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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(8): 228-231

www.thepharmajournal.com
Received: 24-05-2023
Accepted: 28-06-2023

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Influence of integrated nutrient management options of mustard on physico-chemical properties of vertisols

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Abstract
A field experiment was conducted during the Rabi season in 2021-22 and 2022-23. Both years experiments were suited on heavy clay soil at Agriculture Research Farm, College of Agriculture, Banda University of Agriculture & Technology, Banda. Experiment was laidout in randomized block design in three replications with 15 treatments as Influenced integrated nutrient management options of mustard on physico-chemical properties of Vertisols. Nutrients in different treatments were applied through organic and inorganic nutrient sources as and when required as per treatment combination. It was recorded that integrated application nutrients (T_7- 100% RDF+5 ton FYM+ bio-consortia +Nano Zn) reduces the soil bulk density and particle density and increase the porosity in compare to control. the Soil pH and EC were numerically different within the treatments but statistically non-significant. The influence of the INM module on both soil organic carbon and total carbon of soil numerically slightly improved but statistically it was also non- significantly. Overall, the application of organic and inorganic sources of nutrients improves physico- chemical properties of soil.

Keywords: Soil pH, electrical conductivity, organic carbon, bulk and particle density

Introduction
Integrated Nutrient Management (INM) plays a crucial role in improving fertility and productivity in soil and crops. INM involves the balanced and judicious use of various sources of nutrients, including organic and inorganic fertilizers, to enhance soil fertility, promote sustainable agriculture, and achieve higher crop yields. INM aims to improve soil health and receive a balance supply of essential nutrients, including nitrogen, phosphorus, potassium, and micronutrients. This helps to prevent nutrient deficiencies and ensures optimal growth and development throughout the crop's life cycle. For improving soil fertility and increasing crop productivity management of physico-chemical properties of soil is important.

Soil pH plays a critical role in enhancing soil fertility as it directly influences nutrient availability, microbial activity, and overall soil health. The pH scale ranges from 0 to 14, with pH 7.0 considered neutral. For example, in acidic soils (pH below 6.0), essential nutrients like phosphorus, calcium, and magnesium may become less available to plants. On the other hand, alkaline soils (pH above 7.5) can limit the availability of nutrients such as iron, manganese, and zinc. Maintaining the suitable pH level ensures a balanced nutrient supply, promoting better plant growth and higher yields. Soil electrical conductivity (EC) plays a significant role in crop production as it provides valuable information about the soil's salinity, nutrient levels, and water management. Here are the key roles of soil EC in crop production: Excessive salinity can inhibit water uptake by plant roots, leading to dehydration and reduced crop productivity.

Soil organic carbon plays a remarkable role in soil fertility and overall in soil health. It is a key component of soil organic matter, which consists of the remains of plants, animals, and microorganisms in various stages of decomposition. Soil organic carbon provides numerous benefits that contribute to soil fertility. Organic carbon acts as a nutrient reservoir in the soil. It has a high cation exchange capacity (CEC), allowing it to attract and retain essential nutrients like nitrogen, phosphorus, potassium, calcium, and magnesium. The significant role in improving soil structure. It acts as a cementing agent, binding soil particles together and creating stable aggregates. This enhances soil porosity, aeration, and water infiltration, which are vital for root growth, nutrient uptake, and overall plant health. Sustainable agricultural practices that promote soil organic carbon accumulation contribute not only to improved soil fertility but also to long-term soil health, environmental sustainability, and climate change mitigation.

Particle density plays a vital role in influencing various physico-chemical properties of soil. It is an essential parameter that helps in understanding the soil's composition and behavior. Bulk density is an important indicator of soil compaction and porosity. Higher particle density generally leads to higher bulk density, which means there is less pore space available for air and water. Soils with lower particle density generally have higher cation exchange capacity (CEC) because of their increased surface area, which allows them to retain and supply more essential nutrients to plants. Particle density, in combination with organic matter content, influences soil texture. Soils with higher particle density and lower organic matter content tend to have a coarser texture (sandy), while those with lower particle density and higher organic matter content have a finer texture (clayey). It is summarized that particle density is a fundamental property that affects various aspects of soil, like behavior, including water retention, aeration, nutrient availability, root growth, and erosion resistance.

Materials and Methods

Table 1: Treatment details of study.

