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Research Article

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Assessment of Secondary and Micro Nutrient Status under Long-Term Fertilizer Experiment on *Vertisol*

P. Joga Rao[*], P. R. K. Prasad[1], A. Lalitha Kumari[2], P. Prasuna Rani[3] and Ch. Pulla Rao[4]

[1]Associate Dean, Agricultural College, Bapatla, ANGRAU, AP, India

[2]Principal Scientist, Regional Research Unit, RARS, Lam, ANGRAU, Guntur, AP, India

[3]Principal Scientist, Saline Water Scheme, Bapatla, ANGRAU, Guntur, AP, India

[4]Professor, Dept. of Agronomy, Agricultural College, Bapatla, ANGRAU, AP, India

*Corresponding Author E-mail: jogi.bam24@gmail.com

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ABSTRACT

An experiment was conducted during kharif 2013-2014 at RARS, Lam, Guntur, Andhra Pradesh, under rainfed condition to study the effect of long-term influence of manures and fertilizers on secondary and micronutrient status in soils. The results indicated considerable increase in secondary and micronutrients with addition of 100% RD of NPK+FYM @ 10 t ha^{-1} followed by 100% RD of NPK+Gypsum @ 5q ha^{-1}, 100% RD of NPK+$MgSO_4$ @ 50 kg ha^{-1} and 100% RD of NPK+$ZnSO_4$ @ 50 kg ha^{-1}. Individual application of 100% N (T_6) alone and 100% RD of NP (T_5) did not show significant effect regarding secondary and micronutrient status.

Key words: *Secondary nutrients, Micronutrients, Long-term manures, Fertilizers, Gypsum, Recommended dose of fertilizers*

INTRODUCTION

Balanced fertilization plays a major role in improving the nutrient use efficiency. Use of indiscriminate and imbalanced inorganic fertilizers led to soil health problems like salinity, deterioration of soil structure, micro nutrient deficiencies, etc, it also caused the problem of environmental pollution and loss of applied fertilizers through leaching, volatilization and de-nitrification. Application of manures and fertilizers changes the chemical, physical and biological properties of the soil which in turn affects the availability of soil nutrients especially the micronutrients required by growing plants in minute quantities.

MATERIAL AND METHODS

The long-term fertilizer experiment was initiated during the season *kharif* 1991 Regional Agricultural Research Station, *Lam, Guntu,* Andhra Pradesh. The present investigation was carried out during the season *kharif* 2013-14 on Vertisol soil after 22 years of this experimentation in the same field. The experiment involves 11 treatments each replicated three times in a randomized block design. The experiment is being conducted on same site and same randomization.

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The nutrients were applied through the fertilizers like urea, single super phosphate and muariate of potash. The test crop was cotton, variety L-799. The initial soil characters were as following. The soil pH 8.4, E.C. 0.60 dS m^{-1}, organic carbon 0.37% and NPK 196, 23 and 392 kg ha^{-1} respectively. Cotton was raised during *kharif* 2013-14 adopting recommended package of practices. The recommended fertilizers (90:45:45 kg N, P_2O_5 and K_2O ha^{-1}) were applied through urea (46 % N), single superphosphate (16 % P_2O_5) and muriate of potash (60 % K_2O), as per the treatments. FYM was applied 10 days before sowing in the respective treatment. Phosphorus, $ZnSO_4$, $MgSO_4$ and gypsum application was done before sowing. Nitrogen and potassium fertilizers were applied in three splits. Soil samples were collected before sowing of the crop at two depths *i.e.,* 0-15 and 15-30 cm.

Soil reaction was determined in 1: 2.5 soil water suspension using combined glass electrode[3]. The electrical conductivity of soil samples was determined in 1: 2.5 soil water extract using electrical conductivity bridge[3]. Walkley and Black's "wet digestion method" as outlined by Jackson[3] (1973) was followed to determine the organic carbon content of the soils. Available sulphur in soil was extracted using 0.15% $CaCl_2.2H_2O$[8] solution used for extracting of sulphur by turbidometric method using spectrophotometer at 420 nm. Calcium and magnesium were determined by EDTA titration method[7]. Available zinc, iron, manganese and copper in the soils were determined in DTPA extract, using atomic absorption spectrophotometer[4].

