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Changes in Physico-Chemical Properties, Urease Activity and Performance of Maize in Sandy Loam Soils of Coastal Belt of India under Integrated Supply of Nutrients

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ABSTRACT

A field experiment was conducted to study the effect of integrated application of inorganic and organic sources of nutrients onsoil properties and performance of maize (Zea mays L.) incoastal sandy loam soils of Andhra Pradesh. The results showed that the highest drymatter production, grain and stover yield was observed when 125 per cent of recommended dose of fertilizer nitrogen (RDFN) was applied along with 50 per cent of nitrogen through poultry manure (PM). This was followed by the treatments with recommended dose of fertilizer nitrogen (RDFN) alone and its combinations with farmyard manure (FYM) and poultry manure (PM). The physical and physico-chemical properties viz., bulk density, pH, EC and CEC were not significantly influenced by different levels of fertilizer nitrogen along with FYM/ poultry manure. The organic carbon content and urease activity of soils at tasseling and harvest was significantly influenced by the treatments and higher activity was recorded in treatments which received higher levels of nitrogen through fertilizer and FYM/ poultry manure. Significant positive correlation was observed between soil properties and performance of maize.

Key words: *Maize, FYM, Poultry manure, Yield, Soil properties, Urease activity.*

INTRODUCTION

Maize is called “King of Cereals” because of its production potential compared to any other cereal crop. The productivity of maize mainly depends on its nutrient management especially nitrogen. Maize is highly responsive to nutrients compared to most of the crops and responds quickly to chemical fertilizers and gives higher yield. But, continuous application of chemical fertilizers alone has been reported to deteriorate soil health. At the same time application of organic manures alone cannot be an alternative due to their low nutrient status and slow available nature.

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Sustainable yields could be achieved only by integrating all the available nutrient sources in an appropriate combination with chemical fertilizers. Organic manure supplies essential nutrients in available forms to the plants through biological decomposition. Indirectly, it improves physical properties of soil such as aggregation, aeration, permeability and water holding capacity and improves chemical properties like pH, organic carbon and CEC in long run. Biological activity in soils steadily increases by application of organic sources of plant nutrients.

Farmyard manure is the commonly available organic source of nutrients and poultry manure is a valuable fertilizer material having higher quantities of nitrogen and phosphorus compared to other bulky organic manures. It is essential to have well-defined production systems, involving poultry manure/FYM to establish potential nutrient supply packages for a farm or a region.

Effective and prudent use of organic manures can substantially reduce chemical fertilizer use without detrimentally effecting crop yields. Keeping these points in view, the present study was undertaken to study the effect of integrated nutrient management on productivity of maize and to assess the changes in soil physico chemical properties and urease activity.

MATERIALS AND METHODS

The experiment was conducted in Agricultural College Farm, Bapatla of the Acharya N.G. Ranga Agricultural University. The experimental site is located at an altitude of 5.49 m above the mean sea level, 15^o 54’ N latitude, 80^{o}25’ E longitude and about 7 km away from the coast of Bay of Bengal in the Krishna Agro-Climatic Zone of Andhra Pradesh, India. The experimental soil was non saline, slightly alkaline in soil reaction with low organic carbon (1.9 g kg^{-1}) and available nitrogen (122 kg ha^{-1}), medium available phosphorus (40.4 kg ha^{-1}) and high available potassium (392 kg ha^{-1}). Except zinc, other micronutrients *viz.*, iron, manganese and copper were well above the critical limit.

