Correlation of Physical Properties with Yield & Uptake of N, P and K by the effect of Inorganic Fertilizers and Organic Manures under Wheat-Maize Cropping Sequence Grown on Normal and Saline-Sodic Inceptisol

Abstract

The present study was conducted at PGI Research farm, Department of Soil Science and Agriculture Chemistry, Post Graduate Institute, MPKV., Rahuri during *Rabi*-2021 and *Summer*-2022. The experiment consists of eight treatments in the wheat crop *viz*., T_1: RDN (50% N) + 50% N through FYM, T_2: RDN (50% N) + 50% N through vermicompost, T_3: RDN (50% N) + 50% N through poultry manure, T_4: (50% N) + 50% N through press mud compost, T_5: (50% N) + 50% N through goat manure, T_6: (50% N) + 50% N through urban compost T_7: GRDF (120:60:40 N:P_2O_5:K_2O kg ha^{-1}) + 10 t FYM ha^{-1} and T_8: absolute control. In the maize crop, treatments T_1 to T_6 received 50% of the recommended dose of nitrogen (RDN) through inorganic fertilizer, with residual nitrogen applied to wheat through farmyard manure (FYM), vermicompost, poultry manure, press mud compost, goat manure, and urban compost, respectively and T_7: GRDF (120:60:40 N: P_2O_5:K_2O kg ha^{-1}) + 5 t FYM ha^{-1} and T_8: Absolute control were also included. These treatments replicated thrice in Randomized Block Design. The results showed soil temperature and soil moisture tension exhibit a negative correlation, whereas soil moisture content, aggregate stability, hydraulic conductivity and soil available water content demonstrate a positive correlation with grain yield, straw yield and uptake of nitrogen (N), phosphorus (P) and potassium (K) at the 5% and 1% levels of significance in both wheat and maize under normal and saline-sodic Inceptisol.

Keywords: *Inorganic fertilizer, organic manures, saline-sodic soil, physical properties, residual effect*

1. Introduction

The maize-wheat cropping system holds significant importance in addressing local food requirements and ensuring food security for India's ever-growing population. This system, featuring the cultivation of maize (*Zea mays L.*) and wheat (*Triticum aestivum*), is widely recognized as the primary and popular double cropping approach, especially in the irrigated regions of northwestern India [1]. Although maize is traditionally grown during the monsoon season, the maize-wheat combination remains the prevailing maize-based system, covering approximately 1.8 million hectares. This system ranks as the third major crop rotation in India and plays a vital role, contributing 3.0% to the nation's overall food production [2]. Additionally, it serves as a crucial factor in sustaining the country's food supply.

The physical characteristics of soil hold significant importance because they play a crucial role in determining the interactions between soil, air and water within the soil horizons. Parameters such as bulk density, aggregate stability, hydraulic conductivity, water availability, maximum water-holding capacity and infiltration rate serve as key indicators to assess the soil's suitability for successful plant growth. These physical attributes influence various aspects, including the oxygen content in the soil, the movement of water through or within the soil and the ease with which roots can penetrate the soil [3]. The incorporation of organic manures alongside chemical fertilizers can contribute significantly. Organic manures aid in increasing soil organic matter content, thereby enhancing organic carbon levels. This, in

turn, promotes soil aggregation and stability, reduces soil compaction and increases both porosity and the soil's capacity to retain water [4].

Chemical fertilizers have the advantage of rapidly restoring soil fertility, as the nutrients they contain become readily available to plants once the fertilizers dissolve in the soil [5]. Consequently, farmers have placed a strong emphasis on the use of chemical fertilizers to boost agricultural productivity [6]. Inorganic fertilizers, being water-soluble and containing all the essential nutrients in readily usable forms, are particularly effective for promoting rapid plant growth. Their quick and efficient action is attributed to their high nutrient content, requiring only small quantities to enhance productivity [7].

