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Maneesh Bhatt
Ph.D., Scholar, Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

AP Singh
Associate Professor, Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Veer Singh
Associate Professor, Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

DC Kala
Ph.D., Scholar, Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Vineet Kumar
Ph.D., Scholar, Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Correspondence
Maneesh Bhatt
Ph.D., Scholar, Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Long-term effect of organic and inorganic Fertilizers on soil physico-chemical properties of a silty clay loam soil under rice-wheat cropping system in *Tarai* region of Uttarakhand

Maneesh Bhatt, AP Singh, Veer Singh, DC Kala and Vineet Kumar

Abstract

The long-term impact of chemical fertilizers on soils and environment is harmful. Use of unbalanced nutrients in the soils may be harmful in the long run causing soils an unproductive one. It is true that sustainable production of crops cannot be maintained by using only chemical fertilizers and similarly it is not possible to obtain higher crop yield by using organic manure alone. Proper identification and management of soil fertility problems are prerequisite for boosting crop production and sustaining higher yields over a long period of time. So use of organic manure in integration with inorganic fertilizers is very important in improving soil fertility and crop productivity. In order to study the long-term effect of organic and inorganic fertilizers on soil physico-chemical properties of a silty clay loam soil under rice-wheat cropping system in *tarai* region of Uttarakhand, a field experiment was conducted at Norman E. Borlaug Crop Research Centre of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar during 2014-2015. The soil pH, EC, bulk density and Organic carbon ranged from 7.24 to 7.64, 0.26 to 0.32 dSm^{-1}, 1.28 to 1.33 Mgm^{-3} and 0.58 to 1.12 percent, respectively at the surface layer and 7.58 to 7.77, 0.19 to 0.24 dSm^{-1}, 1.34 to 1.41 Mgm^{-3} and 0.27 to 0.61 percent, respectively at the sub-surface layer. The application of NPK along with organic residues increased the pH, EC, organic carbon. The content of available S and Ca improved significantly over the control. The content of S and Ca ranged from 16.87 to 30.41ppm and 141.87 to 268.53 ppm, respectively at the surface layer and 15.07 to 22.51 ppm and 108.21 to 308.61 ppm, respectively at the sub-surface layer. The partial replacement of N through FYM, wheat straw and mung straw caused significant improvement in soil physico-chemical properties. In all the treatments of sub-subsurface layer nutrient status decreased as compared to surface layer except in case of pH, bulk density and Calcium. The treatment T_7 where 25 percent N was applied through FYM and 75 percent through NPK fertilizer and T_{10} where 50 percent N was applied through mung straw and 50 percent through NPK were found best among all the treatments.

Keywords: Long-term effect, organic and inorganic fertilizers, rice-wheat cropping system

Introduction

Agriculture is facing several critical issues like low fertilizer use efficiencies, decreasing factor productivity, low soil organic carbon (SOC) stock, imbalance between nutrient removal and addition to the soil. The whole scenario of agriculture is at a junction where one has to rethink and reform the agricultural packages and practices to fulfill the dreams of million people of the country. Modern agriculture largely depends on the use of high cost inputs such as chemical fertilizers, pesticides, herbicides, improved seeds, assured irrigation, scientific management and labour saving but energy intensive farm machinery. The application of such high input technologies increased the production but there is growing concern over the adverse effects of the use of chemicals on soil productivity and environment quality.

Improvement and maintenance of soil fertility and sustaining crop production are of worldwide importance. Changes in fertility are caused by several factors including imbalanced fertilizer use, acidification, alkalinity and decline in soil organic matter, intensive cropping system etc.

The application of organic materials is fundamentally important in that they supply various kinds of plant nutrients including micronutrients, improve soil physical and chemical properties and hence maintain nutrient holding and buffering capacity, and consequently enhance microbial activities (Suzuki, 1997) [33].

It is well known that inorganic fertilizers supply only nutrients in soil but organic manure supplies nutrients and at the same time improves soil quality. The long-term impact of chemical fertilizers on soils and environment is harmful. Use of unbalanced nutrients in the soils may be harmful in the long run causing soils an unproductive one.