The experiment was laid out in a randomized block design with ten treatments comprising of T_1- 100% RDFN; T_2- 100% RDFN + 25% N through FYM; T_3- 100% RDFN + 50% N through FYM; T_4- 100% RDFN + 25% N through poultry manure; T_5- 100%RDFN + 50% N through poultry manure; T_6- 125% RDFN; T_7- 125% RDFN + 25% N through FYM; T_8- 125% RDFN + 50% N through FYM; T_9- 125% RDFN + 25 % N through poultry manure; T_{10}-125%RDFN + 50% N through poultry manure. Recommended dose of fertilizer is 120, 60 and 40 kg N, P_2O_5 and K_2O ha^{-1}, respectively. Recommended dose of P_2O_5 and K_2O was applied through single superphosphate (SSP) and muriate of potash (MOP) respectively to all the plots. Nitrogen was applied at 100 and 125 per cent of recommended dose (120kg ha^{-1}) as per the treatments in three equal splits, at the time of sowing, at knee high stage and at tasseling. Recommended dose of 60 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied uniformly to all the plots. Entire quantity of phosphorus was applied as basal whereas potassium was applied in two equal splits, one at the time of sowing and other at tasseling stage. All the manures in required quantities were applied as per the treatments duly taking into account their nitrogen contents based on dry weights and incorporated in soil 10 days before sowing of seeds. The treatments were replicated three times. The variety of maize seeds used was hybrid pioneer (30v92). The crops were harvest 100 days after sowing.

Table 1: Characteristics of initial soil

Characteristics	
Particle size analysis[a]	
Sand (%)	77.68
Silt (%)	14.32
Clay (%)	8.0
Soil texture	Sandy loam
Bulk density (Mg m^{-3})[b]	1.5
Soil pH (1:2.5 soil:water)[c]	7.55
Electrical conductivity (dSm^{-1}) (1:2.5 soil:water)[c]	0.11
Cation exchange capacity (c mol (p+) kg^{-1})[d]	13.9
Organic carbon (%)[c]	0.19
Available nitrogen (kg/ha)[e]	122
Available P_2O_5 (kg/ha)[f]	40.4
Available K_2O (kg/ha)[g]	392
Available micronutrients[h] i) Iron (ppm)	8.12
ii) Zinc (ppm)	0.53
iii) Manganese (ppm)	6.49
iv) Copper (ppm)	1.68
Urease activity (µg NH_4^+ - N g^{-1} soil h^{-1})	8.4

a:Piper, 1966. b:Dastane, 1967. c:Jackson, 1973. d:Bower *et al.*, 1952
e:Subbiah and Asija. 1956, f:Olsen *et al.* 1954. g:Muhr *et al.*, 1965.
h:Lindsay and Norvell, 1978.

RESULTS AND DISCUSSION

Grain and stover yield: Application of organic manures have exerted their significant influence on grain yield. Application of 125%RDFN + 50% N (T_{10}) through poultry manure gave the highest grain yield (7225 kg ha^{-1}) as compared to the rest of the treatments . Application of 125% RDFN + 50% N through FYM (T_8) was identified as the next best treatment followed by 125% RDFN + 25 % N through poultry manure (T_9). However, these three treatments were found on par with each other. Significantly the lowest grain yield of was obtained in 100% RDFN.

The increase in grain and stover yield under organic material treated plots might be due to better and continuous availability of nutrients for plants upto cob development which ultimately increased the grain yield[10]. On contrary to the use of NPK fertilizer alone, its combined use with organic matter provided all essential nutrients such as Mg, Cu, Zn, Mn and Fe on all stages of crop growth. Similar results were reported by Shilpashree *et al*.[26] who reported that the higher grain yield was due to optimum supply of nutrients at right time of crop requirement and maize responds well to fertilizer application as a result of its well-developed root system. Crop absorbed required nutrients from soil and effectively utilized for dry matter production and effectively translocated the photosynthates from leaves to the sink for better development of grains. The higher yield in treatments where poultry manure was used as organic source instead of FYM can be attributed to the higher content of macro and micro nutrients in poultry manure compared to FYM.

Increase in stover yield might have been on account of overall improvement in the vegetative growth of the plant due to the application of organic manures in combination with inorganic N fertilizer. Similar results were obtained from Makinde and Ayoola[14] who reported that complementary application of organic and inorganic fertilizers is effective for the growth of maize and the development of the leaves. This might be due to addition of organic material which can markedly increase soil productivity by providing essential plants nutrients and by improving physical properties[24].