A well-balanced approach involving the combined use of fertilizers and manure stands as a highly effective strategy for preventing the depletion of organic matter and the rapid deterioration of soil's physical attributes, particularly its structure [8]; [9]. Integrated nutrient management practices have been developed as efficient methods to rejuvenate both soil's physical properties and chemical fertility while enhancing soil organic matter levels. The introduction of organic matter into the soil leads to an increase in its organic carbon content, which, whether directly or indirectly, impacts on growth and yield parameters of crops [10].

2. Material and Method

The research trials took place at the PGI Research Farm within the Department of Soil Science and Agricultural Chemistry at Mahatma Phule Krishi Vidyapeeth, Rahuri. The experimental plot selected was characterized as a level and uniform area with moderate soil depth, classified as an Inceptisol. Geographically, the experimental site was situated at a latitude of 19.034° N and a longitude of 74.064° E, with an elevation of 513 meters above sea level. This region is positioned on the Eastern side of the Western Ghats in Maharashtra. The climate in this area is categorized as a regional steppe climate, characteristic of a semiarid tropical region. It features dry and hot summers, along with cool winters, and falls within the agro-climatic zone known as the "Scarcity zone. The initial status of both normal and saline-sodic Inceptisol described in table 1.

Table 1. Initial Soil properties of normal and saline-sodic Inceptisol

Sr. No.	Soil properties	Values	
		Normal soil	Saline-sodic soil
A	**Chemical properties**		
1	pH (1:2.5)	8.32	8.41
2	EC (dS m^{-1})	0.29	2.1
3	Organic carbon (%)	0.42	0.46
4	Calcium Carbonate (%)	8.77	11.68
5	Available nitrogen (kg ha^{-1})	182.6	187.1
6	Available phosphorus (kg ha^{-1})	14.16	13.11
7	Available potassium (kg ha^{-1})	389.6	361.3

8	DTPA extractable Fe (mg kg^{-1})	4.09	4.01
9	DTPA extractable Mn (mg kg^{-1})	10.90	10.64
10	DTPA extractable Zn (mg kg^{-1})	0.323	0.307
11	DTPA extractable Cu (mg kg^{-1})	0.724	2.12
12	CEC (cmol(p^{+}) kg^{-1})	57	52
12	ESP (%)	0.25	17.69
B	**Heavy metals**		
1	Pb (mg kg^{-1})	Traces	Traces
2	Cd (mg kg^{-1})	Traces	Traces
3	Cr (mg kg^{-1})	Traces	Traces
4	Ni (mg kg^{-1})	Traces	Traces
C	**Saturation paste extract analysis**		
1	pHs	8.26	8.37
2	ECe	1.33	5.76
3	Ca^{2+} (meL^{-1})	7.19	24.92
4	Mg^{2+}(meL^{-1})	6.80	19.41
5	Na^{+}(meL^{-1})	0.11	11.28
6	K^{+}(meL^{-1})	0.15	0.16
7	CO_3^{2-} (meL^{-1})	-	-
8	HCO_3^{-}(meL^{-1})	5.6	9.4
9	Cl^{-} (meL^{-1})	5.8	24.6
10	SO_4^{2-} (meL^{-1})	2.2	22.3

The experiment consist of eight treatments in wheat crop *viz*., T_1: RDN (50% N) + 50% N through FYM, T_2: RDN (50%N) + 50% N through vermicompost, T_3: RDN (50% N) + 50% N through poultry manure, T_4: (50% N) + 50% N through press mud compost, T_5: (50% N) + 50% N through goat manure, T_6: (50% N) + 50% N through urban compost T_7: GRDF (120:60:40 N:P_2O_5:K_2O kg ha^{-1}) + 10 t FYM ha^{-1} and T_8: absolute control. Whereas, in maize crop treatment from T_1 to T_6 RDN (50% N) is applied with residual N applied to wheat through FYM, vermicompost, poultry manure, goat manure and urban compost, respectively and T_7: GRDF (120:60:40 N: P_2O_5:K_2O kg ha^{-1}) + 5 t FYM ha^{-1} and T_8: Absolute control. The data were analysed statistically and results were interpreted by using methods suggested by [11] Panse and Sukhatme.

