 0 to 200 mg $kg^{-1}$ gave significantly higher Pb content in leaf at 30 DAS from 0.47 to 27.86 mg $kg^{-1}$, 0.63 to 36.47 mg $kg^{-1}$ in shoot and 0.86 to 83.11 mg $kg^{-1}$ in roots. The Pb application increased DTPA–Pb of the soil with increasing rates of Pb. The highest content of Pb (46.16 mg $kg^{-1}$) was found where Pb was applied at 200 mg $kg^{-1}$. Yield parameters like plant height and plant stand at 15, 30, 45 and 60 DAS, green forage yield and dry matter yield of fodder maize were found to increase with the application of FYM @ 20 t $ha^{-1}$ over no FYM. Addition of FYM @ 20 t $ha^{-1}$ increased all nutrients contents in plant components except lead content. With the application of FYM @ 20 t $ha^{-1}$, Pb content in shoot and root of maize was found to decrease at 30 DAS and 60 DAS. Addition of FYM @ 20 t $ha^{-1}$ had reduced the availability of Pb in the soil and significantly increased all nutrients *viz.*, S, OC, Fe and Zn status in soil after harvest of crop. Growth and yield attributes, micronutrients and major nutrients were decreased with increasing levels of Pb but, application of FYM @ 20 t $ha^{-1}$ increased nutrient content in plant and increase in growth and yield with respect to Pb content in plant. DTPA-Pb in soil was increased with increasing levels of Pb but application of FYM @ 20 t $ha^{-1}$ reduced the content and availability of Pb. The overall results pointed out that maximum dry matter yield (15.97 g $pot^{-1}$) of fodder maize was obtained with $Pb_0F_1$ treatment combination; while the minimum yield (6.24 g $pot^{-1}$) was noted under $Pb_{200}F_0$ treatment. Application of FYM @ 20 t $ha^{-1}$ had significant mitigating effect on lead toxicity as it reduced its availability due to stabilization in soil. Between two varieties variation in stabilization of lead in plant was not large.

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# Impact of Industrial Effluent on Quality of Ground Water in Ankleshwar Industrial Estate in Bharuch District of Gujarat

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In recent years, increasing industrialization, urbanization and developmental activities with the population explosion lead to generation of large amount of waste water from domestic, commercial, industrial and other sources. Industrial waste waters directly discharged in to river, lake, nallas, and khadi and created new pollution problem. Industrial pollution is found in large amount in some industrial areas like, Surat, Vapi and Ankleshwar of Gujarat. The study was conducted to evaluate the impact of industrial effluent in Ankleshwar industrial estate of Bharuch district of Gujarat, one of the heavily industrialized regions of Gujarat on ground water quality. This industrial estate has more than 1,200 industries manufacturing diverse range of chemicals, pesticides, pharmaceuticals, bulk drugs, petroleum products, engineering, textiles, plastics, rubber, and packaging. A total of 100 groundwater samples from tube wells/hand pumps from 40 villages of Ankleshwar and Hansot *taluka*s of Bharuch district were collected in the month of June 2016 *i.e.* before monsoon and analysed for pH, EC, cations (Ca, Mg, Na, K), anions (Cl, $SO_4$, $CO_3$, $HCO_3$, $PO_4$), heavy metal content (Cd, Cr, Ni, Pb, As, Mn, Cu, Mn, Zn). Data was analyzed statistically for drawing valid conclusions. Analysis of variance revealed significant differences in sampling sites with respect to many recorded parameters *viz.* EC, pH, Na, Ca, Mg, As, Cr, Co, Cu, Mn, Ni and Pb). Great variation was observed for almost all the recorded parameters in the present study. From the analytical results it is found that electrical conductivity of ground water samples varied from 0.28 to 11.40 with average of 3.24 dS $m^{-1}$ and standard deviation is 2.02. Similarly pH varied from 6.76 to 8.28 which is within the permissible limit. However, some of the samples had higher content of almost all the heavy metals than permissible limit for irrigation/drinking water purpose. Overall, arsenic (0.70 ppm) and cadmium (0.03 ppm) was found to be more than permissible limit in collected samples. Highly significant and positive correlation was observed between arsenic and cobalt; and chromium and lead which might be attributed to chemical nature of effluent discharged in the study area. Multivariate analytical technique revealed that maximum variability in sample data may be attributed to cobalt and arsenic content followed by chloride content. Further, spatial and temporal changes in content and distribution of these elements would be done to assess the impact of industrial effluents on long-term basis.

