

• Original Research Article

Effect of integrated nutrient management (INM) on physico-chemical properties of soils under pearl millet-mustard cropping sequence in Typic ustochrepts

ABSTRACT

In northern plains of India, pearl millet-mustard is an efficient, potential and sustainable cropping system (Parihar *et al.*, 2009). There are indications of stagnation or even decline in the productivity of pearl millet-mustard cropping system due to low soil organic matter, soil nutrient deficiency (secondary and micronutrients) and non-availability of fertilizers to meet farmers' needs. To ameliorate the soil, it is necessary to use organic manures like FYM in combination with inorganic fertilizers to enriched the soils with essential plant nutrients and maintain good soil health. The objective of study is nutrient management on crop productivity and other soil properties. (what is the objective of your study or what problem did you want to solve?) The experiments were conducted during 2018-19 using pearl millet-mustard with sixteen fertilizer treatments which are: Control (T₁), 50 % NPK (T₂), 75 % NPK (T₃), 100 % NPK (T₄), 150 % NPK (T₅), 100 % NP (T₆), 100 % N (T₇), 100 % NPK-S (T₈), 100 % NPK + 25 Kg ZnSO₄/ha (T₉), 100 % NPK + 50 Kg FeSO₄/ha (T₁₀), 100 % NPK + 1% FeSO₄ spray at 25 and 45 DAS (T₁₁), 100 % NPK + Azotobacter + PSB (T₁₂), 50 % NPK + FYM (T₁₃), 75 % NPK + FYM (T₁₄), 100 % NPK + FYM (T₁₅), 100 % NPK + FYM + Azotobacter + PSB (T₁₆). (What are the treatments?) in RCBD with three replications. The SOC content increased with the applications of 100% NPK, 150% NPK, 50% NPK + FYM and 75 %NPK + FYM and 100 % NPK + FYM while it decreased with the application of 50% NPK and 75% NPK, 100%N, 100% NPS-K and control. The optimal dose of fertility (100%NPK) with or without FYM, Azotobacter and PSB and 150% NPK treatment showed build up of all major nutrients NPK. (Give names of the nutrients) while the soil physical and chemical properties were improved relative to the 50% NPK and 75% NPK, 100%N, 100% NPS-K and the control. It improved the productivity, soil physical as well as chemical properties over the sub-optimal dose fertility treatments, with or without FYM, imbalanced fertilizer treatments and control. What were the effects of the treatments on the test crop and possible influence of the test crop on the soil properties and your recommendations?

Keywords: *chemical, FYM, mustard, Pearl millet, physical* (Arrange alphabetically)

1. Introduction

Integrated nutrient management (INM) practices which involves the combined use of inorganic and organic nutrient sources had long been advocated to farmers. The usage is with a goal to enhance good soil health and soil ecosystem balance. Integrated usage of inorganic fertilizers alongside organic manures has been found to enhance not only the nutrient status but also the fitness and soil quality. Integrated nutrient management has been reported to be helpful greatly in increasing soil quality index (Singh 2007) and it has been found that the recycling of organic wastes and use of bio-fertilizers play vital roles in soil nutrient management.

Soil quality is closely associated with soil organic matter hence; high soil organic matter content means high potential productivity and better soil health. Soil management practices like application of inorganic fertilizers and usage of organic amendments played important roles in maintaining soil quality and improves soil health. Balanced and integrated use of fertilizer with farm yard manure significantly improves soil organic carbon (SOC) contents (Singh 2007). (Authority?). it also has overall soil quality improvement which encompasses different physical, chemical and biological properties of the soils (name the physical, chemical and biological aspects improved upon and provide authority/authorities). The C sequestration in soils under various cropping systems, manuring and fertilizer practices provide clues to reinforcing soil quality, soil fertility and productivity through improvements in the soil physical and biological properties.

Soil carbon sequestration is a process that involves the storage of atmospheric CO₂ within the soil carbon pool mediated by plants through photosynthesis (Authority/Authorities). Carbon sequestration describes long-term storage of CO₂ or other sorts of carbon to either mitigate or deter atmospheric heating and avoid overall dangerous global climate change.

Soils comprise the most important pool of organic carbon (OC) within

the terrestrial biosphere. Manures used alone or in combination with inorganic fertilizers are often utilized in agriculture to improve soil fertility in order to increase crop production. But only a fraction of C added through organic manure application is sequestered in the soil, while major part is converted upon decomposition to CO₂ thereby returning same back to atmosphere (Authority?).

Orhan *et al.* (2006) observed application of phosphate solubilising bacterial inocula without application of insoluble phosphorus fertilizer enhanced soil available phosphorus perhaps by solubilization of native insoluble phosphorus in soil. Bacterial inocula applied in combination with organic manure and smaller dose of inorganic nitrogen and phosphorus fertilizer has been found to enhance crop yield and soil physical, chemical, and biological properties which contributed towards long – term sustainable production of rice – legume – rice system.

No review on the test crop and effects of treatments on its growth, production and influence on soil properties and C levels?

