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Impact of integrated nutrient management in maize on Physico-chemical properties of soil

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Abstract
The present investigation was conducted at Research Farm, MPUAT, Udaipur during 2019-2020 on integrated nutrient management with maize. Eleven different treatments having inorganic, biofertilizer and organic nutrients sources in various combinations were tested to determine the effect of integrated nutrient management on soil physical and chemical properties as compared to sole inorganic nutrient application. The experimental was conducted in randomized completely block design with three replications. Application of compost lowered down the soil bulk density and slightly overcame the problem of salinity by reducing electrical conductivity and pH as compared to initial value, control and sole fertilizer application. A considerable increase in the values of cation exchange capacity, water holding capacity and organic carbon were also recorded in integrated nutrient management practices indicating their soil health advantage as compared to sole fertilizer use. Seed treatment with biofertilizer and foliar Zn spay did not affected the soil parameters significantly. In conclusion, the organic (5t ha^{-1} Phospo compost) and inorganic (75% NPK) fertilizer (with or without biofertilizer and Zn) had more favourable soil Physio chemical environment.

Keywords: Biofertilizer, phosphorous enriched compost, soil chemical properties, soil physical properties and soil test based nutrient recommendation

Introduction
Globally, crop production is quite challenging due to soil health degradation. Chemical fertilizers are quite promising for gaining higher yields and furnishing stability in crop production. However, over dependence on inorganic fertilizers has been related to poor soil health and crop yield (Sudhakar and Kuppusamy, 2007) [12]. Moreover, continues chemical fertilizers application hampers soil fertility in long run thus it can be a hindrance against sustainable agricultural production (Kannan *et al*., 2013) [3]. Appropriate and conjunctive use of plant nutrients through organic and inorganic sources can provide the solutions to deteriorating soil health and productivity (Urmi *et al.*, 2022) [16].

Soil physical and chemical properties are directly or indirectly related with soil organic carbon therefore any agronomic practice that add organic matter in the soil has direct bearing on soil bulk density, porosity and water holding capacity. Combined use of organic and inorganic nutrient sources might be the right proposition for the improvement of soil physical health (Urmi *et al*., 2022) [16]. Application of organic manures along with inorganic fertilizers was more effective for moderating soil pH and electrical conductivity as compared to the treatments lacking manure application (Lal Bahadur *et al.*, 2012) [5].

Keeping in this view, a field study was conducted to examine the effects of integrated use of diverse (biological, organic and inorganic) nutrient sources on soil physico-chemical properties under maize cultivation and to find out the best nutrient sources and their combination for sustaining the soil health under nutrient exhaustive maize crop.

Materials and Methods
Study site
This study was conducted on the field site of Rajasthan College of Agriculture, Udaipur, Rajasthan during *Kharif* 2019 and *Kharif* 2020. The experimental site is located at an altitude of 579.5 m above mean sea level (24°34′N; 73°42′E). The region falls under sub-tropical climatic conditions characterized by mild winters and moderate summers associated with higher relative humidity during the months of July to September.

This region receives an average precipitation of 637 mm, most of which is contributed by south west monsoon from July to September. The soil of the experimental site is clay loam in nature belongs to Vertisols (Fine, iso-hyperthermic, montmorillonitic and Typic Haplusterts). The soil are slightly saline (pH 8.32) and medium in organic carbon content (0.63%).

Treatment details
Eleven nutrient management treatments were tested in randomized complete block design and replicated trice (Table 1).