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# Residual Effect of Fly Ash on Soil Physicochemical and Biological Properties under Rice Ecosystem

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To justify suitability of fly ash in agricultural applications, the residual effect of fly ash was assessed on the basis of soil physicochemical and biological properties. The present investigation was carried out during 2015 in the already fly ash applied experimental field at Agricultural Engineering College and Research Institute, Kumulur. The treatments imposed were graded levels of FA *viz.,* 0, 25, 50, 75 and 100 t $ha^{-1}$ with four replications was applied during 2011-12. The results obtained through this research indicated that the application of FA@ 25 t $ha^{-1}$ decreased the bulk density of soil (1.40 Mg $m^{-3}$). An increase in porosity, maximum water holding capacity, hydraulic conductivity, intrinsic permeability and infiltration rate was also observed. The observed values were found to be 36.20%, 31.46%, 59.86 jim/sec, 27.93 jim/sec and 2.34 cm/h, respectively. However, addition of FA@ 100 t $ha^{-1}$ marginally increased the soil pH, EC. Soil OC (1.52 g $kg^{-1}$) and available N (291.5 kg $ha^{-1}$) and P (44.2 kg $ha^{-1}$) increased due to the application of FA@ 25 t $ha^{-1}$. But soil available K and Si responded significantly to FA application up to 100 t $ha^{-1}$. The observed values were found to be 240.4 kg $ha^{-1}$ and 104.5 mg $kg^{-1}$. An increase in soil micronutrients Fe (13.45mg $kg^{-1}$), Mn (10.98 mg $kg^{-1}$), Cu (3.97 mg $kg^{-1}$) and Zn (3.23 mg $kg^{-1}$) also observed due to the application of FA@ 25 t $ha^{-1}$. Similarly for soil microbial population of bacteria, actinomycetes and diazotroph increased $4.0 \times 10^{-6}$ cfu $g^{-1}$, $3.51 \times 10^{-4}$ cfu $g^{-1}$ and $3.78 \times 10^{-5}$ cfu $g^{-1}$ of dry weight soil, respectively and soil enzymes activities of urease, dehydrogenase, alakaline and acid phosphatase increased 13.6 jig $NH_4$-N $g^{-1}$ of soil $h^{-1}$, 12.9 jig TPF $g^{-1}$ soil $h^{-1}$, 75.3 jig of PNP released $h^{-1}$ and 36.8 jig of PNP released $h^{-1}$, respectively. SMBC (79.2 jig $g^{-1}$) and rate of $CO_2$ evolution (44.3 mg of $CO_2$ per 100 g soil) also increased.

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# Effects of Applied Cadmium on It's Accumulation, Dry Matter Production and Net Photosynthesis in Okra and Amelioration of Cadmium Toxicity through Lime Application

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Cadmium (Cd) is one of the highly toxic heavy metal contaminants in soil. It is a natural contaminant of zinc ores and widely distributed in the environment due to anthropogenic activities. Accumulation of Cd in vegetable plants poses high health risk for consumption when these vegetables are grown in Cd contaminated soils. The accumulation may be function of many factors including its concentration and soil pH. Limited information is available on the impact of different levels of soil Cd on its accumulation in different parts of important vegetable like okra. This study attempted for an insight into the impact of different levels of Cd in soil on accumulation in different parts of okra and its cascading effect on overall growth, dry biomass accumulation and photosynthesis rate. Okra *(Abelmoschus esculentus)* was grown in soil treated with different doses of cadmium chloride (to attain 0, 3, 6, and 9 mg $kg^{-1}$ soil Cd) at pH 5.5, 6.5 and 7.5 in pots between March and June 2014. Soil pH levels were attained through addition of 0, 2.5 and 5.0 g lime ($CaCO_3$) per kg soil. The results showed that Cd concentrations were minimum in fruits (0.54, 0.31 and 0.14 mg $kg^{-1}$) and maximum in leaves at pH 5.5 and in roots at 6.5 and 7.5 with all doses of $CdCl_2$ application. The biomass (dried) production decreased significantly at 6 and 9 mg $kg^{-1}$ level of soil cadmium at pH 5.5 while at 9 mg $kg^{-1}$ it increased (24.18 g $pot^{-1}$) at pH 7.5. Decrease in net photosynthesis rate was also observed in okra with increase in cadmium concentration in soil. However, the rate of decline was slower at higher soil pH. The transfer factors (Cd concentration in plant/ Cd concentration in soil) were decreased with increase in soil pH in all the parts of okra. The per cent DTPA extractable portion of total soil Cd decreased from 8.5 to 2 when soil pH increased from 5.5 to 7.5 rendering the Cd less available for plant uptake. Therefore, application of lime can be adopted as ameliorative measures to mitigate the toxicity of Cd contaminated soil to grow vegetable crops like okra.

