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# Residual effect of integrated nitrogen management and cropping systems on soil physical and physico-chemical properties

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**Abstract**
A field experiment was conducted to determine the residual effect of integrated nitrogen management and cropping systems on soil physical and physico-chemical properties during two consecutive years (2015-16 & 2016-17) on clayloam soils of Agricultural College Farm, Bapatla. The experiment was laid out in a two sample t-test for rice in *kharif* season with 2 treatments consists of $M_1$ 100% RDF, $M_2$ (50% RDN+ 25% N through FYM + 25% N through neem cake + Azospirillum + PSB @ 2.5 kg $ha^{-1}$(INM) and replicated thrice. During the immediate *kharif*, the experiment was laid out in a split plot design without disturbing the soil for succeeding *rabi* crops with the two treatments given to *kharif* rice as main plot treatments and each of these divided into five sub-plots of consisting of five crops as sub treatments by taking popular cultivars of rice (BPT 5204), blackgram (PU 31), maize (Sandhya), Sorghum (NSH-54), Sunflower (Shreshta) and mustard (Konark). Residual effect of integrated nitrogen management was non-significantly influenced all soil physical properties. Lowest bulk density, highest water holding capacity & porosity values, decreased pH values, improvement in soil organic carbon and CEC was found by Rice-blackgram cropping system followed by rice-sorghum and rice-maize.

**Keywords:** residual effect of INM- cropping systems- physical, physico-chemical properties

## Introduction
Integrated nitrogen management involving conjunctive use of organic, inorganic and crop residues may improve the soil productivity and system productivity become sustainable. Boosting yield, reducing production cost and improving soil health are three interlinked components of the sustainability triangle. Therefore, combined use of chemical fertilizers, organic manures and bio fertilizers is essential. Organic manures particularly farmyard manure and neem cake are not only supply macronutrients but also meet the requirement of micronutrients. Use of organic manures and biofertilizers have been found to be promising in arresting the decline in productivity through correction of deficiency of macro and micronutrients and influence the physical properties of soil. Cropping system is an important component of a farming system representing cropping pattern used on a farm, which maintains and enhances soil health. Some crops are nutrient exhausting while others help restore soil nutrient status. However, a diversity of crops will maintain soil fertility, minimize spread of pests and disease and keep production level high.

## Material and Methods
A field experiment was conducted for two consecutive years (2015-16 & 2016-17) on clayloam soils of Agricultural College Farm, Bapatla. The experiment was laid out in a two sample t-test for rice in *kharif* season with 2 treatments and replicated thrice. The treatments consists of $M_1$ 100% RDF, $M_2$ (50% RDN+ 25% N through FYM + 25% N through neem cake + Azospirillum + PSB @ 2.5 kg $ha^{-1}$(INM). During the immediate *kharif*, the experiment was laid out in a split plot design without disturbing the soil for succeeding *rabi* crops with the two treatments given to *kharif* rice as main plot treatments and each of these divided into five sub-plots. The experiment was repeated in another field (same block) during *kharif* and *rabi* seasons. Popular cultivars of rice (BPT 5204), blackgram (PU 31), maize (Sandhya), Sorghum (NSH-54), Sunflower (Shreshta) and mustard (Konark) were used for this study. The experimental soils in both locations are clayloam in texture, slightly alkaline in reaction, medium in organic carbon, low in available nitrogen, high in available phosphorus and potassium. The secondary nutrients (Calcium, Magnesium and Sulphur) were also in normal range. All the micronutrients (Iron, Manganese, Zinc and Copper) were sufficient in the soil with the values above theircritical limits (Table.1)