Material and Methods

The experiment was carried out during *kharif* 2017 to *rabi* 2019 in research farm of the Department of Soil Science and Agricultural Chemistry, College of Agriculture, R.V.S.K.V.V., Gwalior, situated in Grid zone at latitude 26° 13'N; longitude 76° 10'E on altitude 197 meters from mean sea level (MSL). The soil of the experimental field was alluvial, sandy clay loam in texture and classified as Typic Ustochrepts (Authority?). Soil samples were collected at 0-15, 15-30, 30-60 and 60-100 cm of soil profile with the help of screw and tube auger to study the impact of various fertilizer treatments on the soil properties within the soil profile of experimental site. The experiment was laid out under randomized complete block design (RCBD) with three replications comprising of 16 treatments. The treatments include the control (T₁), 50 % NPK (T₂), 75 % NPK (T₃), 100 % NPK (T₄), 150 % NPK (T₅), 100 % NP (T₆), 100 % N (T₇), 100 % NPK-S (T₈), 100 % NPK + 25 Kg ZnSO₄/ha (T₉), 100 % NPK + 50 Kg FeSO₄/ha (T₁₀), 100 % NPK + 1% FeSO₄ spray at 25 and 45 DAS (T₁₁), 100 % NPK + Azotobacter + PSB (T₁₂), 50 % NPK + FYM (T₁₃),

75 % NPK + FYM (T₁₄), 100 % NPK + FYM (T₁₅), 100 % NPK + FYM + Azotobacter + PSB (T₁₆).

The recommended fertilizer doses for pearl millet and mustard were 80:40:20 and 100:60:40 of N, P₂O₅ and K₂O kg ha⁻¹, respectively as urea, single superphosphate and muriate of potash, applied at 5 cm away from the seed line and 5 cm deep in the soil. In all, 50% of the N and entire P₂O₅ and K₂O were applied at the time of sowing while the remaining 50% N as top dressing 30 days after sowing. For mustard, fertilizer application was carried out after first irrigation. In treatment with 100 % NPK-S, P was added through DAP to make it S free treatment, while FYM was added at 10 tonnes ha⁻¹ yr⁻¹ before the sowing of *kharif*. The seeds were inoculated with *Azotobacter* (AZO) and phosphate solubilising bacteria (PSB) both at 10 g Kg⁻¹ seed. The pearl millet (Cv. JBV-3) and mustard (Cv. Pusa bold) at 5 kg ha⁻¹ were sown 3 cm deep in furrows. Chemical fertilizers were applied below the seed in furrows before the seed sowing and covered with soil. The inter row distance between pearl millet and mustard was 45 cm and 30 cm respectively, with 10 cm inter plant spacing.

3. Results and Discussion

3.1 Effect of integrated nutrient management on soil physical properties

3.1.1 Soil bulk density (Mg m⁻³)

The data indicates that bulk density of the soils varied from 1.10 -1.57 Mg m⁻³ at 0-15 cm (Table 1). The highest bulk density was obtained for T₇ and followed by T₁ and T₆. The increased bulk density was attributed to the deterioration of the soil structure due to N-fertilizer used alone (Walia *et al.*, 2010). The plots receiving 100% NPK alone or in combination with *Azotobacter* and or PSB and 150% NPK had decreasing bulk density value over the plots treated with 50% and 75% NPK, attributed probably to increase biomass production with consequent increased in the soil organic matter content (Selvi *et al.*, 2005). However, no definite trend in the soil bulk density was

observed at the end of study period but the decreased values obtained may be ascribed to continuous inorganic fertilizer under long term fertilizer experiment. The FYM treated plots (T₁₃, T₁₄, T₁₅ and T₁₆) in combination with various levels of NPK had lower value of bulk density which may be due to the higher organic carbon content of soils resulting to more pore spaces and better soil aggregation. Similar trends had been reported by Thakur *et al.* (2011) when they studied the impact of continuous use of inorganic fertilizers and organic manures on soil properties under soybean-wheat intensive cropping on a Vertisol in which location?.

3.1.2 Soil porosity

The soil porosity as a result of the various fertilizer treatments ranged from 47.33 to 56.58 % (Table 1) indicating that the different fertilizer treatments had significant influences on porosity of the soils. The maximum soil porosity was recorded under 100% NPK+FYM at 10 t ha⁻¹yr⁻¹+ Azotobactor +PSB which increased by 19.0 %, 11.2 % and 10.7 % compared to the control, 100%NPK, and 150% NPK treated plots respectively. The plots NPK treatments in combination with FYM at 10 t ha⁻¹ yr⁻¹ (T₁₃, T₁₄, T₁₅, and T₁₆) had higher soil porosity compared to sole NPK treated plots (T₂, T₃, and T₄). It is pertinent to note that continuous organic manure usage not only influenced the bulk density but also brought about a favourable change in the soil porosity and other soil physical properties. Selvi *et al.*, (2005) in long term field experiment reported significantly higher soil porosity (58.9%) when 100% NPK + FYM at 10 t ha⁻¹ compared to the control (50.2%) on a Vertic Haplustep soil.