3. Result and Discussion

3.1 Correlation of physical parameters with yield and uptake of nutrients by wheat in normal and saline-sodic Inceptisol

The data presented in Tables 2 and 3 indicate the correlation of physical parameters with yield and uptake of nutrients by wheat which is influenced by the application of various organic manures with inorganic fertilizers on normal soil and saline-sodic soil, respectively. The correlation was calculated at 5 % (*) and 1 % (**) level of significance.

3.1.1. Normal soil

The data for normal soil in Table 2 indicate the correlation of physical properties with yield and uptake in normal Inceptisols by wheat crop showed a significant negative correlation was observed between soil temperature and grain yield, straw yield and uptake of nitrogen (N), phosphorus (P) and potassium (K) at a 1 % level of significance. Soil moisture showed a significant positive correlation with grain yield and uptake of P and K at a 1 % level of significance and with straw yield and uptake of N at a 5

% level of significance. Aggregate stability was significantly positively correlated with straw yield and uptake of N and P at a 5 % level of significance. Hydraulic conductivity was significantly positively correlated with grain yield and uptake of N and K at a 5 % level of significance and with straw yield and uptake of P at a 1 % level of significance. Soil moisture tension shows a negative correlation with grain yield, straw yield and uptake of nitrogen (N), phosphorus (P) and potassium (K) at a 5 % level of significance. Soil available water content exhibited a significant positive correlation with grain yield, straw yield and uptake of P and K at a 1 % level of significance and with uptake of N at a 5 % level of significance.

3.1.2. **Saline-sodic Inceptisol**

The data presented in Table 3 for saline-sodic Inceptisol indicates the correlation of physical properties with yield and uptake in saline-sodic Inceptisols by wheat crop showed significant correlations between various soil factors and crop yield. Soil temperature was negatively correlated with grain yield, straw yield and N, P and K uptake at a 5 % significance level. Soil moisture exhibited significant positive correlations with grain yield, straw yield and P and K uptake at a 1 % significance level and positively correlated with nitrogen (N) uptake at a 5 % significance level. Aggregate stability was significantly and positively correlated with grain yield, straw yield and P and K uptake at a 5 % significance level. Hydraulic conductivity showed significant positive correlations with grain yield, straw yield and K uptake at a 5 % significance level and positively correlated with P uptake at a 1 % significance level. Soil moisture tension shows a negative correlation with grain yield, straw yield and uptake of nitrogen (N), phosphorus (P) and potassium (K) at a 1 % level of significance. Soil available water content was significantly and positively correlated with grain yield, straw yield and P and K uptake at a 1 % significance level and positively correlated with N uptake at a 5 % significance level.

Kumari [12] and Madhukar [13] studied the correlation between soil physical properties and the yield of wheat crops and the result showed that the physical properties are positively correlated with the yield of wheat except for soil temperature which was negatively correlated with yield of wheat.

Table 2. Correlation of physical properties with yield and uptake of nutrients by wheat in normal Inceptisol

	Soil temperature (^oC)	Soil moisture (%)	Aggregate stability (mm)	Hydraulic Conductivity (cm h^{-1})	Soil moisture tension (kPa)	Available water content (%)	Grain yield (kg ha^{-1})	straw yield (kg ha^{-1})	Uptake of N (kg ha^{-1})	Uptake of P (kg ha^{-1})	Uptake of K (kg ha^{-1})
Soil temperature (^oC)	1										

Soil moisture (%)	-0.973**	1									
Aggregate stability (mm)	-0.860**	0.864**	1								
Hydraulic conductivity (cm h^{-1})	-0.950**	0.956**	0.913**	1							
Soil moisture tension (kPa)	0.890**	-0.947**	-0.886**	-0.889**	1						
Available water content (%)	-0.941**	0.982**	0.906**	0.953**	-0.936**	1					
Grain yield (kg ha^{-1})	-0.861**	0.871**	0.631	0.767*	-0.742*	0.854**	1				
Straw yield (kg ha^{-1})	-0.851**	0.831*	0.788*	0.841**	-0.693	0.857**	0.884**	1			
Uptake of N (kg ha^{-1})	-0.802*	0.796*	0.720*	0.718*	-0.723*	0.815*	0.929**	0.917**	1		
Uptake of P (kg ha^{-1})	-0.873**	0.884**	0.782*	0.897**	-0.824*	0.857**	0.844**	0.857**	0.826*	1	
Uptake of K (kg ha^{-1})	-0.847**	0.876**	0.661	0.800*	-0.762*	0.868**	0.983**	0.884**	0.920**	0.899**	1
R Table 5 %	0.05	0.706734									
R Table 1 %	0.01	0.834341									