Effort is needed to formulate an input package with a combination of organic and inorganic fertilizers. So that it will be technically effective and feasible, economically viable, socially and environmentally acceptable. Judicious use of organic manures such as FYM wastes along with chemical fertilizers improves soil physical, chemical and biological properties and improves crop productivity.

Long-term fertilizer experiments provide valuable information on impact of continuous cropping and intensive fertilization on the yield of various crops and soil properties. The world's oldest long-term experiment was started by J. B. Lawes and J. H. Gilbert at Rothamsted (United Kingdom) in 1843 (Johnston and Powlson, 1994) [16]. Based on Rothamsted model the long-term manurial experiments were initiated in India with the establishment of first permanent manurial experiment at Kanpur (U.P.) in 1885. Long-term experiments generated valuable information on the effect of organic manure and fertilizers on crop yields, nutrient uptake and soil properties.

Therefore, Long-term studies have been conducted to work out the optimal proportions of organic and mineral fertilizers. Continuous integrated use of organic manures and fertilizers would be quite promising in assessing the sustainability of a cropping system *vis-a-vis* monitoring the soil properties. The present investigation was, therefore, undertaken to study the Long-term effect of organic and inorganic ferilizers on soil physico-chemical properties under rice-wheat cropping system in *Tarai* region of Uttarakhand.

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Materials method

The soil samples from 0-15 cm and 15-30 cm depths were collected after the harvest of wheat crop from the long-term experiment going on since *Kharif* season of 1983 under AICRP-IFS at Norman E. Borlaugh Crop Research Centre, Pantnagar, laid in Randomized block design with twelve treatments and three replications under rice-wheat cropping system *viz*. T_1- control in rice and wheat, T_2- 50% RDF in rice and wheat, T_3- 50% RDF through inorganic source in rice and 100 RDF in wheat, T_4- 75% RDF through inorganic source in rice and wheat, T_5-100% RDF through inorganic source in rice and wheat, T_6- 50% RDF through inorganic source with 50% N through FYM in rice and 100% RDF through inorganic source in wheat, T_7-75% RDF through inorganic source with 25% N through FYM in rice and 75% RDF through inorganic source in wheat, T_8-50% RDF through inorganic source with 50% N through wheat straw in rice and 100% RDF through inorganic source in wheat, T_9-75% RDF through inorganic source with 25% N through wheat straw in rice and 75% RDF through inorganic source in wheat, T_{10}-50% RDF through inorganic source with 50% N through mung straw in rice and 100% RDF through inorganic source in wheat, T_{11}-75% RDF through inorganic source with 25% N through mung straw in rice and 75% RDF through inorganic source in wheat, T_{12}- Farmers' practice.

Note: Recommended dose: N=120kg/ha, P_2O_5=60Kg/ha, K_2O=40Kg/ha
Farmers' practice dose: N=120kg/ha, P2O5=48Kg/ha, K_2O=24Kg/ha

Soil Analysis

The processed soil samples were subjected to following analyses by the methods indicated below:

Bulk density

The core samples drawn from field were used for determining bulk density. The samples were oven dried and weighed and bulk density (Mg m^{-3}) was calculated from the known weight and volume of the soil mass (Wells, 1959) [36].

Soil pH

The pH of the soil was determined in 1:2 (soil: water) ratio after half an hour of equilibrium using glass electrode on a digital pH meter (Jackson, 1967) [15].

Electrical conductivity

Electrical conductivity of the soil sample was measured in 1:2 (soil: water suspension) at 25^0 C using conductivity meter (Bower and Wilcox, 1965) [6].

Organic carbon

Organic carbon content in the soil was determined by modified Walkely and Black method (1934) [35] as described by Jackson (1967) [15].

Available sulphur

The 0.15% calcium chloride extractable sulphur was determined by the method suggested by Williams and Steinbergs (1959) [37].

Available calcium

Soil samples were analyzed for exchangeable Ca in 1N neutral ammonium acetate extract of soils by titration it with EDTA using versanate method following the method outlined by Cheng and Bray (1951) [10].