3.1.2 Infiltration rate (cm hr⁻¹)

The soil infiltration rate due to the treatments varied from 1.83 - 2.61 cm hr⁻¹ (Table 1). The rate was observed to be highest with value of 2.6 cm hr⁻¹ in plots treated with 100% NPK+FYM at 10 t ha⁻¹yr⁻¹+Azotobactor+PSB and was followed by 2.59 cm hr⁻¹ with 100% NPK +FYM at 10t ha⁻¹yr⁻¹. The values were significantly higher compared to other treatments (Fig. 2.c). The sole use of 100% N resulted to the lowest infiltration rate (1.83 cm hr⁻¹) compared to the control (1.87cm hr⁻¹). The plots with FYM in combination with chemical fertilizers as treatments (T₁₃, T₁₄, T₁₅ and T₁₆) had relatively higher infiltration rates than the control and sole chemical fertilizers (T₂, T₃ and T₄). Similar trend had been reported by Bajpai *et al.* (2006) when they studied the integrated nutrient

management on Inceptisols of Chhattisgarh as it affects the soil physico-chemical properties and the productivity of rice-wheat system. The minute changes takes place in every year data so I compared in such way.

NOTE: You have not compared trends for each year and then at the end of the experiments and trends down the soil profile.

UNDER PEER REVIEW

Table : 1 Soil physical properties as affected by integrated nutrient management (2017-2019)

Treatments	BD (Mg m ⁻³) (0-15cm)			Porosity (%) (0-15cm)			Infiltration rate (cm hr ⁻¹)
	Initial (2017)	Final (2019)	B/D	Initial (2017)	Final (2019)	B/D	
T ₁ -CONTROL	1.55	1.57	0.02	47.85	47.33	-0.5	1.73
T ₂ -50%NPK	1.44	1.44	0.00	48.44	48.41	0.0	1.87
T ₃ -75%NPK	1.40	1.40	0.00	48.86	48.83	0.0	1.99
T ₄ -100%NPK	1.35	1.37	0.02	50.21	50.53	0.3	2.13
T ₅ -150%NPK	1.32	1.34	0.02	50.38	50.73	0.4	2.22
T ₆ -100%NP	1.37	1.38	0.01	48.93	49.31	0.2	1.93
T ₇ -100%N	1.40	1.43	0.03	46.88	46.55	-0.3	1.81
T ₈ -100%NPK-S	1.38	1.40	0.02	49.12	49.47	0.3	2.13
T ₉ -100%NPK+25 Kg/ha ZnSO ₄	1.37	1.39	0.02	49.34	49.64	0.3	1.96
T ₁₀ -100%NPK+50 Kg/ha FeSO ₄	1.36	1.38	0.02	48.16	48.45	0.3	1.98
T ₁₁ -100%NPK+1% spray at 25 and 45 DAS	1.38	1.40	0.02	51.09	51.39	0.3	1.99
T ₁₂ -100%NPK+AZO+PSB	1.35	1.32	-0.03	51.23	51.64	0.4	2.26
T ₁₃ -50%NPK+FYM	1.32	1.30	-0.02	51.55	51.86	0.3	2.57
T ₁₄ -75%NPK+FYM	1.25	1.22	-0.03	52.36	52.89	0.5	2.61
T ₁₅ -100%NPK+FYM	1.19	1.16	-0.03	53.56	54.23	0.7	2.64
T ₁₆ -100%NPK+FYM+AZO+PSB	1.15	1.10	-0.05	55.64	56.58	0.9	2.69
SEm±	0.07	0.04		3.09	3.29		0.09
CD(P=0.05)	NS	0.10		NS	NS		0.26

Note: AZO: *Azotobactor*, PSB phosphate solubilizing bacteria, FYM: farmyard manure, D/B: decrease or buildup