**Table 1:** Initial properties of the experimental soil

| Particulars | 2015-16 Field | 2016-17 Field | Class/ Group |
|---|---|---|---|
| 1. Sand (%) | 42 | 40 | |
| 2. Silt (%) | 20 | 21 | |
| 3. Clay (%) | 38 | 39 | |
| Textural class | Clay loam | Clay loam | Clay loam |
| Bulk density (Mg $m^{-3}$) | 1.44 | 1.43 | Normal |
| Porosity (%) | 43.50 | 43.80 | Normal |
| Water holding capacity (%) | 45.10 | 45.80 | Normal |
| pH (1:2.5) | 7.70 | 7.50 | Neutral to slightly alkaline in nature |
| EC (dS $m^{-1}$) | 0.26 | 0.31 | Non-saline |
| Cation exchange capacity (Cmol (p+) $kg^{-1}$) | 35.4 | 37.2 | Normal |
| Organic carbon (%) | 0.55 | 0.50 | medium |
| N (kg $ha^{-1}$) | 266 | 250 | Low |
| $P_2O_5$ (kg $ha^{-1}$) | 59 | 53 | High |
| $K_2O$ (kg $ha^{-1}$) | 630 | 668 | Very high |
| Exchangeable Ca (Cmol (p+) $kg^{-1}$) | 23.39 | 24.07 | Normal |
| Exchangeable Mg (Cmol (p+) $kg^{-1}$) | 5.80 | 5.70 | Normal |
| $SO_4^{-2}$ - Sulphur (mg $kg^{-1}$) | 15.00 | 15.50 | Normal |
| Iron | 27.50 | 25.00 | Sufficient |
| Manganese | 5.50 | 4.90 | Sufficient |
| Zinc | 2.55 | 2.65 | Sufficient |
| Copper | 0.59 | 0.65 | Sufficient |

## Results & Discussion

### Residual effect of integrated nitrogen on soil physical properties

### Bulk Density

Non-significant effect on bulk density was observed due to residual effect of INM. Bulk density of soil after harvest of crop was low in INM ($M_2$) than inorganic ($M_1$) (Table 2). The mean highest bulk density (1.50 Mg $m^{-3}$) was observed in $M_1$ during 2015-16 and 1.53 Mg $m^{-3}$ during 2016-17 was observed with $M_1$. The lowest bulk density (1.44 Mg $m^{-3}$ and 1.43 Mg $m^{-3}$) was recorded with $M_2$ during 2015-16 and 2016-17, respectively. This might be due to addition of root biomass which led to increase in the organic matter of the soil, the increased organic matter content decreased the bulk density of soil. Decrease in bulk density might be due to higher organic carbon content of the soil more pore space and better soil aggregation (Gathala *et al*., 2007) [3]. Crop residues, organic matter content and root growth might be the possible reasons for decrease in bulk density. Similar beneficial effect of decreased bulk density by the addition of organic sources had been reported by Kumpawat (2004) [6].

Irrespective of main plot treatments, the mean bulk density values of sub-plots (*rabi* crops) were also non-significant. Among the sub plots, lowest bulk density was observed in $S_1$ cropping sequence i.e rice- blackgram cropping system 1.41 and 1.46 Mg $m^{-3}$ during two years of study followed by rice-mustard and rice-sunflower. Highest values were obtained in cereal crops i.e sorghum and maize. Similar trend of results were reported by Muhammadshahzad *et al*., (2016) [9]. Lowest bulk density was observed in blackgram sequence due to inclusion of legume in cropping system. Legume crop improved soil physical quality by decreasing soil compaction or soil cone index, while addition of flax, canola or wheat owing to strong deep tap/fibrous root system, increased soil compaction (Doan *et al*., 2005) [2]. Moreover, the crops like sorghum and maize are exhaustive in nature with minimum residue return into the soil, while the legumes are restorative as they shed the leaves and twigs into the soil, thus improving the soil physical environment. Alam and Salahin, (2013) [1] also recorded lowest bulk density in wheat- dhaincha- T.aman cropping pattern. The high amount of added biomass from dhaincha and coupled with deep ploughing made soil loose, porous and less squeezed and led to lowest bulk density.

Interaction effect between sub plots and main plots was non-significant. Mallareddy and Devenderreddy, (2008) [8] also reported non- significant interaction effect between fertilizer sources and cropping system. Though interactions were at par with each other, $M_2S_1$ (INM-rice blackgram sequence) resulted in lowest bulk density of 1.38 and 1.42 Mg $m^{-3}$ during 2015-16 and 2016-17, respectively while $M_1S_2$ (inorganic nutrients - rice maize sequence) recorded the highest bulk density values (1.56 and 1.57 Mg $m^{-3}$) during two years of experimentation.