Tab Table 3. Correlation of physical properties with yield and uptake of nutrients by wheat in Saline-sodic Inceptisol

	Soil temperature (^oC)	**Soil moisture (%)**	**Aggregate stability (mm)**	**Hydraulic Conductivity (cm h^{-1})**	**Soil moisture tension (kPa)**	**Available water content (%)**	**Grain yield (kg ha^{-1})**	**straw yield (kg ha^{-1})**	**Uptake of N (kg ha^{-1})**	**Uptake of P (kg ha^{-1})**	**Uptake of K (kg ha^{-1})**
Soil temperature (^oC)	1										
Soil moisture	-0.951**	1									

(%)											
Aggregate stability (mm)	-0.882**	0.878**	1								
Hydraulic conductivity (cm h^{-1})	-0.964**	0.958**	0.939**	1							
Soil moisture tension (kPa)	0.916**	-0.969**	-0.849**	-0.911**	1						
Available water content (%)	-0.868**	0.963**	0.830*	0.888**	-0.983**	1					
Grain yield (kg ha^{-1})	-0.878**	0.892**	0.797*	0.807*	-0.919**	0.900**	1				
Straw yield (kg ha^{-1})	-0.783*	0.857**	0.745*	0.744*	-0.925**	0.910**	0.955**	1			
Uptake of N (kg ha^{-1})	-0.712*	0.784*	0.468	0.642	-0.790*	0.748*	0.726*	0.784*	1		
Uptake of P (kg ha^{-1})	-0.925**	0.966**	0.779*	0.895**	-0.937**	0.947**	0.912**	0.844**	0.768*	1	
Uptake of K (kg ha^{-1})	-0.764*	0.848**	0.719*	0.758*	-0.870**	0.887**	0.910**	0.935**	0.740*	0.866**	1
R Table 5 %	0.05	0.706734									
R Table 1 %	0.01	0.834341									

3.2 Correlation of physical parameters with yield and uptake of nutrients by maize in normal and saline-sodic Inceptisol

The data presented in Tables 4 and 5 indicates the correlation of physical parameters with yield and uptake of nutrients by maize crop. These correlations are influenced by the application of inorganic fertilizers and the residual effect of organic manures on normal soil and saline-sodic soil, respectively. The correlation was calculated at 5 % (*) and 1 % (**) level of significance.

3.2.1. Normal soil

The data presented in Table 4 indicates the correlation of physical properties with yield and uptake in normal Inceptisols by maize crop showed that the significant negative correlation was observed

between soil temperature and grain yield, straw yield and uptake of nitrogen (N), phosphorus (P) and potassium (K). Soil moisture showed a significant positive correlation with grain yield, straw yield and uptake of N, P and K at a 1 % level of significance. Aggregate stability showed a significant positive correlation with grain yield, straw yield and uptake of N, P and K at a 5 % level of significance. Hydraulic conductivity and available soil water content showed a significant positive correlation with grain yield, straw yield and uptake of N, P and K at a 1 % level of significance. Soil moisture tension shows a negative correlation with grain yield, straw yield and uptake of nitrogen (N), phosphorus (P) and potassium (K) at a 5 % level of significance.