Bulk Density: Analysis of soil after maize crop indicated that bulk density was not significantly influenced by the various treatments. However there is a marginal reduction in integrated treatments than sole inorganics. The lowest bulk density was observed in treatments which received higher doses of FYM along with inorganic fertilizers and the highest was observed in 100% RDFN. Lowering of bulk density by application of organic manures under long term experiments was reported by Selvi *et al*. [23] who reported that reduction in bulk density is due to higher organic carbon, more pore space and good soil aggregation. The effect of manures was non-significant because of shorter time period of study. It has also been observed that a greater quantity of organic material is needed to improve soil structural properties than is necessary to supply the nutrient requirements of a growing crop.

pH: pH of the soil did not show any significant difference between each other in any of the treatments. Numerically the highest pH (7.54) was observed in T_6 (125% RDFN) and the lowest (7.37) was observed in T_7 (125% RDFN + 25% N- FYM). However the pH decreased in all treatments as compared to the initial pH of experimental soil.

Several researchers [15, 30] observed changes in soil pH on addition of organic manure owing to organic matter oxidation and release of CO_2 in the soil. The release of organic acids during decomposition of manures results in slight decline of pH[31]. However, this contradiction might be because of short duration of present study. Some researchers have also indicated non-significant effect of organic manure on soil pH[2].

Electrical Conductivity: Soil samples at harvest indicated that the electrical conductivity of soil was not significantly influenced by the application of sole inorganic fertilizer or in combination with organic manures. This might be due to low quantities of inorganic fertilizer addition, which have not allowed an increase in salt concentration. Even after 5 years of continuous manuring and fertilization, no change in electrical conductivity was found by Badanur *et al*[3].

Organic Carbon: Organic carbon content was significantly affected by different treatments. The organic carbon content at tasseling stage of the soil collected from plots treated with 125 per cent RDFN along with 50 per cent N through FYM recorded the highest (3.8 g kg^{-1}) among all treatments. This is statistically on par with those treatments which received 50 per cent of nitrogen through organic manure along with inorganic fertilizers. The lowest (2.0 g kg^{-1}) was observed in treatment which received 100 % RDFN which was on par with 125% RDFN (2.4 g kg^{-1}). However samples at harvest stage shown lesser amount of organic carbon in all treatments as compared to tasseling stage. At harvest all treatments which received organic manure were on par with each other.

Addition of integrated use of nutrient sources significantly increased the soil carbon content in all treatments compared to use of inorganic fertilizers alone. The increased organic content might be due to enhanced root growth, which leads to the accumulation of organic residues and direct incorporation of organic matter in the soil. These findings are in agreement with that of Sharma and Gupta[25]. All treatments showed increase in organic matter content in soil at both stages of crop growth as compared to initial soil organic carbon content.

When a higher amount of organic manure was added (@ 25 and 50% RDFN) the organic carbon increased accordingly. Addition of organic manure increases microbial activity in the soil[15], which might have increased the organic matter contents in soils compared to control. Addition of organic nutrient source might have created environment conducive for the formation of humic acid, stimulated the activity of soil microorganisms resulting in an increase in the organic carbon content of soil[4]. The differences in the organic carbon content with the application of different sources of nutrients might be due to the result of differential rate of oxidation of organic matter by microbes[29]. Treatments receiving only inorganics @ 100% and 125% RDF also shown increase in organic carbon content compared to initial experimental soil. Increasing levels of fertilizer application increased the organic carbon content, which might be due to increased contribution from the biomass as it also observed that increasing levels of fertilizer application increased the crop yield

[28].The decrease in organic carbon content at harvest might be due to loss of applied organic matter by oxidation.

Cation Exchange Capacity:

The data pertaining to cation exchange capacity (CEC) at harvest is presented in table 2. CEC was significantly affected by different treatments. CEC of soils at harvest ranged between 14.1 to 18.9 c mol kg^{-1} with a mean value of 16.2 c mol kg^{-1}. The highest CEC was observed in T_8 (125% RDF + 50% N - FYM). However these four treatments are on par with each other. The lowest was observed in T_1 (100% RDFN).