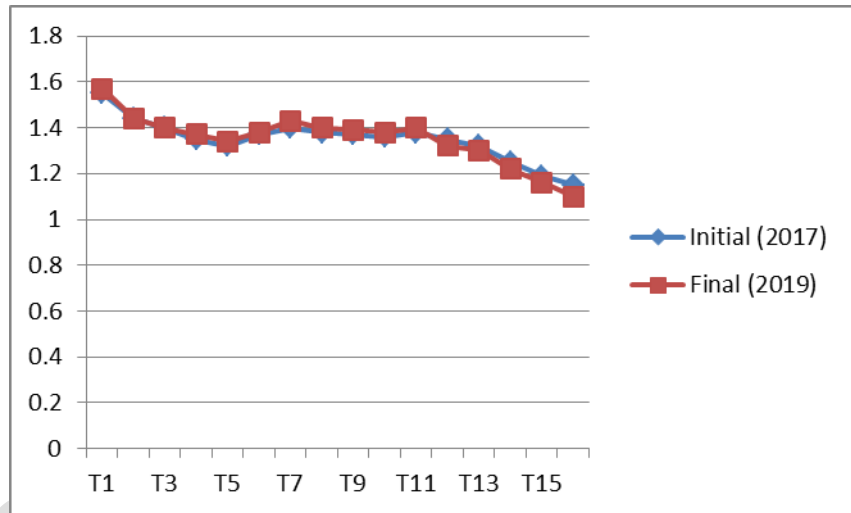
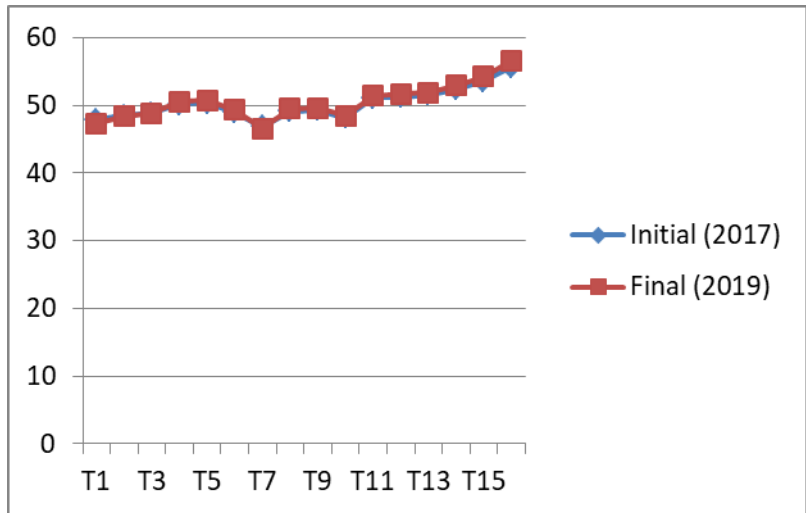
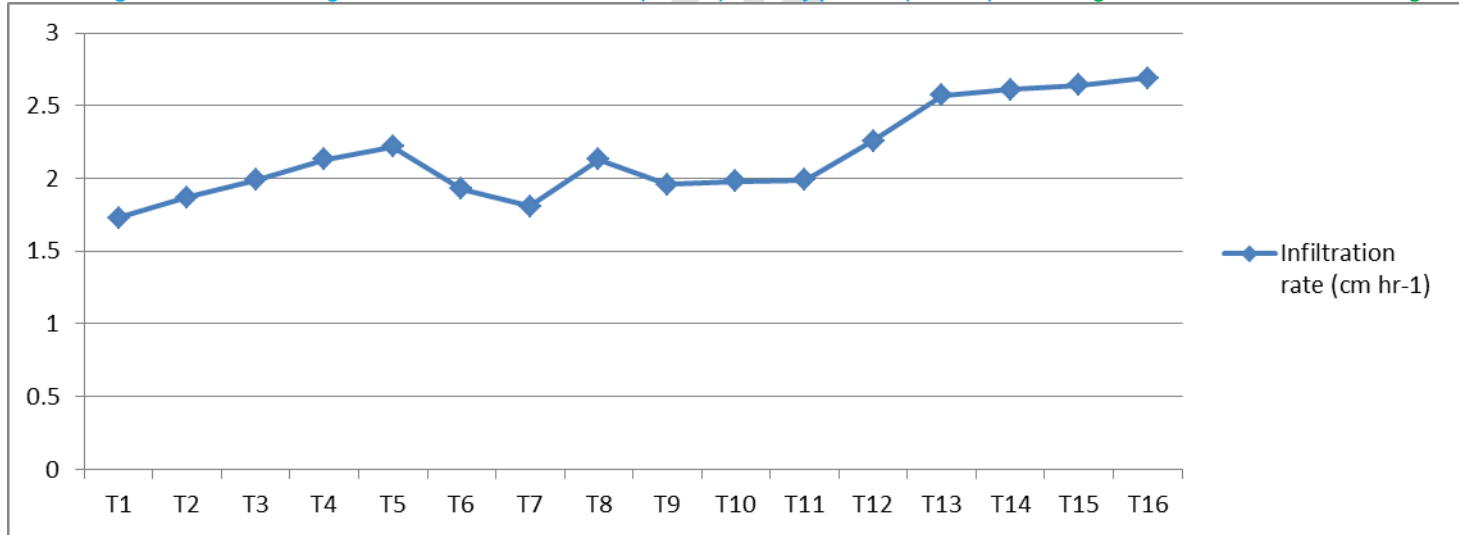


Fig.: 1.(a) Bulk density (Mg m^{-3}) at initial and final study periods (2017-19)

Fig.: 1.(b) Porosity (%) (0-15cm) at initial and final study periods (2017-19)

Fig 1.(c): Effect of integrated nutrient management on soil Infiltration rate (cm ha^{-1}) at study periods (2017-19) NOTE: Fig. Title it should be below the Figure



3.2 Effect of integrated nutrient management on soil chemical properties

3.2.1 Soil reaction (pH)

The soil pH varied from 7.63 -7.83 which increased with soil depth. This was in trend with Sawarkar *et al.* (2013) who reported that soil pH increased with depth. The control treatment has highest value of pH and it was very low due to application of urea and was least when N alone was applied probably due to acid producing nature of nitrogenous fertilizers (Prasad *et al.* 2010, Yaduvanshi *et al.* 2013)

The FYM at 10 t ha⁻¹yr⁻¹ in combination with chemical fertilizers (T₁₃, T₁₄, T₁₅ and T₁₆) resulted to insignificantly decreased soil pH compared to sole use of chemical fertilizers, which may be attributed to the production of organic acids during decomposition of organic manure mediated by microbial organisms in the soil (Gupta *et al.*, 2000).