RESULTS AND DISCUSSION

Soil pH

The glance of the data in table 1 the continuous use of N alone (T_6) had the most acidifying effect with decrease in pH during the twenty third cropping cycle. Increasing NPK level from 50 to 150 per cent also increased the level of acidity. Irrespective of nutrient management provided to cotton crop, the soil pH at different stages of crop growth decreased with increasing level of NPK from 50 to 200% but not at significant level.

Electrical conductivity (dS m^{-1})

The electrical conductivity decreased from initial to harvest stage (Table 2) in all the experimental treatments in surface and sub-surface soils. The heavy root system of the cotton makes the soil loose and porous, so the salts added on addition of chemical fertilizers might have leached away readily resulting in low EC in cotton growing soils.

Cation Exchange Capacity (cmol (p^+) kg^{-1})

Treatment that received 10 t ha^{-1} FYM + 100% NPK (T_7) had higher CEC (Table 3) of soil over inorganic fertilizer treatments. This might be due to application of organic manures and higher amount of crop residues[1].

Soil organic carbon (%)

The glance of the data (Table 4 and Figure1) revealed that organic carbon content increased from initial to flowering stage and it was decreased at harvest in all the experimental treatments in surface as well as in sub-surface soils. An overall increase in organic carbon content was observed in the present study under all the treatments as compared to their initial status of organic carbon. Increase in recommended level of NPK from 50 to 150 per cent (T_2, T_3 and T_4), organic carbon content was gradually increased up to 150 per cent and decreased at 200% RD of NPK (T_{10}).

The highest value 0.61% (Flowering stage, surface soils) was observed in FYM @ 10 t ha^{-1} along with 100% RD of NPK treated plot (T_7) followed by 150% RD of NPK treated plot (T_4) and 200% RD of NPK treated plot (T_{11}) whereas the lowest value 0.33% (initial, subsurface soil) was observed in control (T_1) (Table 3). The marked increase in the soil organic carbon content following incorporation of FYM along with NPK as compared to most of the treatments was attributed to resultant enhanced crop productivity and associated greater returns of added organic materials in the form of decaying roots, litter and crop residues over the years of utilization. Similar reports were stated by Sharma *et al*[5].

Available Sulphur (ppm)

The data presented in table 5 revealed that available sulphur increased up to flowering stage and decreased at harvest in all the treatments in surface and sub-surface soils. The available sulphur was relatively higher in plots those received 100% RD of NPK along with $ZnSO_4$ (T_8), $MgSO_4$ (T_9) and gypsum (T_{11}), 100% RD of NPK+FYM @ 10 t ha^{-1} (T_7), and increased dose of RD of NPK from 50 to 150 per cent and over other treatments. At all the stages (initial, flowering and harvest stage) available S content was significantly influenced by the different treatments.

The high content of available sulphur in treatments T_8, T_9 and T_{11} could be due to the addition of S through $ZnSO_4$, $MgSO_4$ and gypsum. According to Tripathi and Singh[6], the higher concentration of sulphate-sulphur was due to greater plant and microbial activities resulting in the accumulation of soluble sulphate sulphur.

Exchangeable sodium (cmol (p^+) kg^{-1})

With increasing levels of NPK from 50 to 200% (T_2, T_3, T_4 and T_{10}), there was gradual increased exchangeable Na content in the soil was observed. Among all the treatments, T_{11} (100% NPK+gypsum @ 5 q ha^{-1}) recorded comparatively lower exchangeable Na content.

Exchangeable potassium (cmol (p^+) kg^{-1})

Increase in exchangeable K content in the soil was observed with increasing levels of RD of NPK (T_2, T_3, T_4 and T_{10}). Among the combined treatments (T_7, T_8, T_9 and T_{11}), application of 100% NPK+FYM @ 10 t ha^{-1} (T_7) recorded comparatively higher exchangeable K content over the application of RD of NPK (T_3) alone.