Soil organic matter and clay minerals are the two most important constituents that contribute for soil CEC. Thus increasing soil organic matter is likely to increase CEC. McConnell *et al.*[17] has reported that applying organic manures at normal agronomic rates (38 to 75 Mg ha^{-1}) can increase the CEC of most mineral soils used for agriculture by a minimum of 10%. These manures are known to decompose in soils to form humus and humid substances, which play a dominant role along with clay micelles in the complex soil reactions that, enhance the CEC of soils [1].

Humus has a highly negatively charged soil component, and is thus capable of holding a large amount of cations. The highly charged humic fraction gives the SOM the ability to act similarly to a slow release fertilizer. Similar results were also reported by Mbah and Mbagwu[16].

Urease activity:

Data pertaining to the urease activity of the soils at tasseling and harvest are presented in the table 3. Urease activity was significantly affected by different treatments at different stages. Urease activity at tasseling ranged between 9.8 to 17.0 µg NH_4^+ - N g^{-1} h^{-1} with a mean value of 13.9 µg NH_4^+ - N g^{-1} h^{-1}. The highest urease activity at tasseling was found in T_{10} (125%RDFN + 50% N- PM) and the lowest was observed in T_1 (100% RDFN). Urease activity at harvest ranged between 6.8 to 9.8 µg NH_4^+ - N g^{-1} h^{-1} with a mean value of 8.3 µg NH_4^+ - N g^{-1} h^{-1}. The highest urease activity at tasseling was found in T_{10} (125%RDFN + 50% N- PM) which was on par with all treatments which included 125% RDFN through urea *i.e*. T_9, T_8, T_7 and T_6.

Urease activity was higher in all treatments which received higher dose of urea compared to similar treatments which received lower dose. The rate of urea hydrolysis of urea by soil urease increases with increase in substrate (urea) concentration until the quantity of urea added is saturating and its activity becomes constant[7]. Urease activity is reported to be positively related to the total N in soil. Organic manure also influenced the urease activity at both stages. Incorporation of organic materials into soil promotes microbial activity and also soil urease activity [19] and the increased levels of urease activity have been generally attributed to increased microbial biomass[12].

Urease activity was higher in poultry manure treatments compared to corresponding combinations of FYM. Similar results were also reported by Rai and Yadav[22]. Urease activity in soils is positively correlated with organic C and total N which are the indices of organic matter content. Burns[8] speculated that increasing urease activity after the addition of organic materials could be due to trigger molecule or promoter released by the decay of organic amendments that stimulates soil organisms to secrete a high level of enzyme. Maximum urease activity with increased rate of nitrogen application along with FYM/ poultry manure to soil might be due to added organic manures which acted as sole source of carbon and energy for microbes by which their population increased with an increase in enzymatic activities as also reported previously by Selvi *et al.*[23]. This was evident from significant positive correlation between urease activity and organic carbon at tasseling (r= 0.5807) and harvest (r= 0.6701*) of crop. Similar relationships with organic carbon and enzyme activities were reported by Bohme and Bohme[5]. Further, the applied organic manures undergo mineralization and provide sufficient nutrition for the proliferation of microbes and their activities in terms of soil enzymes. This statement was further supported by a positive relationship of urease activity with available N, P, K, Fe, Zn, Mn and Cu at both stages. Balanced nutrition of crop under integrated use of fertilizer nitrogen with FYM / poultry manure responsible for better proliferation of root was responsible for maximum activity of enzymes.

TABLES AND FIGURES

Table 1: Effect of integrated nutrient management on drymatter production, grain and stover yield of maize

Treatments	Dry matter production	Grain yield	Stover yield
	(kg ha^{-1})		
T_1 : 100% RDFN	4187	4747	7497
T_2 : 100% RDFN + 25% N – FYM	4618	5291	7973
T_3 : 100% RDFN + 50% N – FYM	5095	5979	8397
T_4 : 100% RDFN + 25% N – PM	4732	5615	8077
T_5 : 100% RDFN + 50% N – PM	5156	6353	8663
T_6 : 125% RDFN	4954	5783	8365
T_7 : 125% RDFN + 25% N – FYM	5255	6284	8968
T_8 : 125% RDFN + 50% N – FYM	5910	6818	9348
T_9 : 125% RDFN + 25 % N – PM	5656	6530	9144
T_{10} :125% RDFN + 50% N – PM	6337	7225	9825
SEm±	256	261	280
CD (P = 0.05)	761	776	833
CV%	8.6	7.5	5.6