3.2.2. Saline-sodic Inceptisol

The data displayed in Table 5 indicates the correlation of physical properties with yield and uptake in saline-sodic Inceptisols by maize crop showed that the soil temperature negatively correlates with grain yield, stover yield and K uptake at a 1 % significance level. Soil moisture positively correlates with grain yield, stover yield and N, P and K uptake at a 1 % significance level. Aggregate stability positively correlates with grain yield, stover yield and N, P and K uptake at a 5 % significance level. Hydraulic conductivity positively correlates with grain yield and N and P uptake at a 5 % significance level and with stover yield and K uptake at a 1 % significance level. Soil moisture tension shows a negative correlation with grain yield, straw yield and uptake of nitrogen (N), phosphorus (P) and potassium (K) at a 1 % level of significance. Available soil water content showed a significant positive correlation with grain yield, straw yield and uptake of N, P and K at a 1 % level of significance.

Sainju [14] studied the correlation between soil physical properties and the yield of maize crop and the result showed that the physical properties are positively correlated with the yield of maize except for soil temperature and soil moisture tension.

Table 4. Correlation of physical properties with yield and uptake of nutrients by maize in normal Inceptisol

	Soil temperature (^{o}C)	Soil moisture (%)	Aggregate stability (mm)	Hydraulic Conductivity (cm h^{-1})	Soil moisture tension (kPa)	Available water content (%)	Grain yield (kg ha^{-1})	straw yield (kg ha^{-1})	Uptake of N (kg ha^{-1})	Uptake of P (kg ha^{-1})	Uptake of K (kg ha^{-1})
Soil temperature (^{o}C)	1										
Soil moisture (%)	-0.642	1									

Aggregate stability (mm)	-0.848**	0.867**	1								
Hydraulic conductivity (cm h^{-1})	-0.667	0.964**	0.907**	1							
Soil moisture tension (kPa)	0.592	-0.943**	-0.864**	-0.920**	1						
Available water content (%)	-0.663	0.956**	0.916**	0.968**	-0.981**	1					
Grain yield (kg ha^{-1})	-0.545	0.942**	0.818*	0.929**	-0.973**	0.976**	1				
Straw yield (kg ha^{-1})	-0.528	0.928**	0.792*	0.930**	-0.941**	0.962**	0.986**	1			
Uptake of N (kg ha^{-1})	-0.518	0.949**	0.727*	0.906**	-0.920**	0.920**	0.957**	0.965**	1		
Uptake of P (kg ha^{-1})	-0.569	0.963**	0.737*	0.910**	-0.875**	0.888**	0.905**	0.918**	0.980**	1	
Uptake of K (kg ha^{-1})	-0.547	0.971**	0.762*	0.924**	-0.925**	0.930**	0.953**	0.961**	0.995**	0.990**	1
R Table 5 %	0.05	0.706734									
R Table 1 %	0.01	0.834341									

Table 5. Correlation of physical properties with yield and uptake of nutrients by maize in saline-sodic Inceptisol

	Soil temperature (^oC)	**Soil moisture (%)**	**Aggregate stability (mm)**	**Hydraulic Conductivity (cm h^{-1})**	**Soil moisture tension (kPa)**	**Available water content (%)**	**Grain yield (kg ha^{-1})**	**straw yield (kg ha^{-1})**	**Uptake of N (kg ha^{-1})**	**Uptake of P (kg ha^{-1})**	**Uptake of K (kg ha^{-1})**
Soil temperature (^oC)	1										
Soil moisture (%)	-0.875**	1									
Aggregat	-0.768*	0.806*	1								

e stability (mm)											
Hydraulic conductivity (cm h^{-1})	-0.854**	0.851**	0.980**	1							
Soil moisture tension (kPa)	0.826*	-0.961**	-0.800*	-0.842**	1						
Available water content (%)	-0.891**	0.993**	0.817*	0.869**	-0.982**	1					
Grain yield (kg ha^{-1})	-0.847**	0.983**	0.775*	0.818*	-0.983**	0.991**	1				
Straw yield (kg ha^{-1})	-0.886**	0.982**	0.805*	0.860**	-0.987**	0.996**	0.992**	1			
Uptake of N (kg ha^{-1})	-0.816*	0.987**	0.777*	0.805*	-0.953**	0.975**	0.979**	0.960**	1		
Uptake of P (kg ha^{-1})	-0.674	0.935**	0.771*	0.784*	-0.947**	0.929**	0.932**	0.921**	0.944**	1	
Uptake of K (kg ha^{-1})	-0.883**	0.993**	0.827*	0.869**	-0.965**	0.990**	0.976**	0.976**	0.987**	0.929**	1
R Table 5 %	0.05	0.706734									
R Table 1 %	0.01	0.834341									