**Table 2:** Residual effect of INM & cropping systems on soil bulk density (Mg $m^{-3}$) at harvest of *rabi* crops

| Treatment | 2015-16 | | | | | Mean | 2016-17 | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | |
| $M_1$ | 1.45 | 1.56 | 1.53 | 1.49 | 1.50 | 1.50 | 1.51 | 1.57 | 1.55 | 1.55 | 1.50 | 1.53 |
| $M_2$ | 1.38 | 1.50 | 1.50 | 1.46 | 1.40 | 1.44 | 1.42 | 1.49 | 1.43 | 1.42 | 1.43 | 1.43 |
| Mean | 1.41 | 1.53 | 1.51 | 1.47 | 1.45 | | 1.46 | 1.53 | 1.49 | 1.48 | 1.46 | |

| | SEm± | CD (p=0.05) | CV (%) | | SEm± | CD (p=0.05) | CV (%) |
|---|---|---|---|---|---|---|---|
| Main plots(M) | 0.028 | NS | 7.38 | Main plots(M) | 0.03 | NS | 10.27 |
| Sub plots (S) | 0.035 | NS | 9.78 | Sub plots (S) | 0.040 | NS | 6.66 |
| Interaction (MXS) | 0.050 | NS | | Interaction (MXS) | 0.057 | NS | |

$M_1$=100 % RDN $M_2$= 50% RDN+25% N - FYM+ 25% N - neem cake + bacterial consortium

$S_1$= Blackgram $S_2$=Maize $S_3$= Sorghum $S_4$=Sunflower $S_5$= Mustard

**Water holding capacity**

The highest water holding capacity was recorded in the treatment INM with 57.6 and 58.3% during first and second year of the study, respectively (Table 3). The increase in water holding capacity of soil after harvest of *rabi* crops in treatments those received organic manure to preceding rice crop was evidently due to residual effect of organic sources (Talathi *et al*., 2010) [15]. Organic matter improved soil water holding capacity and helped the soil to maintain good tilth and thereby better aeration for germinating seeds and plant root development. Singh *et al*., (2000) [14] also stated that farmyard manure and neem cake possibly improved the soil physical conditions through increased organic matter content and organic colloidal fraction of the soil. Decomposition products of organic residues act as binding agents for stable aggregate formation. Sarwad *et al*. (2005) [13] observed reduction in bulk density and improved infiltration rate and water holding capacity of the soil with the incorporation of organic residues in a *rabi* sorghum-chickpea cropping sequence.

Among the subplots, highest water holding capacity was observed in $S_1$ cropping sequence i.e blackgram cropping sequence with 56.2% and 60.7% (mean values) during two years followed by mustard and sunflower and lowest values were obtained in cereal crops i.e sorghum and maize. Similar type of results were reported by Muhammadshahzad *et al*., (2016) [9].

However, the main plot treatments (inorganic and INM sources of N), subplot treatments (*rabi* crops) and also interactions between them were not significantly varying. However, among the interactions, $M_2S_1$ hold maximum moisture at harvest in 2015-16 and 2016-17, respectively. It was evident, cropping system involving legume crop (blackgram), had relatively higher water holding capacity than other crops (Doan *et al*., 2005) [2].

**Table 3:** Residual effect of INM & cropping systems on soil water holding capacity (%) at harvest of *rabi* crops

| Treatment | 2015-16 | | | | | Mean | 2016-17 | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | |
| $M_1$ | 53.7 | 47.3 | 46.2 | 46.1 | 47.4 | 48.1 | 59.5 | 56.2 | 53.0 | 55.8 | 54.3 | 55.7 |
| $M_2$ | 58.8 | 56.6 | 56.3 | 58.5 | 58.0 | 57.6 | 62.0 | 56.3 | 57.5 | 57.1 | 59.0 | 58.3 |
| Mean | 56.2 | 51.9 | 51.2 | 52.3 | 52.7 | | 60.7 | 56.2 | 55.2 | 56.4 | 56.6 | |

| | SEm± | CD (p=0.05) | CV (%) | | SEm± | CD (p=0.05) | CV (%) |
|---|---|---|---|---|---|---|---|
| Main plots(M) | 0.17 | NS | 12.94 | Main plots(M) | 0.13 | NS | 9.4 |
| Sub plots (S) | 0.60 | NS | 12.66 | Sub plots (S) | 0.37 | NS | 7.93 |
| Interaction (MXS) | 0.81 | NS | | Interaction (MXS) | 0.52 | NS | |