3.2.2 Electrical conductivity (dSm⁻¹)

The soil electrical conductivity (EC) ranged from 0.108-0.244 dSm⁻¹ at 0-15 cm and decreased with soil depth. The EC was not significantly affected by different levels of NPK and FYM. However, there was slight increase under the various fertilizer treatments over the control. The electrical conductivity indicated that there was no threat since the values were within safe limits, which was in tren with findings of Babu *et al.* (2007).

Table : 2 Soil reaction (pH) as affected by nutrient management practices under a long term study

Treatments/ Depth (m)	Initial (2017)				Final (2019)				D/B			
	0-15	15-30	30-60	60-100	0-15	15-30	30-60	60-100	0-15	15-30	30-60	60-100
T ₁ -CONTROL	7.81	7.81	7.81	7.82	7.83	7.82	7.81	7.82	0.02	0.01	0.00	0.00
T ₂ -50%NPK	7.77	7.79	7.78	7.81	7.80	7.81	7.78	7.81	0.03	0.02	0.00	0.00
T ₃ -75%NPK	7.76	7.76	7.77	7.78	7.76	7.76	7.77	7.78	0.00	0.00	0.00	0.00
T ₄ -100%NPK	7.75	7.75	7.76	7.75	7.74	7.74	7.76	7.75	-0.01	-0.01	0.00	0.00
T ₅ -150%NPK	7.74	7.73	7.74	7.75	7.72	7.71	7.74	7.75	-0.02	-0.02	0.00	0.00
T ₆ -100%NP	7.77	7.77	7.77	7.76	7.76	7.79	7.77	7.76	-0.01	0.02	0.00	0.00
T ₇ -100%N	7.79	7.78	7.78	7.80	7.80	7.82	7.78	7.80	0.01	0.04	0.00	0.00
T ₈ -100%NPK-S	7.73	7.73	7.74	7.74	7.76	7.71	7.75	7.74	0.03	-0.02	0.01	0.00
T ₉ -100%NPK+25 Kg/ha ZnSO ₄	7.75	7.74	7.72	7.73	7.75	7.74	7.72	7.73	0.00	0.00	0.00	0.00
T ₁₀ -100%NPK+50 Kg/ha FeSO ₄	7.73	7.74	7.73	7.73	7.72	7.75	7.73	7.73	-0.01	0.01	0.00	0.00
T ₁₁ -100%NPK+1% spray at 25 and 45 DAS	7.75	7.74	7.74	7.76	7.74	7.73	7.74	7.76	-0.01	-0.01	0.00	0.00
T ₁₂ -100%NPK+AZO+PSB	7.76	7.75	7.74	7.75	7.75	7.73	7.73	7.75	-0.01	-0.02	-0.01	0.00
T ₁₃ -50%NPK+FYM	7.77	7.78	7.74	7.77	7.77	7.78	7.74	7.77	0.00	0.00	0.00	0.00
T ₁₄ -75%NPK+FYM	7.70	7.71	7.71	7.72	7.68	7.71	7.71	7.72	-0.02	0.00	0.00	0.00
T ₁₅ -100%NPK+FYM	7.70	7.70	7.72	7.71	7.66	7.67	7.71	7.71	-0.04	-0.03	-0.02	0.00
T ₁₆ -100%NPK+FYM+AZO+PSB	7.66	7.67	7.68	7.69	7.63	7.64	7.65	7.66	-0.05	-0.04	-0.03	0.00
SEm±	0.04	0.06	0.04	0.07	0.03	0.06	0.06	0.08				
CD(P=0.05)	NS	NS	NS	NS	0.09	NS	NS	NS				

Note: AZO: *Azotobactor*, PSB phosphate solubilizing bacteria, FYM: farmyard manure, D/B: decrease or buildup

Fig 2: Effect of integrated nutrient management on Soil reaction (pH) at initial and final study periods (2017-19)