Table 2: Effect of integrated nutrient management on physical and physico-chemical properties of soil at harvest of maize

Treatments	Bulk density (Mg m^{-3})	pH	EC (dS m^{-1})	CEC (cmol (p+) kg^{-1})
		(1:2.5)		
T_1 : 100% RDFN	1.47	7.51	0.11	14.1
T_2 : 100% RDFN + 25% N - FYM	1.43	7.49	0.13	15.9
T_3: 100% RDFN + 50% N - FYM	1.41	7.44	0.13	17.6
T_4: 100% RDFN + 25% N - PM	1.45	7.45	0.12	15.1
T_5: 100% RDFN + 50% N - PM	1.43	7.42	0.13	16.4
T_6: 125% RDFN	1.46	7.54	0.11	14.6
T_7: 125% RDFN + 25% N- FYM	1.44	7.37	0.12	16.1
T_8: 125% RDFN + 50% N -FYM	1.41	7.38	0.13	17.9
T_9: 125% RDFN + 25 % N - PM	1.45	7.40	0.12	15.4
T_{10}: 125% RDFN + 50% N - PM	1.44	7.44	0.12	17.2
SEm±	0.03	0.2	0.01	0.9
CD (P =0.05)	NS	NS	NS	NS
CV%	3.80	5.1	10.87	10.5

Table 3: Effect of integrated nutrient management on organic carbon and urease activity of soil under maize crop

Treatments	Urease activity ($\mu g\ NH_4^+$ - N g^{-1} soil h^{-1})		Organic carbon ($g\ kg^{-1}$)	
	At tasseling	At harvest	At tasseling	At harvest
T_1 : 100% RDFN	9.8	6.77	2.0	2.4
T_2 : 100% RDFN + 25% N - FYM	10.5	7.70	2.9	3.2
T_3 : 100% RDFN + 50% N - FYM	12.1	8.33	3.8	3.4
T_4 : 100% RDFN + 25% N - PM	13.5	7.47	2.8	3.0
T_5 : 100% RDFN + 50% N - PM	14.7	8.10	3.6	3.2
T_6 : 125% RDFN	14.5	7.90	2.4	2.6
T_7 : 125% RDFN + 25% N - FYM	14.7	8.87	3.0	3.2
T_8 : 125% RDFN + 50% N - FYM	16.1	9.10	3.9	3.5
T_9 : 125% RDFN + 25 % N - PM	15.6	8.87	3.2	3.0
T_{10} :125% RDFN + 50% N - PM	17.0	9.57	3.7	3.2
SEm±	0.7	0.4	0.2	0.2
CD (P = 0.05)	2.1	1.0	0.6	0.6
CV%	8.8	7.4	10.28	11.16

CONCLUSION

Results indicated that the crop is highly responding to additional dose of nitrogen up to 75 per cent of the recommended dose indicating high nutrient requirement of the crop. Supplementation of increased level of nitrogen through fertilizer urea and locally available FYM/ poultry manure performed well in respect to drymatter production, increased yield components and yield by maize over sole application of fertilizer nitrogen. Bulk density, pH and EC of soils were not influenced by increased level of fertilizer nitrogen application along with FYM/ poultry manure, but CEC of soil was significantly improved. Significant variation in organic carbon and urease activity in soil was observed among treatments both at tasseling and harvest.

Addition of well decomposed FYM not only supplies plant nutrients but also acts as binding material and improves the soil physical properties. Poultry manure has been adjudged to be the most valuable of all bulky organic manures produced and is relatively a cheap source of both macro and micronutrients and can increase soil carbon, soil porosity and microbial activity.

However, the application of organic matter alone to soil is not a complete substitute for inorganic fertilizer and vice-versa and their roles are complementary to each other. Therefore, the combined use of chemical fertilizers and organic manures seems to be the better way to replenish the soil nutrients and sustain crop productivity.

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