Table 1: Treatment Details

Treatment details	Short form
Control	**CK**
125% NPK (STR)	125% NPK
100% NPK (STR) + Foliar spray of Zn @ 0.5%	100% NPK + Zn
100% NPK (STR) + *Azotobacter* + PSB	100% NPK + BF
100% NPK (STR) + *Azotobacter* + PSB + Foliar spray of Zn @ 0.5%	100% NPK + BF + Zn
75% NPK (STR) + 5 t ha^{-1} Phosphorus Enriched Compost	75% NPK + 5 t ha^{-1}PEC
75% NPK (STR) + 5 t ha^{-1} Phosphorus Enriched Compost + *Azotobacter* + PSB	75% NPK + 5 t ha^{-1} PEC + BF
75% NPK (STR) + 5 t ha^{-1} Phosphorus Enriched Compost + *Azotobacter* + PSB + Foliar spray of Zn @ 0.5%	75% NPK + 5 t ha^{-1}PEC + BF + Zn
50% NPK (STR) + 5 t ha^{-1} Phosphorus Enriched Compost	50% NPK + 5 t ha^{-1} PEC
50% NPK (STR) + 5 t ha^{-1} Phosphorus Enriched Compost + *Azotobacter* + PSB	50% NPK + 5 t ha^{-1} PEC + BF
50% NPK (STR) + 5 t ha^{-1} Phosphorus Enriched Compost + *Azotobacter* + PSB + Foliar spray of Zn @ 0.5%	50% NPK + 5 t ha^{-1} PEC + BF + Zn

Crop management
The maize variety PEHM-3 was planted during first week of July in both the years. Planting was done by keeping 60 cm row to row and 20 cm plant to plant spacing. The dose of urea**,** diammonium phosphate and muriate of potash was decided based on soil test based recommendation (STR). Phosphorus enriched compost was prepared using maize stover, rock phosphate and waste mica. To reduce the C:N ratio of maize stover, urea solution @ 0.25 kg N per 100 kg of stover and fresh cow dung @ 10 kg per 100 kg of stover was added as natural inoculants. Moreover, Phosphate solubilizing microorganism (*Aspergillus awamori, Pseudomonas striata and Bacillus polymixa*) @ 50 g per 100 kg was also added to maize stover. The fully decomposed PEC contained 0.85% N, 1.21% P and 1.15% K and 115 ppm Zinc. The phospho-enriched compost was applied in the field as per treatments and was thoroughly mixed at the time of last ploughing. Seed treatment method was used for *Azotobacter* and PSB (*Bacillus megatherium var. phosphaticum*) inoculation. Foliar application of $ZnSO_4.7H_2O$ @ 0.5% was carried out at 35 days after sowing as per treatment. All the recommended package of practices was followed to raise the crop.

Soil sampling and analysis
Representative soil samples were collected from 0-15 cm depth before sowing and after crop harvesting. The soil analysis for various physical and chemical parameters was carried out by the methodology given in Table 2.

Table 2: Methods to be adopted for analysis the physical-chemical properties of soil and their value at the beginning of the experiment

S. No.	Determination	Methods followed	Reference	Initial value
(1)	Bulk density	Undisturbed core sampler method	Singh (1980) [11]	1.45 Mg m^{-3}
(2)	Particle density	Relative density bottles method	Richards (1954) [10]	2.53Mg m^{-3}
(3)	Porosity (%)	Calculated by using the formula USDA, Hand book No. 60 $\text{Porosity (\%)} = \frac{PD - BD}{PD} \times 100$	Richards (1954) [10]	42.7%
(4)	Water holding capacity	Gravimetric method	Veihmeyer and Hendrickson (1931) [14]	39.3%
(5)	Soil pH	Using pH meter in 1:2 soil water suspension	Richards (1954) [10]	8.32
(6)	Electrical conductivity	ECe was measured with the help of "Solubridge" in soil saturation extract	Richards (1954) [10]	0.847
(7)	Organic carbon	Walkley and Black's rapid titration method	Walkley and Black (1934) [15]	0.63%
(8)	Cation exchange capacity	Schollenberger's method using neutral normal ammonium acetate	Metson (1956) [8]	

Statistical analysis
The data was analyzed by using SAS statistical software (ver.9.2; SAS Institute., Cary, NC, United States).The significant differences between means were identified using Fisher least significant differences (LSD) at P = 0.05.