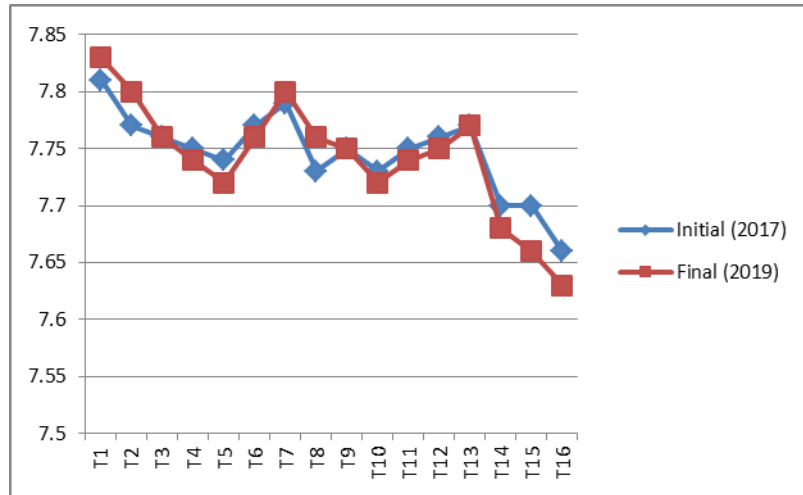


Fig.: 2.(a) Soil reaction (pH) at 0-15cm soil depth.

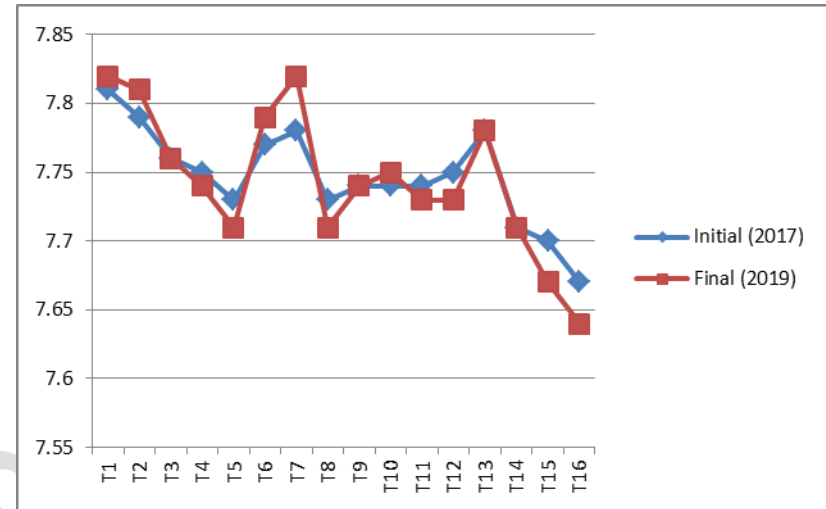


Fig.: 2.(b) Soil reaction (pH) at 15-30cm soil depth

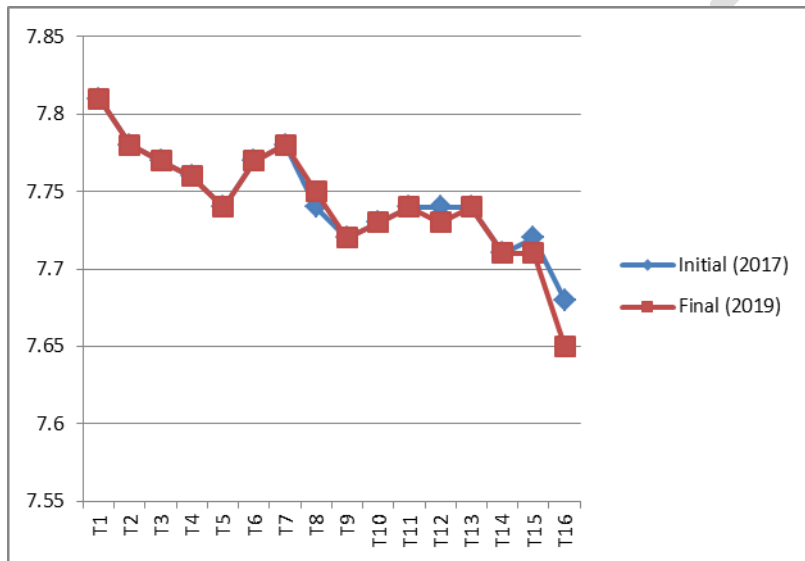


Fig.: 2 (c) Soil reaction (pH) at 30-60 cm soil depth.