Exchangeable calcium (cmol (p^+) kg^{-1})

All through exchangeable Ca did not show significant effect among the different treatments at irrespective stages, treatment that received 100% RD of NPK with gypsum (T_{11}) resulted in higher exchangeable Ca concentrations followed by T_7 (T_3+FYM 10 t ha^{-1}).

Exchangeable magnesium (cmol (p^+) kg^{-1})

At initial stage, surface and sub-surface soils were statistically significant among the different treatments. At both the surfaces, the exchangeable Mg content was highest (3.93 and 3.37 cmol (p^+) kg^{-1}) in T_9 (T_3+$MgSO_4$ @ 50 kg ha^{-1}) followed by T_{11} (T_3+gypsum @ 5 q ha^{-1}), T_7 (100% NPK+FYM @ 10 t ha^{-1}) and T_8 (100% NPK+$ZnSO_4$ @ 50 kg ha^{-1}).

At flowering stage, surface soils were non-significant among the different treatments. The value was in between 3.63 and 4.23 cmol (p^+) kg^{-1}. In sub-surface soils significant among the different treatments. The exchangeable Mg values were in between 2.33 and 3.37 cmol kg^{-1}. Highest was recorded in T_9 (T_3+$MgSO_4$ @ 50 kg ha^{-1}).

Percent Base Saturation (%)

The data presented in the table 10 revealed that soil PBS slightly increased from initial to flowering and decreased at harvest stage. The treatmental effects on PBS were non-significant at any stage of treatments in both surface and sub-surface.

Micronutrients (ppm)

The status of available micronutrients i.e. Fe, Mn, Cu and Zn were also significantly influenced by the application of organics in conjunction with inorganics. The increased availability of these nutrients in the treatments those received application of organic manure might be due to their release on mineralization[2] and also due to production of chelating agents during the decay of organic manure, which have the ability to transform insoluble form of micronutrients into the soluble metal complexes.

Table 1. Effect of long-term use of manures and fertilizers on soil pH

Treatments	Surface			Sub-surface		
	Initial	Flowering	Harvest	Initial	Flowering	Harvest
T_1: Control	8.3	8.4	8.4	8.3	8.3	8.3
T_2: 50% RD of NPK	8.3	8.3	8.3	8.3	8.3	8.3
T_3: 100% RD of NPK	8.3	8.3	8.3	8.2	8.3	8.3
T_4: 150% RD of NPK	8.3	8.3	8.3	8.2	8.3	8.3
T_5: 100% RD of NP	8.2	8.3	8.3	8.2	8.2	8.2
T_6: 100% RD of N	8.2	8.2	8.2	8.1	8.2	8.1
T_7: T_3 + FYM @10 t ha^{-1}	8.1	8.1	8.2	8.0	8.1	8.0
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	8.2	8.3	8.3	8.2	8.3	8.2
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	8.2	8.3	8.3	8.2	8.2	8.3
T_{10}: 200% RD of NPK	8.2	8.3	8.3	8.2	8.2	8.3
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	8.2	8.2	8.2	8.1	8.1	8.2
SEm±	0.24	0.25	0.27	0.24	0.24	0.24
CD (0.05)	NS	NS	NS	NS	NS	NS
CV (%)	5.1	5.2	5.0	5.1	5.1	5.1

Table 2. Effect of long-term use of manures and fertilizers on soil EC (dSm^{-1})

Treatments	Surface			Sub-surface		
	Initial	Flowering	Harvest	Initial	Flowering	Harvest
T_1: Control	0.21	0.20	0.19	0.20	0.19	0.18
T_2: 50% RD of NPK	0.26	0.25	0.24	0.24	0.23	0.23
T_3: 100% RD of NPK	0.28	0.26	0.25	0.26	0.25	0.24
T_4: 150% RD of NPK	0.29	0.27	0.26	0.27	0.26	0.25
T_5: 100% RD of NP	0.27	0.26	0.25	0.25	0.25	0.24
T_6: 100% RD of N	0.26	0.24	0.23	0.25	0.23	0.23
T_7: T_3 + FYM @10 t ha^{-1}	0.23	0.22	0.21	0.22	0.21	0.20
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	0.29	0.26	0.25	0.27	0.25	0.25
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	0.27	0.26	0.25	0.26	0.25	0.24
T_{10}: 200% RD of NPK	0.30	0.29	0.28	0.29	0.27	0.27
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	0.24	0.23	0.22	0.22	0.22	0.21
SEm±	0.01	0.01	0.02	0.01	0.01	0.01
CD (0.05)	0.04	0.03	NS	0.03	0.04	0.04
CV (%)	8.1	7.2	12.7	7.5	10.8	10.4