Treatment details	Treat. S. No.
Control	T_1
100% RDF (90:50:30:18)	T_2
100% RDF+5-ton FYM	T_3
100% RDF+ Bio-consortia	T_4
100% RDF+ Nano Zn	T_5
100% RDF+5-ton FYM+ Bio-consortia	T_6
100% RDF+5-ton FYM+ Bio-consortia+ Nano Zn	T_7
75% RDF+5-ton FYM	T_8
75% RDF+ Bio-consortia	T_9
75% RDF+5-ton FYM + Bio-consortia	T_{10}
75% RDF+5-ton FYM +Bio-consortia+ Nano Zn	T_{11}
STCR (for gird region) developed at JNKVV	T_{12}
STCR+5-ton FYM+ Bio-consortia	T_{13}
STCR+ 5-ton FYM +Bio-consortia +Nano Zn	T_{14}
75% STCR +5-ton FYM + Bio-consortia + Nano Zn	T_{15}

This experiment was conducted at Agriculture Research Farm, CoA, Banda during the rabi season 2021-2022 and 2022-23, which is located at a latitude of 25.528259° N and longitude of 80.335688° E with a mean sea level of 168 m. The zone is hills and part of the Vindhyan plateau, Uttar Pradesh and has a semi-arid to sub-tropical climate. The experiment was laid out in a randomized block design (RBD) with fifteen treatments comprising in three replications. The size of each plot was 4.5×3.7 m. All recommended packages and practices (RDF= 90, 50,30,18 and STCR 103, 46.7, 52.5 N, P, K, S with Bio-consortia and Nano Zn) were followed during the experiment. The weather data for the experimental period was recorded at the meteorological observatory of BUAT, Banda during the crop growing season. Soil samples from a depth of 0-15 cm were collected as initial and after harvest of crop to determine the physical and chemical properties of soils such as pH, Electrical conductivity (dS m^{-1}), soil organic carbon (%), Total carbon (%), bulk density (Mg m^{-3}), particle density (Mg m^{-3}) textural class (%) and soil color.

Table 2: Methods adopted and procedure used in soil analysis.

Particulars	Method/ formula	References
Soil pH 1:2.5	Electrometrically using glass Electrode	Jackson, 1973 [3]
EC (dS m^{-1} at 25 °C)	Conductometrically using 1:2.5 soil water suspension	Jackson, 1973 [3]
Organic carbon (%)	Wet oxidation	Walkley and Black's (1934) [11]
Total soil organic carbon (%)	Dry combustion method by CHNS elemental analyzer	Michael Thompson (2008) [5]
Bulk density (gcm^{-3})	$BD = \frac{W}{V}$	(Blake and Hartge, 1986) [2].
	W= Weight of oven-dry soil (g)	
	V = Volume of soil sample (cm^{-3})	
Particle density (g cm^{-3})	$PD = \frac{W}{Vs}$	(Piper, 1966) [12]
	W= Weight of oven-dry soil (g)	
	Vs = Volume of soil solid particle (cm^{-3})	
Soil porosity (%)	$\text{Porosity} = \frac{(PD - BD)\times 100}{PD}$	
	PD = Particle density (g cm^{-3})	
	BD= Bulk density (g cm^{-3})	

Table 3: Effect of integrated nutrient management on physical properties of soil.