$M_1$=100 % RDN $M_2$= 50% RDN+25% N - FYM+ 25% N - neem cake + bacterial consortium $S_1$= Blackgram $S_2$=Maize $S_3$= Sorghum $S_4$=Sunflower $S_5$= Mustard

**Porosity**

Similar to other physical properties, soil porosity was also not significantly varying with main plot treatments ($M_1$ and $M_2$), sub-plot treatments (cropping systems, $S_1$ to $S_5$) and their interactions (Table 4).

The highest porosity was recorded in the treatment $M_2$ with 54 and 51% (mean values) during first and second year of the study respectively. Alam and Salahin (2013) [1] also reported that the wheat- Dhaincha –T aman cropping pattern got the highest porosity. The increase in porosity of soil after harvest of *rabi* crops in treatments those received organic manure to preceding rice crop was evidently due to residual effect of organic sources. Organic matter improved soil water holding capacity and helped the soil to maintain good tilth and thereby better aeration Muhammadshahzad *et al*. (2016) [9].

**Table 4:** Residual effect of INM & cropping systems on soil porosity (%) at harvest of *rabi* crops

| Treatment | 2015-16 | | | | | Mean | 2016-17 | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | |
| $M_1$ | 54.16 | 47.00 | 45.40 | 46.80 | 52.40 | 49.15 | 55.00 | 47.30 | 47.90 | 49.00 | 50.16 | 49.87 |
| $M_2$ | 60.00 | 48.60 | 54.20 | 54.60 | 57.18 | 54.91 | 58.40 | 48.90 | 48.30 | 49.40 | 51.60 | 51.32 |
| Mean | 57.08 | 47.80 | 49.80 | 50.70 | 54.79 | | 56.70 | 48.10 | 48.10 | 49.20 | 50.88 | |

| | SEm± | CD (p=0.05) | CV (%) | | SEm± | CD (p=0.05) | CV(%) |
|---|---|---|---|---|---|---|---|
| Main plots(M) | 0.36 | NS | 8.50 | Main plots(M) | 0.60 | NS | 7.07 |
| Sub plots (S) | 0.63 | NS | 12.90 | Sub plots (S) | 1.55 | NS | 10.50 |
| Interaction (MXS) | 0.89 | NS | | Interaction (MXS) | 2.19 | NS | |

$M_1$=100 % RDN $M_2$= 50% RDN+25% N - FYM+ 25% N - neem cake + bacterial consortium $S_1$= Blackgram $S_2$=Maize $S_3$= Sorghum $S_4$=Sunflower $S_5$= Mustard

**Residual effect of INM on soil physico-chemical properties during crop growth**

**Soil pH**

The variations observed in the status of soil pH after the completion of rice based sequences were statistically non-significant during both the years of the study (Table 5). Irrespective of the crop raised in *rabi* season, the soil pH after harvest of *rabi* crops was less by 0.2 units following organic application together with 50% RDN + 25% N through neem cake + 25% N through farmyard manure and bacterial inoculants than that of 100% inorganic alone added to preceding rice crop during both the years of study. The findings were same with Nagar *et al*. (2016) with pigeonpea based intercropping systems due to addition of organic matter through biomass of intercrops, root nodules and huge leaf fall decomposition in the system.

In both the locations, both the treatments ($M_1$ and $M_2$) recorded less soil pH than the initial soil pH. Khusbhoosrivastava *et al*. (2016) [4] quoted lowest soil pH with sorghum-berseem cropping system which included the leguminous crop leads to decrease in soil pH. Comparison the soil pH in the subplots after harvest of *rabi* crops, the plots where blackgram was grown had relatively low pH value than in the plots of cereal crops (maize and sorghum) in both the years of study, which was attributed to root exudates secreted from the root system. Interaction effect of cropping system and INM was non-significant. However, $M_2S_1$ recorded lower values of soil pH.