Table 3. Effect of long-term use of manures and fertilizers on soil CEC (cmol (p^+) kg^{-1})

Treatments	Surface			Subsurface		
	Initial	Flowering	Harvest	Initial	Flowering	Harvest
T_1: Control	36.2	37.8	36.1	35.7	36.2	35.6
T_2: 50% RD of NPK	37.2	39.1	38.8	36.5	37.4	37.9
T_3: 100% RD of NPK	38.4	40.3	39.4	37.9	39.4	38.8
T_4: 150% RD of NPK	40.3	42.6	41.7	40.1	41.2	41.6
T_5: 100% RD of NP	39.5	41.5	38.1	38.8	39.6	37.0
T_6: 100% RD of N	39.2	40.8	38.4	38.0	38.7	37.2
T_7: T_3 + FYM @10 t ha^{-1}	41.2	43.4	42.7	41.0	42.2	41.9
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	40.3	41.2	40.8	38.1	39.3	38.8
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	39.1	40.5	40.4	38.7	40.1	40.3
T_{10}: 200% RD of NPK	40.2	41.3	40.6	40.1	40.7	40.2
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	40.0	40.4	39.6	39.9	38.4	37.5
SEm±	1.44	1.63	1.57	1.52	1.82	1.39
CD (0.05)	NS	NS	NS	4.5	NS	NS
CV (%)	6.4	6.9	6.8	6.8	8	6.2

Table 4. Effect of long-term use of manures and fertilizers on soil organic carbon content (%).

Treatments	Surface			Sub-surface		
	Initial	Flowering	Harvest	Initial	Flowering	Harvest
T_1: Control	0.34	0.37	0.36	0.33	0.36	0.35
T_2: 50% RD of NPK	0.36	0.40	0.38	0.35	0.39	0.37
T_3: 100% RD of NPK	0.45	0.48	0.48	0.44	0.47	0.47
T_4: 150% RD of NPK	0.56	0.60	0.56	0.53	0.56	0.54
T_5: 100% RD of NP	0.44	0.48	0.47	0.43	0.47	0.45
T_6: 100% RD of N	0.43	0.48	0.46	0.42	0.46	0.45
T_7: T_3 + FYM @10 t ha^{-1}	0.58	0.61	0.59	0.56	0.58	0.57
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	0.47	0.50	0.49	0.45	0.48	0.48
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	0.46	0.49	0.48	0.45	0.47	0.47
T_{10}: 200% RD of NPK	0.52	0.55	0.53	0.51	0.53	0.51
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	0.48	0.52	0.49	0.46	0.49	0.49
SEm±	0.02	0.02	0.02	0.02	0.02	0.03
CD (0.05)	0.07	NS	0.05	0.06	0.07	0.08
CV (%)	8.4	5.5	6.6	7.3	8.4	9.6

Table 5. Effect of long-term use of manures and fertilizers on soil available sulphur (ppm)

Treatments	Surface			Sub-surface		
	Initial	Flowering	Harvest	Initial	Flowering	Harvest
T_1: Control	43.0	48.7	43.4	41.1	45.4	41.7
T_2: 50% RD of NPK	47.4	59.3	54.0	45.5	53.3	51.8
T_3: 100% RD of NPK	51.5	62.8	57.9	49.2	57.0	55.5
T_4: 150% RD of NPK	55.2	67.4	62.8	53.1	64.2	61.5
T_5: 100% RD of NP	49.6	60.0	55.1	47.9	54.8	52.1
T_6: 100% RD of N	48.7	50.9	46.5	47.3	48.5	45.9
T_7: T_3 + FYM @10 t ha^{-1}	55.5	68.2	62.9	53.1	64.4	62.1
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	56.2	69.3	63.9	55.2	64.6	64.0
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	56.7	69.9	64.0	55.5	66.0	62.8
T_{10}: 200% RD of NPK	54.5	67.0	61.7	51.7	62.1	58.9
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	58.0	71.5	66.8	56.5	68.5	64.9
SEm±	1.43	2.67	2.17	2.17	2.74	1.80
CD (0.05)	4.2	7.9	6.4	6.4	8.1	NS
CV (%)	5.2	7.3	6.5	7.4	8.1	5.5