Treat. Syb	Treatment details	Bulk density Mg m^{-3}			Particle density Mg m^{-3}			Soil porosity (%)		
		2021-22	2022-23	Pool data	2021-22	2022-23	Pool data	2021-22	2022-23	Pool data
T_1	Control	1.34	1.34	1.34	2.68	2.68	2.68	49.94	49.85	49.83
T_2	100% RDF(NPKS)	1.33	1.33	1.33	2.66	2.66	2.66	49.91	49.88	49.85
T_3	100% RDF+5-ton FYM	1.32	1.33	1.33	2.65	2.65	2.65	49.94	50.16	50.00
T_4	100% RDF+ Bio-consortia	1.33	1.33	1.33	2.65	2.66	2.66	50.04	49.94	49.94
T_5	100% RDF+ Nano Zn	1.33	1.32	1.33	2.66	2.67	2.67	49.94	49.52	49.68
T_6	100% RDF+5-ton FYM+ Bio-consortia	1.32	1.33	1.33	2.65	2.66	2.66	49.97	50.13	49.90
T_7	100% RDF+5-ton FYM+ Bio-consortia+ Nano Zn	1.32	1.32	1.32	2.64	2.62	2.62	50.13	50.51	50.55
T_8	75% RDF+5-ton FYM	1.33	1.34	1.33	2.66	2.67	2.67	49.92	50.26	50.04
T_9	75% RDF+ Bio-consortia	1.33	1.33	1.33	2.66	2.67	2.67	49.96	49.95	49.90
T_{10}	75% RDF+5-ton FYM + Bio-consortia	1.32	1.34	1.33	2.65	2.65	2.65	49.80	50.55	50.12
T_{11}	75% RDF+5-ton FYM Bio-consortia+ Nano Zn	1.32	1.32	1.32	2.64	2.64	2.64	50.12	50.11	50.14
T_{12}	STCR (for gird region) developed at JNKVV	1.33	1.33	1.33	2.66	2.66	2.66	49.87	49.80	49.78
T_{13}	STCR+5-ton FYM+ Bio-consortia	1.32	1.33	1.33	2.64	2.66	2.66	49.94	49.99	49.75
T_{14}	STCR+ 5-ton FYM +Bio-consortia +Nano Zn	1.32	1.32	1.32	2.64	2.64	2.64	50.13	50.04	50.07
T_{15}	75% STCR +5-ton FYM + Bio-consortia + Nano Zn	1.32	1.33	1.32	2.64	2.64	2.64	49.92	50.35	50.09
	SEm±	0.01	0.01	0.01	0.01	0.01	0.01	0.20	0.35	0.03
	CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
	CV(%)	0.70	0.81	0.65	0.72	0.75	0.75	0.68	1.20	1.04

Table 4: Effect of integrated nutrient management on physico-chemical properties of soil.

Treat. Syb	Treatment details	pH (1:2.5)			EC (dSm^{-1})			Organic carbon (%)			Total carbon (%)		
		2021-22	2022-23	Pool data	2021-22	2022-23	Pool data	2021-22	2022-23	Pool data	2021-22	2022-23	Pool data
T_1	Control	7.83	7.82	7.83	0.18	0.18	0.18	0.37	0.37	0.37	1.39	1.39	1.39
T_2	100% RDF(NPKS)	7.80	7.79	7.80	0.19	0.18	0.19	0.38	0.38	0.38	1.40	1.41	1.41
T_3	100% RDF+5-ton FYM	7.71	7.67	7.69	0.19	0.19	0.19	0.38	0.39	0.39	1.42	1.42	1.42
T_4	100% RDF+ Bio-consortia	7.75	7.75	7.75	0.19	0.19	0.19	0.38	0.39	0.38	1.41	1.41	1.41
T_5	100% RDF+ Nano Zn	7.71	7.71	7.71	0.20	0.20	0.20	0.37	0.38	0.38	1.40	1.40	1.40
T_6	100% RDF+5-ton FYM+ Bio-consortia	7.69	7.61	7.65	0.21	0.21	0.21	0.39	0.40	0.39	1.42	1.42	1.42
T_7	100% RDF+5-ton FYM+ Bio-consortia+ Nano Zn	7.65	7.53	7.59	0.20	0.20	0.20	0.40	0.41	0.40	1.42	1.43	1.43
T_8	75% RDF+5-ton FYM	7.82	7.82	7.82	0.19	0.19	0.19	0.38	0.39	0.38	1.41	1.41	1.41
T_9	75% RDF+ Bio-consortia	7.72	7.72	7.72	0.19	0.19	0.19	0.38	0.38	0.38	1.40	1.40	1.40
T_{10}	75% RDF+5-ton FYM + Bio-consortia	7.70	7.69	7.70	0.20	0.20	0.20	0.38	0.39	0.39	1.41	1.42	1.42
T_{11}	75% RDF+5-ton FYM Bio-consortia+ Nano Zn	7.65	7.52	7.58	0.20	0.20	0.20	0.39	0.39	0.39	1.42	1.43	1.43
T_{12}	STCR (for gird region) developed at JNKVV	7.82	7.82	7.82	0.19	0.19	0.19	0.38	0.38	0.38	1.40	1.40	1.40
T_{13}	STCR+5-ton FYM+ Bio-consortia	7.79	7.78	7.79	0.20	0.20	0.20	0.38	0.39	0.38	1.41	1.42	1.42
T_{14}	STCR+ 5-ton FYM +Bio-consortia +Nano Zn	7.65	7.52	7.58	0.20	0.20	0.20	0.39	0.40	0.40	1.42	1.42	1.42
T_{15}	75% STCR +5-ton FYM + Bio-consortia + Nano Zn	7.63	7.62	7.63	0.20	0.20	0.20	0.38	0.39	0.39	1.41	1.42	1.42
	SEm±	0.06	0.08	0.07	0.01	0.006	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	CV(%)	1.43	1.78	1.52	5.30	5.33	5.32	3.03	3.00	3.02	1.03	1.04	1.03