Results and Discussion

Soil pH: The results observed after 32 years of continuous rice-wheat cropping and fertilization revealed non-significant impact of various treatments on soil pH at soil depths, *viz*. 0-15 cm and 15-30 cm similar results were reported by (Grewal *et al*., 1981) [13]. The soil pH of surface varied from 7.24 to 7.64 (Table 1). As compared to initial pH, its value increased slightly too 0.34 units over the years. This rise in soil pH is attributed to decrease in organic carbon content of the soil due to continuous cropping. Organic matter produces different acids, which slightly decreased the soil pH. Singh (1997) [31] also reported non-significant change in pH of soil after 24 years of continuous cropping and fertilization. Soil pH was slight high in treatments where integrated use of fertilizers and manures was made. This marginal increase in soil pH in integrated treatments might be due to the moderating effect of organics over the years as it decreases the activity of exchangeable Al^{3+} ions in soil solution due to chelating effect of organic molecules (Prasad *et al*., 2010) [24]. Tyagi (1989) [34] observed similar results for a Hapludoll and Goyal and Singh (1987) [12] for an Ustochrept. The soil pH increased with increase in soil depths. This might be due to leaching of soluble salt from surface to sub-surface soil. Sime (2001) reported similar result in his investigation.

Electrical conductivity

All the treatments showed non-significant difference. The EC of soil ranged between 0.26 to 0.32 dSm^{-1} and 0.19 to 0.24 dSm^{-1} at the surface and sub-surface depths, respectively (Table 1). The electrical conductivity decreased with increase in depth. The highest value of electrical conductivity was recorded in T_5 treatment (0.32 dSm^{-1}) where 100% NPK was applied followed by T_7 (0.30 dSm^{-1}) treatment where 25% N applied through FYM with 75% NPK while, the lowest value of EC was found in T_1 (0.26 dSm^{-1}) which was under control. The EC of T_8 (where 50% N applied through wheat straw and 50% through NPK) and T_9 (where 25% N applied through wheat straw and 75% through NPK) treatment was found similar i.e. 0.27 dSm^{-1}. The electrical conductivity in case of T_{12} treatment (Farmers' practices) was found 0.28 dSm^{-1}. The EC of T_5 treatment was found 23 and 18.5 percent more than T_1 (control) and T_{12} (Farmers' practices), respectively. The electrical conductivity of the soil decreased in all the treatment over initial value 0.35 dSm^{-1}. The T_1 (control) treatment showed 34% declined in EC over initial value followed by 29% in T_2 (50% recommended dose of fertilizer through inorganic source), T_8 (50% NPK + 50% wheat straw) and T_9 (75% NPK + 25 wheat straw), respectively.

In 0-15 cm depth electrical conductivity varied from 0.26 dSm^{-1} in control (T_1) to 0.32 dSm^{-1} in T_5 treatment where 100% NPK was applied. The highest value of electrical conductivity was recorded in T_5 treatment where 100% NPK was applied. This might be due to the effect of inorganic fertilizers on electrical conductivity which was increased with increase in recommended inorganic fertilizers levels. Aziz *et al.* (2012) [2] also found similar results while studying effect of integrated nutrient management on soil physical properties using soybean as indicator crop under temperate conditions. T_5 was followed by T_7 treatment where 25% N applied through FYM with 75% NPK. This might be due to release of electrolytes upon the decomposition of applied manure and fertilizers. While the lowest value of EC was found in control where no fertilizer was applied. Similar results were observed by Lakshmi Prasanna (1991) [19] and Babu *et al.* (2007) [3]. Kumar e*t al.* (2011) [17] also reported similar effect of long-term application of organic material and fertilizers on soil properties in pearl millet-wheat cropping system. A study in a Permanent Manurial Experiment (PME) on Aridisols showed an increase in soil EC value from 0.67 dSm^{-1} to 0.80 dSm^{-1} due to the continuous application of fertilizers for over 30 years. The increase in the EC of the soil with continuous application of fertilizers was due to the addition of salts through fertilizers and solubilisation of native minerals due to the reduction in the pH (Hemalatha *et al*., 2013) [14].

In subsurface layer, the electrical conductivity varied from 0.19 dSm^{-1} in control plot to 0.24 dSm^{-1} under 100% NPK. The trend of variation in EC of the soil between the treatments in both the soil layer was almost negligible and statistically non-significant. This was supported by several workers (Chawla and Chhabra, 1991; Santhy *et al*., 1998 and Stalin *et al*., 2006) [9, 26, 32].