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# Carbon Sequestration Potential of Sewage Irrigated Areas of Bhopal

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The scarcity of fresh water for crop production, pushing the agriculture sector to use waste water for irrigation in peri-urban areas. Due to progressive industrial developmental activities and increasing population growth, huge volume of domestic sewage water is being produced in mega cities. Sewage water (SW) contains plant nutrients and organic matter which may help in maintaining fertility and productivity of soils. Long-term use of untreated sewage water to crops results in a significant increase in soil organic carbon (SOC) than soils irrigated with groundwater. Patranala of Bhopal is an untreated sewage channel and most of the adjoining villages are using this sewage water as a source of irrigation water. Geo-referenced profile soil samples (0-60 cm) were collected from sewage water irrigated farmer's fields at a distance of 2 km interval and covered 2 km distance at the interval of 0.5 km along the full stretch of sewage channel. The samples were collected at 0-15, 15-30, 30-45 and 45-60 cm depth. The collected soil samples were processed and analyzed for SOC by Walkley and Black method. Microbial population and activities were also measured following standard procedures. The average organic carbon content of sewage irrigated soils were 1.13, 0.96, 0.87 and 0.75% at 0-15, 15-30, 30-45 and 45-60 cm depth, respectively. The corresponding values for tubewell irrigated soils were 0.70, 0.55, 0.42 and 0.30%, respectively. The per cent increment in SOC were 61, 75, 107 and 150 in 0-15, 15-30, 30-45 and 45-60 cm depth, respectively as compared to tubewell irrigated field. The SOC build-up was higher in deeper soil layers than the upper soil layers. The microbial population and activities were also higher in the sewage irrigated field as compared to tubewell irrigated field. More number of microbial populations in the sewage irrigated field might be due to higher amount of SOC. Long-term untreated sewage water irrigation has been found to sequester carbon in the soil profile in the farmers' fields of peri-urban areas around Bhopal city. Large addition of organic matter from sewage water irrigation and anaerobic conditions developed due to heavy loading of organic matter had reduced organic carbon mineralization and has resulted in a build-up of SOC. Hence, long-term sewage water irrigation can be a good means of sequestering carbon in Vertisol and can thus be referred as a soil quality sustaining practice.

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# Impact of Integrated Fish Farming System in Medium Black Soils under Malwa Region of Madhya Pradesh

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In India, the farming community accounts for 80% under marginal and small farmer's category. Farmers under these categories are economically poor working in diverse, risk prone environments and with hardly sufficient to sustain their family. The declining trend in land holding per capita poses a serious challenge to the sustainability and profitability of farming. Considering the efficacy of this viable production system, the study was conducted in purposively selected ponds of farmers which had available space of the pond bund used for production of horticulture produce. The initial status of soil was pH 7.8, Electrical conductivity 0.46 dS $m^{-1}$, available N, P, K and S @ 170, 18.7, 395 and 15.7 kg $ha^{-1}$, respectively. The trial was conducted minimum 6 replications were taken under farm field condition. Vegetable growing in the trellis and dykes is an additional component which helps in maximizing profit from unit area. The data were collected from each treatment for consecutively 3 years to judge the status of soil, economic profitability and sustainability of the practice. It was observed that the available status of soil were increased as compare to initial status of soil and better production with sustainable economic return achieved through integrated production technology or with dyke vegetable cultivation in pond based integrated farming practices.

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# Technological Interventions for Food Security

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Results of our laboratory experiments on integrated nutrient management, water saving technology and crop diversification were demonstrated at farmers' field in 16 acres of land of 14 farmers in Kenthia village (Kharagpur Block–II, Paschim Medinipur). The land was barren for last 5-7 years without any crop cultivation even in rainy season. Lack of irrigation facility, farmers' knowledge about cropping system management, and smaller plot size, non-availability of labour are the major limitations of food production. Farmers agreed for converting of 120 small plots into 46 larger plots and provide manpower free of charge for all the field operations.