Result and Discussion
Bulk density
In the present experiment the bulk density was ranged from 1.36 to 1.47 Mg $m^{-3}$and was significantly influenced by the integrated nutrient management practices (Table 3). Slight decline in bulk density was seen with the addition of phosphorus enriched compost. The bulk density was reduced under integrated nutrient management (with compost) over control and sole fertilizer treatments but the quantity of reduction was significant only when compost was applied @ 5 t ha^{-1}. The decrease in bulk density with compost addition is related with increased soil organic matter content, which reduces soil compaction and therefore bulk density (Tana and Woldesenbet, 2017) [13]. The decline in bulk density with increase in organic matter content was also reported by Dutta *et al.* (2018) [2] and Kranz *et al.* (2020) [4]. Moreover, the

decomposition of compost may produce cementing agents that convert soil micro-pores into macro-pores and thus lowers the soil bulk density (Dutta *et al*., 2018) [2].

Particle density
The particle density of soil was not influenced significantly due to the integrated nutrient management. It ranged between 2.58 to 2.61 Mg m^{-3} under various treatments (Table 3).

Porosity
Phosphorus enriched compost based fertilizer management strategies in this study had non-significant but positive effect on soil porosity (Table 3). Porosity followed the reverse trend of bulk density. Treatment that received compost reported the highest soil porosity (46.3-47.1%) while control plots had the least (43.6%). This increased porosity with the application of compost may be due to addition of soil organic matter. Soil organic matter helps in soil structure formation and stabilization therefore; it plays a key role in making soil more porous (Tana and Woldesenbet, 2017) [13].

Water holding capacity
The application of compost caused a considerable improvement (up to 6.6%) in water soil holding capacity as compared to its initial value (39.4%) (Table 3). The highest water holding capacity (45.9%) was obtained under 75% NPK + 5 t ha^{-1} PEC + BF + Zn treatment whereas the lowest (39.9%) was recorded under control. The improved soil aggregation, higher porosity and more stable aggregates under compost plots may be responsible for such desirable effect on soil water retention capacity and soil water dynamics (Bhatacharyya *et al*., 2008) [1]. Similar type of results of phosphorous enriched compost use on water holding capacity was also registered by Kranz *et al.* (2020) [4] and Pandiyana *et al.* (2020) [9].

Table 3: Effect of integrated nutrient management practices on soil physical properties (after two years)

Treatment	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Porosity (%)	Water holding capacity (%)
CK	1.47	2.61	43.6	39.9
125% NPK	1.45	2.60	44.9	43.6
100% NPK + Zn	1.46	2.61	45.5	41.6
100% NPK + BF	1.45	2.60	45.7	41.9
100% NPK + BF + Zn	1.44	2.60	45.7	42.5
75% NPK + 5 t ha^{-1}PEC	1.38	2.59	46.5	45.5
75% NPK + 5 t ha^{-1} PEC + BF	1.37	2.58	46.8	45.8
75% NPK + 5 t ha^{-1}PEC + BF + Zn	1.36	2.58	47.1	45.9
50% NPK + 5 t ha^{-1} PEC	1.40	2.59	45.9	44.6
50% NPK + 5 t ha^{-1} PEC + BF	1.39	2.59	46.3	45.0
50% NPK + 5 t ha^{-1} PEC + BF + Zn	1.39	2.59	46.3	45.0
S.Em±	0.03	0.04	1.50	0.83
CD at 5%	0.07	NS	NS	2.46
Initial value	1.45	2.53	42.7	39.3

Note: CK=Control; PEC=phosphorous enriched compost; BF= biofertilizer

Soil pH
The pH of soil after two years of experimentation varied from 8.27-8.38 (Table 4). The highest pH observed in the soils of the 125% NPK plot (8.38). Due to the application of compost @ rate 5 t ha^{-1} and 5 t ha^{-1}, the pH were reduced to 8.27 and 8.30, respectively. The comparatively lower pH under compost plots which might be due to the production of organic acids from decomposition of phospho-compost. Compared to the initial value, the soil pH was increased in chemical fertilized plot, remained constant in control and decreased at compost plots.