Table 1: Long-term effect of different treatments on soil pH and Electrical conductivity

Treatment	pH		E.C. (dSm^{-1})	
	0-15cm	15-30 cm	0-15cm	15-30 cm
T_1	7.64	7.66	0.26	0.19
T_2	7.41	7.77	0.27	0.21
T_3	7.44	7.73	0.28	0.22
T_4	7.39	7.73	0.29	0.21
T_5	7.35	7.74	0.32	0.24
T_6	7.32	7.74	0.28	0.23
T_7	7.30	7.72	0.30	0.23
T_8	7.35	7.63	0.27	0.21
T_9	7.37	7.70	0.27	0.23
T_{10}	7.44	7.76	0.28	0.22
T_{11}	7.24	7.58	0.29	0.23
T_{12}	7.42	7.73	0.28	0.20
S.Em±	0.08	0.06	0.02	0.01
CD at 5%	NS	NS	NS	NS
Initial value (1983)	7.30-		0.35-	

Bulk density

The data did not show any significant difference in all the treatments at both depths. The bulk density of soil ranged from 1.28 to 1.33 Mg m^{-3} at the surface and from 1.34 to 1.41Mg m^{-3} at sub-surface depth (Table 2). The bulk density of sub-surface soil was found more than surface soil under all treatments but did not show much difference. This showed that bulk density of soil increased slightly with increase in depths. The highest bulk density was found in T_1 control plot (1.33 Mg m^{-3}) followed by T_5 treatment (1.32 Mg m^{-3}). While, the lowest bulk density i.e. 1.28 Mg m $^{-3}$ was found under T_6 (where 50 percent of N dose was applied through FYM and 50 percent through NPK), T_{10} (where 50 percent of N dose was applied through mung straw and 50 percent through NPK) and T_{11} (where 25% N applied through mung straw and 75% through NPK) treatments. The bulk density of T_{12} treatment (Farmers' practices) was found 1.29 Mg m^{-3} which was almost similar to T_6, T_{10} and T_{11} treatment.

The decrease in bulk density could be due to that the organic matter resulted in considerable increase in polysaccharides and microbial gum synthesis in the soil. The microbial decomposition product, being resistance to further decomposition and act as binding agent. This might help in soil aggregation resulting lower bulk density of soil. Similar result has also been reported by Sarkar *et al.* (1997) [27], Mishra *et al.* (1998) [20], Sharma and Gupta (1998) [30] and Kumar *et al.* (2011) [17]. Singh *et al.* (2007) had also reported the decrease in soil bulk density with long-term application of green manure, FYM and wheat straw under rice-wheat cropping system.

Application of fertilizers alone also decreased the soil bulk density as compared to control. This might be due to increased soil organic carbon as a result of higher root biomass with application of fertilizers. Similar result was reported by Selvi *et al.* (2005) [29] under the effect of inorganics alone and in combination with farmyard manure on physical properties and productivity of Vertic Haplustepts under long-term fertilization.

The bulk density of sub-surface soil was found more than surface soil under all treatments but did not show much difference. This showed that bulk density of soil increased slightly with increase in depths. This could be due to the greater soil organic carbon content in the surface soil and more compaction in the subsurface layer. Similar result was reported by (Celik, Ortas and Kilic, 2004) [8] under the effects of compost, mycorrhiza, manure and fertilizer on some physical properties of a Chromoxerert soil. Schjonning, Christensen, and Cartensen (1994) [28] also reported reduced bulk density of soil resulting from application of farmyard manure in a long-term integrated nutrient-management experiment. However, there is a marginal reduction in bulk density under sole NPK treatments than control, probably because of increased biomass production with consequent increase in organic matter content of the soil by application of graded doses of NPK fertilizers.