As a result of successful demonstration of sustainable production technologies at the farmers filed average rice yield increased from merely 2.5 to 7.4 t $ha^{-1}$ is a significant contribution in ensuring food security of villagers. Also the farmers could realize higher return from other crops such as sweet corn, peanut, and sesame with less fertilizer, labor and water besides improvement of soil health. Furthermore, vermicomposting technology was demonstrated among the farmers to encourage them to take up organic farming. The most important impact of this study had been is the change in the mind set of farmers that they can now grow other soil restoring crops, with less labour, water and fertilizer. Farmers had been planting only IR36 during Kharif, but introduction new varieties like Hybrid Bio-799 has yielded between 6.5 to 8.6 t $ha^{-1}$. Integrated Planning with multi-disciplinary including socio-economic aspects was the one of the objective at the demonstration site. The participatory approach of Public Private Participation (PPP) Model, creation of permanent water resource-ground water exploitation and development of cropping pattern will certainly be of immense use for livelihood of the farmer. The project has created the impact in the mind of farmers in the village that such an approach is the only solution to the growth of our sustained agricultural and drudgery reducing rural technologies.

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# Role of Soil Scientist in Nation Programme in Swatch Bharat Abhiyan- A point to Ponder

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Irrespective of party rule, Swatch Bharat Abhiyan is a good programme in Nation's interest. It may increase prestige as well as increase the flow of tourists which will enhance our economy. This needs special significance for smart cities. It is an opportunity for soil scientists to provide a guide line to Government (Central/State) and develop technologies which are suitable for particular situation.

We have to look into composition of organic waste in big cities by transporting materials to particular place (dumping/ composting area). This involves carrying materials to long distances which involves in financial burden to Municipality/ Municipal Nigam. We can produce in compost/ vermicompost/ vermiwash at every Indian home/ dhaba's / hospital/ township. Specific technologies can be developed for a particular situation. Indian Council of Agricultural Research (ICAR), New Delhi can be requested to launch special programme for this activity. Technologies can be developed on the following aspects:

1. To increase the rate of chemical decomposition which is more useful for plants/ crops.
2. To improve quality compost, vermicompost/ vermiwash by adding ordinary super phosphate (rock phosphate), potash and microorganisms (various types).
3. To develop marketing strategies for sale of vermi wash to costly hotels/establishments and the spray of vermi wash will improve the appearance of potted plant as well as source plants nutrients.
4. Reduce the time of decomposition by using aerobic compositing system instead of un-aerobic system.
5. Development of laboratories for analysis or giving responsibilities to the existing soil testing laboratories in our country.
6. Maximum utilization of urine, feces and cow/ buffalo dung.
7. Reduce the foul smell in vermi wash by using special bacteria/ activated carbon or activated charcoal.
8. Use of information provided on farm compositing methods for the benefits farmers and develop new techniques which are easily adoptable by farmers and decomposition in situ.

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# Characterization, Classification and Evaluation of Soils Developed from Different Parent Materials in Semi-arid Region of Srikalahasthi Mandal in Chittoor District, Andhra Pradesh

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A reconnaissance soil survey was undertaken in Srikalahasthi mandal of Chittoor district in Andhra Pradesh. Seven typical pedons were selected, which were confined to plains (pedons 1, 2, 5, 6 and 7) and gently sloping topography (pedons 3 and 4).Pedons 1 and 4 were originated from alluvium and weathered granite containing plagioclase feldspars with pegmatite veins, respectively. However, the remaining pedons were originated from granite-gneiss The survey revealed that the soils were deep to very deep, pale brown to red, excessively to poorly drained, slightly acidic to slightly alkaline, low in organic carbon, low to medium in cation exchange capacity with wide textural variations. Soils were low to medium in available N and K and low in available P and high in available S. However, 57% of the samples were deficient in DTPA-extractable Zn. All the soils were sufficient in DTPA-extractable Cu and Mn. DTPA-extractable Fe was sufficient in surface horizons while deficient in sub-surface horizons. The Alfisols and Inceptisols exhibited the development of argillic (Bt) horizon and cambic (Bw) diagnostic horizons. The Entisols did not show presence of any diagnostic horizon. The soils have been classified as Typic Ustipsamments, Typic Ustorthents, Typic Ustifluvents, Vertic Haplustepts, Typic Haplustepts and Typic Haplustalfs. Based on the soils properties, the soils of Srikalahasthi mandal have been classified into land capability classes and sub-classes *viz.,* IIe (pedon 3 and 6), IIse (pedon 7), IIIs (pedon 1), IIIe (pedon 5), IIIse (pedon 2) and IVse (pedon 4).On the basis of major soil constraints, sustainable land use plan for Srikalahasthi mandal has also been suggested for their better management.

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