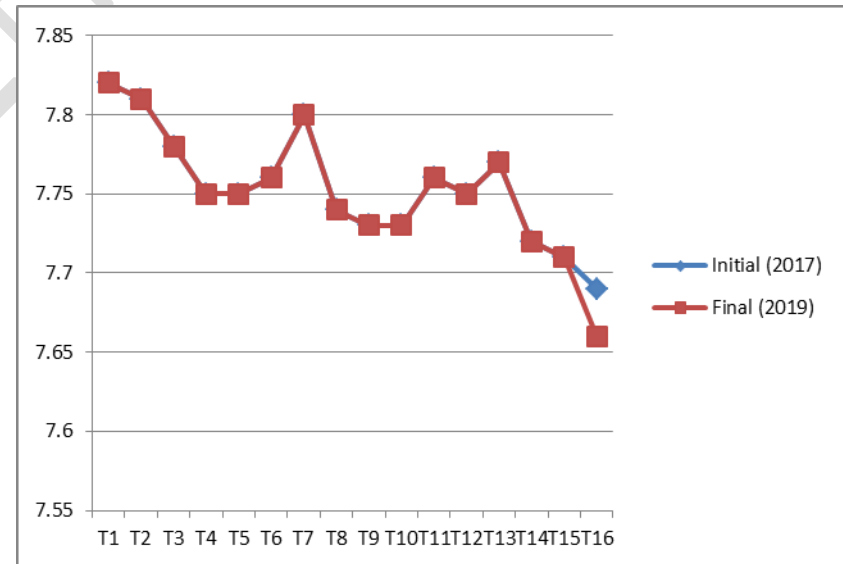


Fig.: 2.(d) Soil reaction (pH) at 60-100cm soil depth

Table : 3 Electrical conductivity (dSm⁻¹) affected by integrated nutrient management (2017-2019)

Treatments/ Depth (m)	Initial (2017)				Final (2019)				D/B			
	0-15	15-30	30-60	60-100	0-15	15-30	30-60	60-100	0-15	15-30	30-60	60-100
T ₁ -CONTROL	0.112	0.109	0.101	0.096	0.108	0.107	0.099	0.095	-0.004	-0.002	-0.002	-0.002
T ₂ -50%NPK	0.126	0.122	0.105	0.102	0.124	0.121	0.104	0.102	-0.002	-0.001	-0.001	0.000
T ₃ -75%NPK	0.135	0.129	0.109	0.105	0.134	0.129	0.109	0.105	-0.001	0.000	0.000	0.000
T ₄ -100%NPK	0.144	0.140	0.114	0.106	0.147	0.142	0.116	0.107	0.003	0.002	0.002	0.001
T ₅ -150%NPK	0.155	0.153	0.125	0.108	0.159	0.156	0.127	0.110	0.004	0.003	0.002	0.002
T ₆ -100%NP	0.130	0.126	0.105	0.103	0.132	0.127	0.105	0.103	0.002	0.001	0.000	0.000
T ₇ -100%N	0.122	0.119	0.101	0.101	0.115	0.114	0.099	0.101	-0.007	-0.005	-0.002	0.000
T ₈ -100%NPK-S	0.142	0.139	0.111	0.102	0.146	0.142	0.113	0.103	0.004	0.003	0.002	0.001
T ₉ -100%NPK+25 Kg/ha ZnSO ₄	0.152	0.150	0.115	0.116	0.159	0.154	0.118	0.116	0.007	0.004	0.003	0.000
T ₁₀ -100%NPK+50 Kg/ha FeSO ₄	0.152	0.151	0.116	0.122	0.161	0.156	0.120	0.123	0.010	0.005	0.004	0.001
T ₁₁ -100%NPK+1% spray at 25 and 45 DAS	0.145	0.138	0.117	0.112	0.149	0.141	0.118	0.113	0.004	0.003	0.001	0.001
T ₁₂ -100%NPK+AZO+PSB	0.151	0.150	0.121	0.109	0.156	0.154	0.124	0.110	0.005	0.004	0.003	0.001
T ₁₃ -50%NPK+FYM	0.167	0.137	0.111	0.106	0.170	0.138	0.111	0.106	0.003	0.001	0.001	0.000
T ₁₄ -75%NPK+FYM	0.230	0.144	0.116	0.108	0.239	0.149	0.118	0.109	0.009	0.005	0.002	0.001
T ₁₅ -100%NPK+FYM	0.232	0.169	0.125	0.114	0.244	0.175	0.129	0.117	0.013	0.006	0.003	0.003
T ₁₆ -100%NPK+FYM+AZO+PSB	0.267	0.190	0.137	0.123	0.282	0.198	0.142	0.126	0.015	0.009	0.005	0.003
SEm±	0.022	0.033	0.021	0.015	0.025	0.024	0.028	0.020				
CD(P=0.05)	0.063	NS	NS	NS	0.072	NS	NS	NS				

Note: AZO: *Azotobacter* , PSB phosphate solubilizing bacteria, FYM: farmyard manure, D/B: decrease or buildup

Fig 3 : Effect of integrated nutrient management on Electrical conductivity (dSm^{-1}) at initial and final study periods (2017-19)

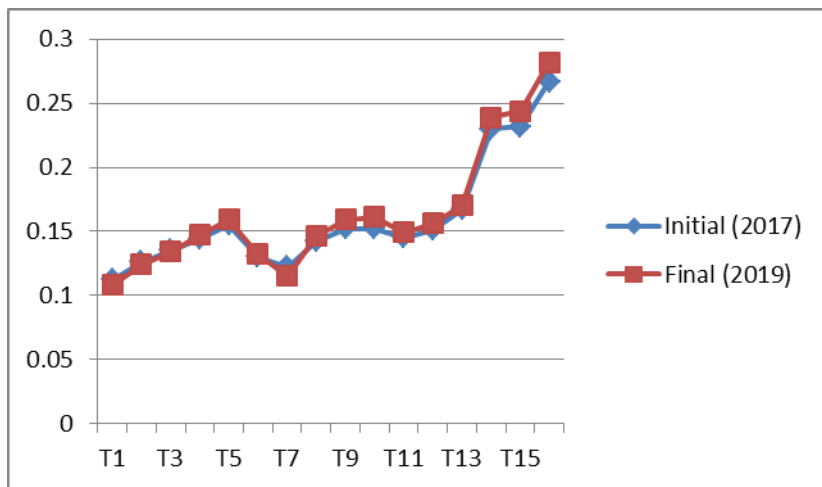


Fig.: 3.(a) Electrical conductivity (dSm^{-1}) at 0-15cm soil depth.