Table 6. Effect of long-term use of manures and fertilizers on soil Exchangeable Na (cmol (p^+) kg^{-1})

Treatments	Surface			Sub-surface		
	Initial	Flowering	Harvest	Initial	Flowering	Harvest
T_1: Control	1.59	1.74	1.61	1.55	1.62	1.63
T_2: 50% RD of NPK	1.80	1.91	1.83	1.74	1.87	1.77
T_3: 100% RD of NPK	1.97	2.08	1.97	1.91	2.06	1.90
T_4: 150% RD of NPK	2.24	2.37	2.05	2.13	2.23	2.00
T_5: 100% RD of NP	1.92	2.11	1.97	1.90	2.04	1.84
T_6: 100% RD of N	1.80	1.99	1.77	2.14	1.96	1.70
T_7: T_3 + FYM @10 t ha^{-1}	2.15	2.29	2.03	2.11	2.15	1.97
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	1.91	2.00	1.96	1.88	1.93	1.85
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	1.93	2.23	2.08	1.90	2.19	1.90
T_{10}: 200% RD of NPK	1.96	2.29	2.12	1.55	2.21	2.01
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	1.88	2.14	1.77	1.77	2.13	1.72
SEm±	0.08	0.11	0.14	0.11	0.14	0.10
CD (0.05)	0.2	0.33	NS	0.3	NS	NS
CV (%)	6.9	9.1	12.1	9.8	11.9	9.5

Table 7. Effect of long-term use of manures and fertilizers on soil Exchangeable K (cmol (p^+) kg^{-1})

Treatments	Surface			Sub-surface		
	Initial	Flowering	Harvest	Initial	Flowering	Harvest
T_1: Control	0.74	1.31	1.27	0.74	1.27	1.63
T_2: 50% RD of NPK	1.03	1.49	1.39	1.01	1.32	1.77
T_3: 100% RD of NPK	1.20	1.74	1.63	1.11	1.55	1.90
T_4: 150% RD of NPK	1.49	1.87	1.84	1.32	1.62	2.00
T_5: 100% RD of NP	1.06	1.57	1.33	1.03	1.46	1.84
T_6: 100% RD of N	1.01	1.39	1.30	1.01	1.35	1.70
T_7: T_3 + FYM @10 t ha^{-1}	1.52	1.70	1.73	1.49	1.70	1.97
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	1.04	1.84	1.64	0.92	1.43	1.85
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	1.01	1.40	1.65	1.11	1.43	1.90
T_{10}: 200% RD of NPK	1.50	1.66	1.72	1.21	1.65	2.01
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	1.08	1.52	1.65	1.04	1.40	1.72
SEm±	0.08	0.12	0.07	0.07	0.08	0.10
CD (0.05)	0.25	NS	0.2	0.2	0.2	NS
CV (%)	11.5	13.5	8.2	11.7	9.4	9.5

Table 8. Effect of long-term use of manures and fertilizers on soil Exchangeable Ca (cmol (p^+) kg^{-1})