**Table 5:** Residual effect of INM & cropping systems on soil pH at harvest of *rabi* crops

| Treatment | 2015-16 | | | | | Mean | 2016-17 | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | |
| $M_1$ | 7.6 | 7.5 | 7.4 | 7.7 | 7.8 | 7.6 | 7.5 | 7.6 | 7.5 | 7.5 | 7.4 | 7.5 |
| $M_2$ | 7.4 | 7.3 | 7.0 | 7.6 | 7.7 | 7.4 | 7.3 | 7.3 | 7.3 | 7.5 | 7.3 | 7.34 |
| Mean | 7.5 | 7.4 | 7.2 | 7.65 | 7.75 | | 7.4 | 7.45 | 7.4 | 7.5 | 7.35 | |

| | SEm± | CD (p=0.05) | CV (%) | | SEm± | CD (p=0.05) | CV (%) |
|---|---|---|---|---|---|---|---|
| Main plots(M) | 0.127 | NS | 6.55 | Main plots(M) | 0.18 | NS | 9.62 |
| Sub plots (S) | 0.32 | NS | 10.70 | Sub plots (S) | 0.29 | NS | 9.52 |
| Interaction (MXS) | 0.46 | NS | | Interaction (MXS) | 0.41 | NS | |

$M_1$=100 % RDN $M_2$= 50% RDN+25% N - FYM+ 25% N - neem cake + bacterial consortium $S_1$= Blackgram $S_2$=Maize $S_3$= Sorghum $S_4$=Sunflower $S_5$= Mustard

### Electrical conductivity (EC)

A significant decrease in electrical conductivity was noticed in soils treated with integrated nitrogen management irrespective of *rabi* crops grown during 2016 only (Table 6). The decrease 0.15 and 0.04 dSm$^{-1}$ in electrical conductivity was observed with $M_2$ treatment when compared to 100% inorganics during 2015-16 and 2016-17 years. Irrespective of the rate of NPK level applied to *rabi* crops in the sequence, the soil electrical conductivity after harvest of *rabi* crops was decreased following INM ($M_2$) than that of inorganic alone given to preceding rice crop during both the years of study. Mairan *et al.* (2005) [7] concluded that there was decline in values of soil electrical conductivity of Vertisol with crop residue incorporation over fertilizer application in long-term fertilizer experiment with sorghum-sunflower sequence. Khusbhoosrivastava *et al.*, 2016 [4] also recorded similar results i.e the lowest EC values were reported in maize-wheat-greengram cropping system. It might be attributed that more organic matter provided by these crops which decrease bulk density, an enhancement of soil porosity, aeration and permeability of soil thereby reducing soil salinity and reduced the EC values (Rathod *et al*., 2003) [12].

**Table 6:** Residual effect of INM & cropping systems on soil electrical conductivity (dS m$^{-1}$) at harvest of *rabi* crops

| Treatment | 2015-16 | | | | | Mean | 2016-17 | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | |
| $M_1$ | 0.40 | 0.43 | 0.45 | 0.42 | 0.37 | 0.41 | 0.53 | 0.62 | 0.57 | 0.70 | 0.73 | 0.63 |
| $M_2$ | 0.26 | 0.25 | 0.26 | 0.25 | 0.32 | 0.26 | 0.55 | 0.59 | 0.60 | 0.60 | 0.63 | 0.59 |
| Mean | 0.33 | 0.34 | 0.35 | 0.33 | 0.34 | | 0.54 | 0.60 | 0.58 | 0.65 | 0.68 | |

| | SEm± | CD (p=0.05) | CV (%) | | SEm± | CD (p=0.05) | CV (%) |
|---|---|---|---|---|---|---|---|
| Main plots(M) | 0.010 | 0.06 | 11.45 | Main plots(M) | 0.017 | 0.04 | 11.13 |
| Sub plots (S) | 0.014 | NS | 10.36 | Sub plots (S) | 0.041 | NS | 16.44 |
| Interaction (MXS) | 0.020 | NS | | Interaction (MXS) | 0.058 | NS | |