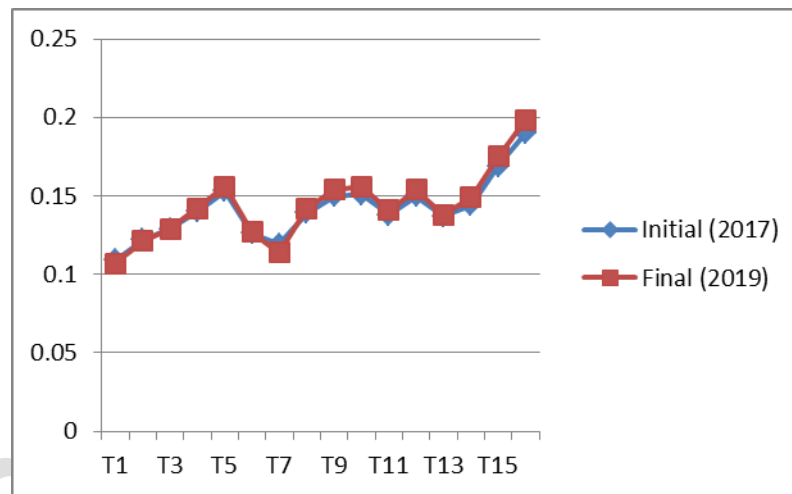


Fig.: 3.(b) Electrical conductivity (dSm^{-1}) at 15-30cm soil depth

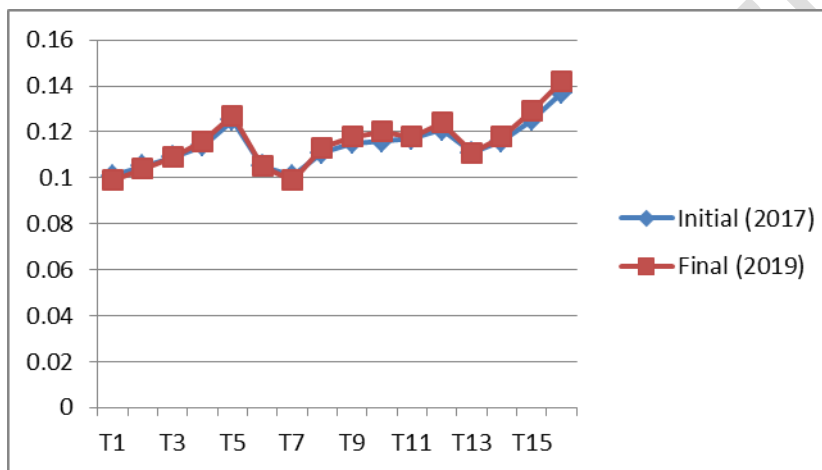


Fig.: 3.(c) Electrical conductivity (dSm^{-1}) at 30-60 cm soil depth.

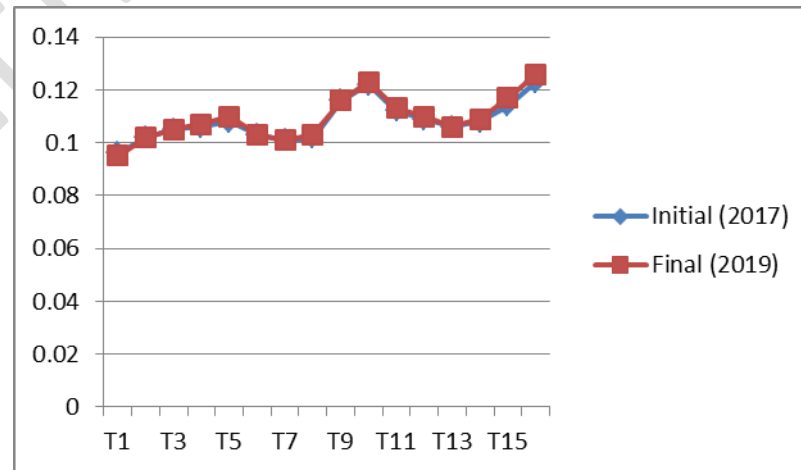


Fig.: 3.(d) Electrical conductivity (dSm^{-1}) at 60-100cm soil depth.

Conclusion

The results indicated that, the management practices such as application of fertilizer and organic amendments together plays an important role in maintaining soil physico-chemical properties and total carbon sequestration (you did not discuss anything on Carbon sequestration in your report?) under the pearl millet - mustard cropping sequence.

References

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