Treatments	Surface			Sub-surface		
	Initial	Flowering	Harvest	Initial	Flowering	Harvest
T_1: Control	27.4	27.9	27.5	26.8	27.3	27.1
T_2: 50% RD of NPK	29.1	29.5	28.9	28.5	28.8	27.6
T_3: 100% RD of NPK	29.3	30.7	29.8	29.0	30.1	28.8
T_4: 150% RD of NPK	30.0	31.6	30.7	29.6	30.4	29.1
T_5: 100% RD of NP	28.8	28.8	29.0	28.7	27.8	28.3
T_6: 100% RD of N	28.8	28.0	29.0	26.7	27.8	27.6
T_7: T_3 + FYM @10 t ha^{-1}	31.9	31.3	29.9	31.1	30.8	29.0
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	28.5	30.5	29.7	27.7	29.0	27.4
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	28.8	28.6	29.9	28.8	28.1	28.5
T_{10}: 200% RD of NPK	31.6	29.9	31.6	30.8	29.3	30.8
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	33.4	31.9	32.5	32.2	31.0	31.1
SEm±	2.15	1.2	1.65	1.83	1.70	1.73
CD (0.05)	NS	NS	NS	NS	NS	NS
CV (%)	12.5	7.0	9.5	10.9	10.2	10.4

Table 9. Effect of long-term use of manures and fertilizers on soil Exchangeable Mg (cmol (p^+) kg^{-1})

Treatments	Surface			Sub-surface		
	Initial	Flowering	Harvest	Initial	Flowering	Harvest
T_1: Control	2.53	3.63	3.60	2.33	2.33	3.50
T_2: 50% RD of NPK	2.60	3.87	3.73	2.53	2.53	3.57
T_3: 100% RD of NPK	3.33	3.92	3.83	2.87	2.87	3.83
T_4: 150% RD of NPK	3.47	4.03	3.87	3.17	3.17	3.87
T_5: 100% RD of NP	3.00	3.80	3.77	2.97	2.97	3.80
T_6: 100% RD of N	2.83	3.79	3.67	2.53	2.53	3.63
T_7: T_3 + FYM @10 t ha^{-1}	3.40	4.20	4.20	3.33	3.33	4.17
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	3.20	3.93	3.87	2.10	2.10	3.81
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	3.93	4.23	4.87	3.37	3.37	4.60
T_{10}: 200% RD of NPK	2.80	4.14	4.00	2.40	2.40	3.37
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	3.73	4.13	3.64	3.33	3.33	3.16
SEm±	0.23	0.44	0.37	0.13	0.13	0.29
CD (0.05)	0.7	NS	NS	0.4	0.4	NS
CV (%)	12.8	9.2	16.3	7.9	7.9	13.0

Table 10. Effect of long-term use of manures and fertilizers on PBS (%)

Treatments	Surface			Sub-surface		
	Initial	Flowering	Harvest	Initial	Flowering	Harvest
T_1: Control	89.2	91.6	94.2	88.3	89.8	94.1
T_2: 50% RD of NPK	92.9	94.1	92.3	92.7	92.5	90.5
T_3: 100% RD of NPK	93.3	95.3	94.4	92.1	93.0	92.9
T_4: 150% RD of NPK	92.2	93.6	92.4	90.4	91.0	88.3
T_5: 100% RD of NP	88.1	87.5	94.7	89.2	86.6	95.4
T_6: 100% RD of N	87.8	86.2	93.2	85.3	87.1	91.8
T_7: T_3 + FYM @10 t ha^{-1}	98.3	91.1	88.7	92.8	90.7	87.8
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	85.9	92.8	91.1	85.6	87.8	88.9
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	90.8	90.0	95.3	91.0	87.6	90.3
T_{10}: 200% RD of NPK	94.1	92.0	97.2	93.4	87.5	94.2
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	96.9	98.2	99.8	92.6	98.2	99.8
SEm±	2.93	2.93	3.25	2.63	2.63	2.93
CD (0.05)	NS	NS	NS	NS	NS	NS
CV (%)	5.7	5.7	6.3	5.3	5.3	5.7

Table 11. Effect of long-term use of manures and fertilizers on soil available iron content (ppm)