$M_1$=100 % RDN $M_2$= 50% RDN+25% N - FYM+ 25% N - neem cake + bacterial consortium $S_1$= Blackgram $S_2$=Maize $S_3$= Sorghum $S_4$=Sunflower $S_5$= Mustard

### Soil organic carbon

Residual INM ($M_2$) treated soil showed significantly higher organic carbon content over 100% RDN during both the years of study (Table 7). An absolute value of 0.05 and 0.12% (relative increase of 9.09 and 19.99%) higher organic carbon content was accumulated in $M_2$ sub-plots (residual INM) at the end of *rabi* season irrespective of *rabi* crops of 2015-16 and 2016-17, respectively. This might be due to the direct incorporation of organic matter, better root growth and more plant residues addition (Gathala *et al*., 2007) [3]. Kumar and Singh (2010) [5] also reported the higher organic carbon with 100% NPK and 10t FYM ha$^{-1}$ after harvest of wheat crop in rice-wheat cropping system. Non-significant but the highest mean organic carbon (0.60% and 0.71%) was obtained with effect of application of $S_1$ (rice-blackgram) cropping system than other cropping systems (Khusbhoo Srivastava *et al.*, 2016) [4]. Inclusion of legumes in the cropping system improved the organic carbon content in rice-rice-blackgram cropping sequence than other cropping sequences. (Porpavai *et al*., 2011) [11]. He also stated that increase in organic carbon content was attributed to the accumulation of root residues and shedding of leaves by the leguminous crops. Pal and Shurpali (2006) [10] also stated that rice-pulse cropping system maintained higher soil organic carbon, may be attributed to anaerobic rice culture resulting in lower rate of decomposition of soil organic matter followed by aerobic crop cycle for pulse. The pulse crop contributes to soil organic carbon from litter fall, moribund root tissues and decomposing root nodules. The interaction effect was non-significant. However, $M_2S_1$ accumulated highest (0.64 and 0.76%) while $M_1S_3$ lowest (0.53%) organic carbon during first and second years, respectively.

**Table 7:** Residual effect of INM & cropping systems on soil organic carbon (%) at harvest of *rabi* crops

| Treatment | 2015-16 | | | | | Mean | 2016-17 | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | |
| $M_1$ | 0.57 | 0.56 | 0.53 | 0.55 | 0.56 | 0.55 | 0.67 | 0.56 | 0.53 | 0.64 | 0.63 | 0.60 |
| $M_2$ | 0.64 | 0.60 | 0.53 | 0.63 | 0.62 | 0.60 | 0.76 | 0.66 | 0.70 | 0.75 | 0.73 | 0.72 |
| Mean | 0.60 | 0.58 | 0.53 | 0.59 | 0.59 | | 0.71 | 0.61 | 0.61 | 0.69 | 0.68 | |

| | SEm± | CD (p=0.05) | CV (%) | | SEm± | CD (p=0.05) | CV(%) |
|---|---|---|---|---|---|---|---|
| Main plots(M) | 0.008 | 0.04 | 8.35 | Main plots(M) | 0.018 | 0.11 | 11.55 |
| Sub plots (S) | 0.01 | NS | 8.80 | Sub plots (S) | 0.04 | NS | 7.02 |
| Interaction (MXS) | 0.019 | NS | | Interaction (MXS) | 0.05 | NS | |

$M_1$=100 % RDN $M_2$= 50% RDN+25% N - FYM+ 25% N - neem cake + bacterial consortium $S_1$= Blackgram $S_2$=Maize $S_3$= Sorghum $S_4$=Sunflower $S_5$= Mustard

## Cation exchange capacity

Cation exchange capacity of soil after harvest of *rabi* crops was non-significantly higher in INM treated plots when compared to 100% RDN during both the years of study (Table 8). Based on the mean values without any regard to sub-plot (*rabi* crops), $M_2$ (INM treatment) recorded CEC values of 34.43 and 36.05 as against 33.65 and 34.75 cmol $(p^+)kg^{-1}$ in $M_1$ during 2015-16 and 2016-17. This was attributed to relatively higher accumulation of organic colloids in $M_2$ plots as indicated earlier by Yahaya *et al* (2014) [16], respectively.