Results and Discussions

Data is presented in table No.3. related to physical and physico-chemical properties of the experimental field reflected that bulk density of soil varied from (1.32-1.34 Mg m^{-3}) along with pool data during both years. A little bit variation in BD of treatment plot was observed from the initial value (1.34 Mg m^{-3}) in both years. Lowest BD (1.32 Mg m^{-3}) was observed in treatment T_7 (100% RDF+5 ton FYM+ bio-consortia +Nano Zn) during the study period and it was higher in control. Numerically value of BD were different in various treatments but statistically it was non-significant. Lower value of BD in FYM and bio-consortia treated plot may be due to soil become porous and finer. Our findings in the agreements of earlier workers Bhattacharya *et al.* (2004) [1] and Nikam *et al.* (2006) [6].

The particle density of soil varied from 2.64 - 2.68 Mg m^{-3} and was more or less similar to initial values. Pool data also varies from 2.62-2.68 Mg $m^{-3}$and has similar trends of variation as observed in first and second year data. Integrated application of organic and inorganic sources of nutrients had lowering effects on PD of soil and it was 2.62 Mg m^{-3} in these treatments. Similar results reported by Majumdar *et al* (2010) [7], Tripathi *et al.* (2011) [10].

Soil porosity of the experimental field is varied from 49.85% to 50.55% in both years and in pool data also. Increasing trends in soil porosity was found with the combined application of organic and inorganic sources of nutrient. Various workers also reported the same results (Bhattacharya *et al.* 2004) [1].

Soils of the experimental field was analyzed for pH and treatment wise recorded value presented in table No:4.0. Critical review of analytical data revealed that highest soil pH of 7.83 and lowest soil pH 7.65 was found in treatment T_1 (control) and T_7 (100% RDF+5 ton FYM+ bio consortia +Nano Zn) respectively in 2021-22 and similar trends were observed in 2022-23 and in pool data also. Statistically soil pH was non-significant but it had positive effect on nutrient availability to crop and consequently mustard yield has been increased. Our study is supported with the finding of Khanday *et al.* (2012) [4] and Mishra *et al*. (2022) [9].

Soluble salt concentration (EC) of the soil was varies from 0.18-021 dSm^{-1} during both the years and in pooled data also. Values of EC numerically differ from each other within the treatments but significant effect of different treatments was not found. The slightly lowering effects of organic sources of nutrients on EC were marked. our results are in agreement with the findings of earlier co-workers, Saha *et al.* (2010) [7-8] and Majumdar *et al* 2010) [7].

Trend of a slight improvement in the organic carbon content of soil from the initial valve (0.36%) to second year value (0.41%) was recorded during experimentation. Numerically organic carbon values are different among the treatment but statistically non-significant. Improvement in organic carbon is positive indication in improvement of soil properties. Improvement in organic carbon might be due to the application of FYM and Bio consortia and mineralization of organic matter. Several workers reported the same results (Saha *et al.* 2010, and Majumdar *et al.* 2010) [7-8].

Total carbon (%) varies from 1.39 (T_1-control) to 1.43 T_7 (100% RDF+5 ton FYM+ bio consortia +Nano Zn). Statistical analysis of total carbon resulted non-significant. Integration of nutrient sources may improve the total carbon content is soil. finding of this study are supported by results of other researchers also Mishra *et al*. (2022) [9], Bhattacharya *et al.* (2004) [1] and Khanday *et al.* (2012) [4].

Conclusion

It is concluded that the various levels of organic and inorganic sources of nutrients applied in the experiment, treatment T_7 - (100% RDF+5 ton FYM+ bio consortia +Nano Zn) was found given best response among all the treatment combinations. Critical review of revealed that pool data bulk density (1.32 $Mg\ m^{-3}$), particle density (2.62 $Mg\ m^{-3}$), pore space (50.55%), pH (7.59), EC (0.20 dsm^{-1}), organic carbon (0.40%), were positively affected after two year of experimentation due to application of integrated nutrient management.

Acknowledgments

Authors are highly thankful to BUAT Banda, for their help in various aspects of this research work were gratefully acknowledged help and support. This work is the part of Ph.D. Thesis to be summitted to Banda University of Agriculture Technology, Banda.

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