Organic carbon

The organic carbon of soil ranged between 0.58 to 1.12 percent at 0-15 cm depth and 0.27 to 0.61 percent at 15-30 cm depths, respectively and showed significant difference (Table 2). The soil organic carbon decreased with increase in depth from 0-15 to 15-30 cm depths. The highest value of organic carbon was recorded in T_6 treatment (1.12 %) where 50 percent of N dose was applied through FYM and 50 percent through NPK followed by T_{10} treatment (0.95%) where 50 percent of N dose was applied through mung straw and 50 percent through NPK. The lowest organic carbon was found in T_1 (0.58 %) which was under control. The organic carbon in T_{12} (Farmers' practices) treatment was found (0.71 %). The organic carbon of T_6 (50% NPK + 50% FYM), T_{10} (50% NPK + 50% mung straw) and T_{12} (75% NPK + 25% mung straw) treatments were found 93%, 63% and 22% respectively, more than T_1 which was under control. The data showed that high organic carbon was found in those treatments where organic sources applied. The organic carbon content of the soil decreased in all the treatments from its initial value 1.48%. The T_1 treatment showed 155% decreased in organic carbon content over initial value followed by 134% in T_4 (75% recommended dose of fertilizer through inorganic source) and 121% in T_3 (50% recommended dose of fertilizer through inorganic source), while T_6 treatment showed 32% decreased in organic carbon content over initial value, which showed slight decrease in organic carbon content among all the treatments.

Table 2: Long-term effect of different treatments on Bulk density and Organic carbon content of soil

Treatment	Bulk density		Organic carbon	
		(Mg m^{-3})		(%)
	0-15cm	15-30 cm	0-15cm	15-30 cm
T_1	1.33	1.39	0.58	0.27
T_2	1.31	1.39	0.76	0.38
T_3	1.32	1.38	0.67	0.29
T_4	1.30	1.34	0.63	0.41
T_5	1.32	1.41	0.79	0.28
T_6	1.28	1.35	1.12	0.61
T_7	1.30	1.37	0.90	0.38
T_8	1.29	1.36	0.93	0.52
T_9	1.30	1.37	0.82	0.30
T_{10}	1.28	1.36	0.95	0.57
T_{11}	1.28	1.39	0.89	0.39
T_{12}	1.29	1.36	0.71	0.32
S.Em±	0.02	0.02	0.07	0.04
CD at 5%	NS	NS	0.22	0.13
Initial value (1983)	-		1.48	
	-		-	

The higher level of soil organic carbon with the long-term application of manures along with the fertilizers may be due to enhanced root growth, resulting more organic residues in soil, which after decomposition might have increase the soil organic carbon content. These results are in conformity with findings of Kumpawat and Jat (2005) [18], Balyan *et al*. (2006) [5] and Brar *et al*. (1998) [7]. Parmar and Sharma (2000) [21] also found similar effect under long-term integrated plant nutrient system in. rice-wheat sequence of North Western Himalayas. The soil organic carbon decreased with increase in depth from 0-30 cm depth. The higher retention of carbon either in active or passive pools in surface soil depth in comparision to subsurface soil might be because of the fact that every year organic manure was added along with inorganic fertilizer and mixed thoroughly only in surface soil depth. What so ever build was observed in these pools of C in subsurface soil depth might be because of downward movement of C due to climatic and crop management factors over the years under rice-wheat cropping system. Similar result was reported by Raina and Bharati (2013) [25] under carbon sequestration and nutrient dynamics in a long-term lantana amended soil in rice-wheat system.

Available Sulphur: The available sulphur of soil ranged from 16.87 to 30.41 ppm and 15.07 to 22.51 ppm at the surface and sub-surface depths, respectively (Table 3). The highest value of available sulphur was found in T_{10} treatment (30.41ppm) where 50 percent of N was applied through mung straw along with 50 percent through NPK followed, by T_{11} (28.45 ppm) where 25 percent of N was applied through mung straw along with 75 percent through NPK while, the lowest value of available sulphur was found in T_1 treatment (16.87 ppm) which was under control. The value of available potassium under T_{12} treatment where farmers' practices applied was found to be 24.67 ppm. The T_{10} and T_{11} treatments showed 80% and 68% more values of available potassium over control T_1, whereas T_{12} treatment showed 46% more value of available S over control. The available sulphur was found significant at both the surface and sub-surface soil. The availability of sulphur decreased with increase in depths.