Treatments	Surface			Sub-surface		
	Initial	Flowering	Harvest	Initial	Flowering	Harvest
T_1: Control	5.45	7.78	6.54	5.37	7.53	6.18
T_2: 50% RD of NPK	6.58	9.03	8.08	6.00	8.95	7.78
T_3: 100% RD of NPK	6.25	8.51	7.73	5.93	8.31	7.30
T_4: 150% RD of NPK	6.11	8.42	7.52	5.86	8.18	7.17
T_5: 100% RD of NP	6.56	8.59	7.79	6.12	8.36	7.56
T_6: 100% RD of N	6.05	8.75	7.58	5.85	8.58	7.44
T_7: T_3 + FYM @10 t ha^{-1}	8.23	10.13	9.47	8.13	9.78	8.99
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	6.30	8.28	7.38	5.96	8.24	7.16
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	6.48	8.72	7.65	6.18	8.42	7.38
T_{10}: 200% RD of NPK	5.94	8.19	7.37	5.65	7.94	7.10
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	6.44	8.54	7.52	6.26	8.51	7.72
SEm±	0.38	0.39	0.34	0.21	0.34	0.39
CD (0.05)	1.13	NS	0.99	0.63	1.01	1.14
CV (%)	10.4	7.8	7.5	6.1	6.9	9.0

Table 12. Effect of long-term use of manures and fertilizers on soil available manganese content (ppm)

Treatments	Surface			Sub-surface		
	Initial	Flowering	Harvest	Initial	Flowering	Harvest
T_1: Control	2.94	2.28	2.44	2.78	2.17	2.36
T_2: 50% RD of NPK	3.74	3.06	3.40	3.42	2.86	3.23
T_3: 100% RD of NPK	3.48	2.97	3.31	3.31	2.77	2.96
T_4: 150% RD of NPK	3.29	2.55	3.18	3.26	2.33	2.85
T_5: 100% RD of NP	3.61	2.98	3.42	3.35	2.88	3.09
T_6: 100% RD of N	3.55	2.81	3.39	3.33	2.74	3.22
T_7: T_3 + FYM @10 t ha^{-1}	4.45	3.77	4.24	4.29	3.53	4.00
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	3.53	2.80	3.24	3.56	2.68	3.22
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	3.90	3.63	3.61	3.33	3.28	3.40
T_{10}: 200% RD of NPK	3.13	2.39	2.96	3.05	2.23	2.78
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	3.60	3.10	3.38	3.43	2.98	3.31
SEm±	0.11	0.17	0.15	0.19	0.15	0.18
CD (0.05)	0.31	0.49	0.43	0.57	0.46	0.52
CV (%)	6.2	10.6	7.6	9.9	9.7	9.7

Table 13. Effect of long-term use of manures and fertilizers on soil available copper content (ppm)

Treatments	Surface			Sub-surface		
	Initial	Flowering	Harvest	Initial	Flowering	Harvest
T_1: Control	1.58	2.14	1.98	1.55	2.10	1.70
T_2: 50% RD of NPK	1.80	2.55	2.42	1.70	2.39	2.34
T_3: 100% RD of NPK	1.72	2.44	2.34	1.68	2.30	2.22
T_4: 150% RD of NPK	1.64	2.37	2.29	1.58	2.26	2.09
T_5: 100% RD of NP	1.74	2.46	2.37	1.69	2.34	2.23
T_6: 100% RD of N	1.69	2.43	2.31	1.57	2.31	2.24
T_7: T_3 + FYM @10 t ha^{-1}	2.02	2.97	2.88	1.93	2.90	2.61
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	1.77	2.45	2.33	1.75	2.30	2.20
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	1.81	2.60	2.38	1.77	2.41	2.30
T_{10}: 200% RD of NPK	1.63	2.25	2.15	1.59	2.18	2.05
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	1.83	2.54	2.43	1.80	2.41	2.34
SEm±	0.05	0.09	0.11	0.11	0.10	0.13
CD (0.05)	0.16	0.26	0.32	NS	0.28	0.39
CV (%)	5.9	6.1	8.1	11.0	7.0	10.3

Table 14. Effect of long-term use of manures and fertilizers on soil available zinc content (ppm)