Even though non-significant, there was a slight increment in CEC in rice-blackgram crop followed by mustard and sunflower and lowest CEC were obtained with rice-maize and rice- sorghum cropping sequence. The highest cation exchange capacity (34.75 and 35.73 cmol (p+) $kg^{-1}$) was recorded in the treatment $S_1$ treatment i.e rice - blackgram cropping system than others during two years, irrespective of main plot treatments.

The interaction effects were also non-significant on soil CEC. However, $M_1S_3$(32.5 cmol (p+) $kg^{-1}$ )and $M_1S_2$ (34.2 cmol (p+) $kg^{-1}$) recorded lower values whereas $M_2S_1$ recorded higher values of 35.5 and 36.6 cmol (p+) $kg^{-1}$ in 2015-16 and 2016-17, respectively.

**Table 8:** Residual effect of INM & cropping systems on soil cation exchange capacity (cmol (p+) $kg^{-1}$) at harvest of *rabi* crops

| Treatment | 2015-16 | | | | | Mean | 2016-17 | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | |
| $M_1$ | 34.00 | 33.30 | 32.50 | 34.10 | 33.78 | 33.53 | 34.80 | 34.20 | 34.73 | 35.46 | 34.55 | 34.75 |
| $M_2$ | 35.50 | 33.90 | 34.65 | 34.33 | 34.35 | 34.54 | 36.66 | 35.50 | 36.13 | 35.50 | 36.53 | 36.06 |
| Mean | 34.75 | 33.60 | 33.57 | 34.21 | 34.06 | | 35.73 | 34.85 | 35.43 | 35.48 | 35.54 | |

| | SEm± | CD (p=0.05) | CV (%) | | SEm± | CD (p=0.05) | CV (%) |
|---|---|---|---|---|---|---|---|
| Main plots(M) | 0.19 | NS | 12.18 | Main plots(M) | 0.04 | NS | 7.50 |
| Sub plots (S) | 0.53 | NS | 10.81 | Sub plots (S) | 0.35 | NS | 12.46 |
| Interaction (MXS) | 0.74 | NS | | Interaction (MXS) | 0.50 | NS | |

$M_1$=100 % RDN $M_2$= 50% RDN+25% N - FYM+ 25% N - neem cake + bacterial consortium $S_1$= Blackgram $S_2$=Maize $S_3$= Sorghum $S_4$=Sunflower $S_5$= Mustard

## Conclusion

Residual effect of integrated nitrogen management was non-significantly influenced all soil physical properties. But with inclusion of different *rabi* crops in different cropping systems, influenced soil physical properties significantly. Lowest bulk density, highest water holding capacity & porosity values were observed in $S_1$ cropping sequence i.e rice-blackgram cropping system during two years of study followed by rice-mustard and rice-sunflower whereas the lowest water holding & porosity values were obtained in rice- sorghum & rice-maize cropping systems. Because crops like sorghum and maize are exhaustive in nature with minimum residue return into the soil, while the legumes are restorative as they shed the leaves and twigs into the soil, thus improving the soil physical environment. Soil physico-chemical properties were also improved by the blackgram cropping system which was attributed to root exudates secreted from the root system. Non-significant but the highest mean organic carbon (0.60% and 0.71%) was obtained with effect of application of $S_1$ (rice-blackgram) cropping system than other cropping systems due to legume crops. Even though non-significant, there was a slight increment in CEC in rice-blackgram cropping system followed by mustard and sunflower and the lowest CEC was obtained with rice-maize and rice- sorghum cropping system. Rice-blackgram cropping system was better due more organic matter provided by crop which decrease bulk density, an enhancement of soil porosity, aeration and permeability of soil thereby reducing soil salinity and reduced the EC values, and improving organic carbon and CEC.

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