The highest value of available sulphur was found in T_{10} treatment where 50 percent of N was applied through mung straw along with 50 percent through NPK followed by T_{11} where 25 percent of N was applied through mung straw along with 75 percent through NPK. It might be due to addition of organic manures (major source of soil S) which when subjected to decay and recycling could add to the soil sulphur reserve. Patnaik *et al*. (1989) [23] observed the similar results. The lowest value of available sulphur was found in control plot. This could be due to continuous cropping without application of fertilizer or organic manures. Similar result was observed by (Panda and Mishra, 1987).

The subsurface layer showed same effects on all the treatments as was observed under surface layer, but in subsurface layer availability of sulphur decreased with increase in depths. This might be attributed to decrease in organic sulphur content with increase in depth due to reduction of organic carbon content at lower depths. Patel *et al*. (2011) [22] and Balanagoudar and Satyanarayana (1990) [4] also observed similar result under the distribution of different forms of sulphur in Vertisols and Alfisols.

Available Calcium: The available calcium of soil ranged between 141.87 to 268.53 ppm at the surface soil and 108.21

to 308.61 ppm at the sub-surface soil (Table 3). The highest value of available Ca was recorded in T_6 (268.53 ppm) treatment where 50 percent of N was applied through FYM along with 50 percent through NPK followed by T_7 (261.18 ppm) treatment where 25 percent through FYM with 75 percent NPK while, the lowest value of available Ca was found in T_1 (141.87 ppm) treatment which was under control. The availability of Ca under T_{12} treatment was found 187.72 ppm. The T_6 and T_7 treatments showed 89% and 83% more values of available calcium over control T_1, whereas T_{12} treatment showed 32% more value of available Ca over control T_1. Availability of Ca both at the surface and sub-surface were found significant. The availability of Ca was recorded high at sub-surface and low at surface which was found opposite to all other nutrients.

The highest value of available Ca was recorded in T_6 treatment where 50 percent of N was applied through FYM along with 50 percent through NPK followed by T_7 treatment where 25 percent through FYM with 75 percent NPK. It might be due to the solubilising action of different organic acids produced during decomposition of organic manures increased the release of Ca. Adeleye *et al.* (2010) [1] reported similar result under the Effect of poultry manure on soil physico-chemical properties, leaf nutrient contents and yield of Yam (*Dioscorea rotundata*) on Alfisol in South-western Nigeria.

T_6 and T_7 treatments showed 89% and 83% respectively, more values of available calcium over control T_1. This might be due to positive effect of FYM toward Ca content in soil and also showed high adsorptive capacity that might have adsorbed Ca which would otherwise be leached. Hemalatha *et al.* (2013) [14] reported similar result under the Influence of long term fertilization on soil fertility.

The availability of calcium increased in subsurface soil as compared to surface soil. This may be due to presence of organic residues which increases Ca^{2+} mobility due to the formation of organic and metallic complexes, and could explain increased values of this cation in the subsurface. Similar result was reported by Friesen *et al.* (1982) [11] under the residual value of lime and leaching of calcium in a kaolinitic Ultisol in the high rainfall tropics.

Table 3: Long-term effect of different treatments on available S and Ca content of soil

Treatment	S (ppm)		Ca (ppm)	
	0-15cm	15-30 cm	0-15cm	15-30 cm
T_1	16.87	15.23	141.87	156.46
T_2	19.51	16.27	144.72	162.98
T_3	19.25	15.07	155.97	187.73
T_4	20.27	15.68	164.32	206.56
T_5	22.65	15.91	178.93	235.21
T_6	24.46	18.18	268.53	308.61
T_7	26.67	20.36	261.18	293.91
T_8	25.79	18.63	225.78	275.21
T_9	26.31	20.11	213.75	241.81
T_{10}	30.41	22.51	247.96	258.54
T_{11}	28.45	19.93	196.38	225.78
T_{12}	24.67	21.49	187.72	183.02
S.Em±	1.14	1.68	10.15	12.24
CD at 5%	3.36	4.95	29.79	35.92

Conclusion

Thus, it can be concluded that treatment where 25 percent N was applied through FYM and 75 percent through NPK fertilizer and where 50 percent N was applied through mung straw and 50 percent through NPK were found best among all the treatments. The Farmyard manure and green gram straw were observed to be the best organic sources which improve soil physico-chemical properties.

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