Treatments	Surface			Sub-surface		
	Initial	Flowering	Harvest	Initial	Flowering	Harvest
T_1: Control	0.50	0.39	0.47	0.44	0.33	0.48
T_2: 50% RD of NPK	0.84	0.74	0.81	0.75	0.69	0.72
T_3: 100% RD of NPK	0.78	0.71	0.76	0.71	0.63	0.62
T_4: 150% RD of NPK	0.70	0.59	0.68	0.62	0.52	0.57
T_5: 100% RD of NP	0.79	0.69	0.76	0.74	0.63	0.64
T_6: 100% RD of N	0.76	0.63	0.80	0.76	0.58	0.62
T_7: T_3 + FYM @10 t ha^{-1}	0.87	0.79	0.83	0.77	0.71	0.73
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	1.17	1.08	1.29	1.16	1.04	1.08
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	0.83	0.71	0.76	0.71	0.68	0.65
T_{10}: 200% RD of NPK	0.64	0.53	0.64	0.56	0.49	0.55
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	0.83	0.75	0.82	0.72	0.68	0.67
SEm±	0.04	0.05	0.05	0.04	0.04	0.04
CD (0.05)	NS	0.15	0.14	0.12	0.10	0.11
CV (%)	10.2	13.1	10.1	9.9	9.7	9.8

Table 15. data of initial soil samples (1991)

S. No.	Soil Properties	Soil values
1	pH	0.84
2	EC dS m^{-1}	0.60
3	OC (%)	0.37
4	Available nitrogen (kg ha^{-1})	196
5	Available phosphorus (kg ha^{-1})	23
6	Available potassium (kg ha^{-1})	392

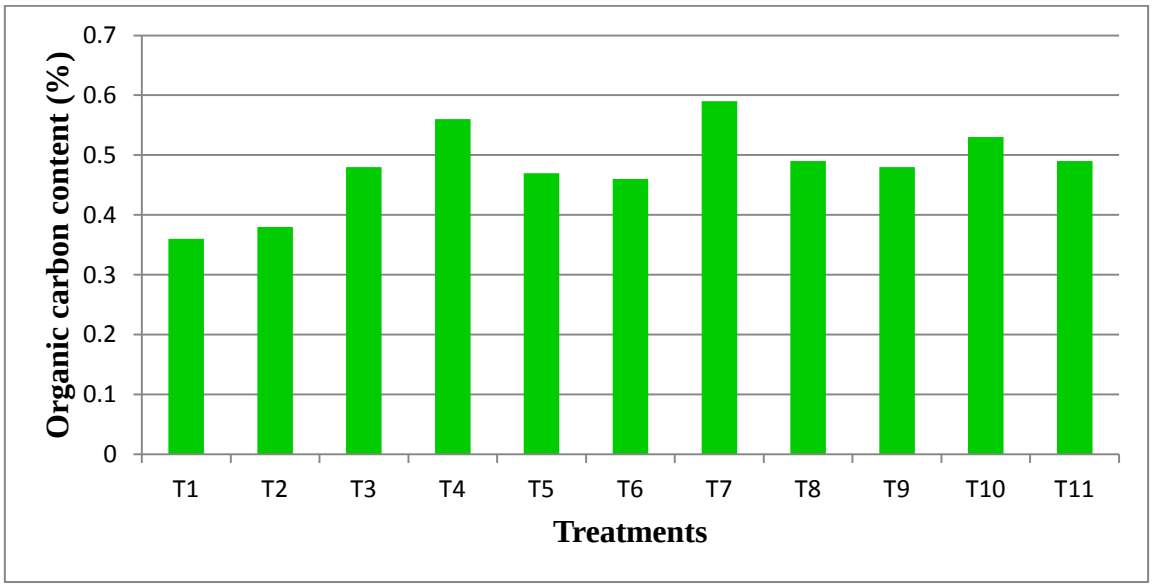

Fig: 1. Effect of long-term use of manures and fertilizers on organic carbon content (%) at harvest stage

CONCLUSION

Application of organics in conjunction with inorganic fertilizer recorded higher availability of secondary and micronutrients compared to individual application of inorganics alone. The soil analysis revealed that availability of all the nutrients (sulphur, calcium, magnesium, zinc and manganese) increased up to flowering and decreased at harvest. At all the stages at higher levels of NPK the micronutrient content was decreased at both the layers. The available zinc content which was highest in T_8 (100% RD of NPK+$ZnSO_4$ @ 50 kg ha^{-1}) followed by T_7 (100% RD of NPK+FYM @ 10 t ha^{-1}).

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