4. Conclusion

It can be concluded that, Soil moisture tension and soil temperature shows a negative correlation while, soil moisture, aggregate stability, hydraulic conductivity and soil available water content show a positive correlation with grain yield, straw yield and uptake of nitrogen (N), phosphorus (P) and potassium (K) at a 5 % and 1 % level of significance in both wheat and maize under normal and saline-sodic Inceptisol.

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5. References:

1. Jat, M. L., Satyanarayana, T., Majumdar, K., Tetarwal, J. P., Jat, R. K. and Sharawat, Y. S. Fertilizer best management practices for maize systems. Indian Journal of Fertilizers. 2013;9: 80-94.

2. Jat, R. K., Sapkota, T.B., Singh, R.G., Jat, M.L., Kumar, M and Gupta, R.K. Seven years of conservation agriculture in a rice-wheat rotation of Eastern Gangetic Plains of South Asia. Field and Crop Research. 2014;164:199-210.

3. Katkar, R.N., Sonune, B.A. and Kadu, P.R. Long term effect of fertilization on soil chemical and biological characteristic and productivity under sorghum-wheat system in Vertisol. Indian Journal of Agricultural Sciences. 2011;81(8): 734-739

4. Hussain, N., Hamdy, G. and Arshadullah, M. Evaluation of amendments for the improvement of physical properties of sodic soil. International Journal of Agriculture and Botany, 2011; 3(3): 319-322.

5. Scholl, L. and Nieuwenhuis, R. Soil Fertility Management. Agromisa Foundation, Wageningen, Netherlands. 2004.

6. Basel, N. and Sami, M. Effect of organic and inorganic fertilizers application on soil and cucumber (*Cucumis sativa L*.) plant productivity. International Journal of Agriculture and Forestry. 2014;4:166-170.

7. Han, S.H., Young, J., Hwang, J., Kima, S.B. and Parka, B. The effects of organic manure and chemical fertilizer on the growth and nutrient concentrations of Yellow Poplar (*Liriodendron tulipifera Lin*.) in a Nursery System. Forest Science and Technology. 2016;12:137-143.

8. Singh, G., Jalota, S.K. and Singh, Y. Manuring and residue management effects on physical properties of a soil under the rice-wheat system in Punjab, India. Soil and Tillage Research. 2007;94:229-238.

9. Hati, K.M. and Bandyoopadhay, K. Fertilizers (mineral and organic) effect on soil physical properties. Encyclopedia of Agrophysics. 2014;6:296-299.

10. Rudrappa, L., Purakayastha, T.J., Singh, D., Bhadraray, S. Long-term manuring and fertilization effects on soil organic carbon pools in a Typic Haplustept of semi-arid sub-tropical India. Soil and Tillage Research. 2006;88:180–192.

11. Panse, V.G. and Sukhatme, P.V. Statistical Methods for Agricultural Workers. IVEd. ICAR, New Delhi; 1995.

12. Kumari, V.V., Mishra, A.K., Parihar, S.S., Srivastava, T.K. and Khan, C. (2013) Soil moisture dynamics of wheat crop at New Delhi conditions. *American-Eurasian Journal of Agricultural and Environmental Sciences* **13**(5): 713-722.

13. Madhukar, A., Kumar, V. and Dashora, K. (2022) Temperature and precipitation are adversely affected wheat yield in India. *Journal of Water and Climate Change 13*(4): 1631-1656.
14. Sainju, U.M., Liptzin, D. and Jabro, J.D. (2022) Relating soil physical properties to other soil properties and crop yield. *Scientific Reports* **12**: 114-117.