Electrical conductivity
The visualization of the data from Table 4 showed narrower and non-significant variation in EC values within all the treatments (0.814-0.875 dSm^{-1}).Like pH, electrical conductivity were also higher at 125% NPK treatment (8.75 dSm^{-1}) followed by 100% NPK+Zn (8.65 dSm^{-1}). Integration of organic and inorganic fertilizers showed slight decrease (up to 0.061 dSm^{-1}) in electrical conductivity than inorganic fertilizers. The release of organic acids during organic matter decomposition might have lowered down soil electrical conductivity. Similar phospho compost on soil chemical properties were also reported by Meena (2017) [7] and Meena (2019) [6]. After two years experiment, the electrical conductivity was declined due integrated nutrient management and enhanced by chemical fertilizer use as compared to its initial value.

Cation Exchange Capacity
The combined application of organic and inorganic fertilizers significantly improved cation exchange capacity of soil. The maximum value of cation exchange capacity (15.59 Cmol(p+) kg^{-1}) of soil was obtained under 75% NPK + 5 t ha^{-1} PEC + BF + Zn which was significantly at par with 75% NPK + 5 t ha^{-1} PEC + BF treatment (15.48 Cmol(p+) kg^{-1}) and 75% NPK + 5 t ha^{-1} PEC (15.12 Cmol(p+) kg^{-1}) while the lowest soil cation exchange capacity (112.0 Cmol (p+) kg^{-1}) was recorded under control (Table 4). Tana and Woldesenbet (2017) [13] also reported the higher cation exchange capacity with integrated use of organic manure with inorganic fertilizer. Leaching of bases with heavy rains and lack of fertilizer replenishment of these bases resulted in least cation exchange capacity under control plot. Compared to initial value, up to 32% higher cation exchange capacity was after two with compost addition.

Soil organic carbon
The treatments comprising of chemical fertilizer and compost significantly increased the soil organic carbon contents over the control (Table 4). Maximum organic carbon content (0.799%) was observed with 75% NPK + 5 t ha^{-1} PEC + BF + Znand75% NPK + 5 t ha^{-1} PEC + BF (0.785) and minimum (0.641%) at control. Among organic and inorganics, organic

treatments showed higher organic carbon content. Addition of 10 t compost ha^{-1} (5-5 t ha^{-1} each year) resulted into 0.16% improvement in soil organic carbon than its initial value. This increase in organic carbon content of soil in the aforesaid treatments might be due to the buildup of humus by application of compost in these treatments. Similar kinds of finding were also reported by Dutta *et al*. (2018) [2].

Table 4: Effect of integrated nutrient management practices on soil chemical properties (after two years)

Treatment	pH	EC (dSm^{-1})	OC (%)	CEC (c mol (P^{+}) kg^{-1})
CK	8.32	0.841	0.641	12.00
125% NPK	8.38	0.875	0.702	13.22
100% NPK + Zn	8.34	0.865	0.666	12.18
100% NPK + BF	8.33	0.855	0.676	12.49
100% NPK + BF + Zn	8.32	0.855	0.687	12.82
75% NPK + 5 t ha^{-1}PEC	8.28	0.824	0.785	15.12
75% NPK + 5 t ha^{-1} PEC + BF	8.27	0.814	0.794	15.48
75% NPK + 5 t ha^{-1}PEC + BF + Zn	8.27	0.814	0.799	15.59
50% NPK + 5 t ha^{-1} PEC	8.31	0.845	0.712	13.97
50% NPK + 5 t ha^{-1} PEC + BF	8.30	0.835	0.726	14.18
50% NPK + 5 t ha^{-1} PEC + BF + Zn	8.29	0.835	0.731	14.31
S.Em±	0.03	0.011	0.008	12.00
CD at 5%	0.087	0.032	0.023	0.28
Initial value	8.32	0.847	0.630	0.82

Note: CK=Control; PEC=phosphorous enriched compost; BF= biofertilizer; OC-organic carbon; EC= electrical conductivity; CEC=cation exchange capacity

Conclusion

The sole use of chemical fertilizers without organic compost had negative impact on soil health. Integration of organic and inorganic nutrient sources resulted in improvement in soil physico-chemical properties. Nutrient management with 75% NPK + 5 t ha^{-1} phosphorus enriched compost with or without biofertilizer and Zn spray had maximum positive effect on soil health. Therefore, in nutshell the integrated and balance application of organic and inorganic nutrient is crucial for long lasting crop cultivation.

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