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Long-Term Effect of Manures and Fertilizers on Nutrient Status under Cotton Mono-Cropping in Vertisol

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A B S T R A C T

The status of nutrients-their depletion and build up in soil and crop productivity after twenty two years (1991-2012) of cotton mono-cropping were studied under continuous use of various inorganic fertilizers and organic manure in a Vertisol. Results showed that application of 100% RD of NPK (90:45:45 kg ha^{-1}) +FYM @ 10 t ha^{-1} recorded highest seed cotton yield of 2181 kg ha^{-1} which was on par with 150% RD of NPK treated plot. The soil pH and EC did not change significantly but markedly changed the organic carbon and available nutrient contents of the soil. Thus, the balanced use of fertilizers continuously either alone or in combination with organic manure is necessary for sustaining soil fertility and productivity of cotton under rainfed conditions.

Introduction

Cotton is the most important fiber crop of the world. It is the most beneficial fiber and cash crop of India and earns a good fortune for the country in the form of foreign exchange (Ahmed *et al.*, 2009). Increased nitrogen rate resulting in increased biological yield may be due to increase in N rate and increases mineral uptake, photosynthetic assimilation and accumulation in sinks Sawan *et al.*, (2006). The decline in soil fertility due to imbalanced fertilizer use has been recognized as one of the most important factor limiting crop yields (Nambiar *et al.*, 1989). Decline in yield has been observed in many cropping systems in many parts of the country due to nutrient depletion, soil structure deterioration and imbalanced use of plant nutrients, acidification, and sub-optimal addition of organic and inorganic fertilizers to soil. The capacity of soil for sustaining production depends on its fertility status. Organic matter helps in increasing adsorptive power of soil for nutrient ions. These adsorbed nutrient ions are released slowly for the benefit of crop during entire growth period. It helps to improve the soil physical (Biswas and Khosla, 1971) and chemical properties. Organic manures can play an important role in sustaining the productivity by not only acting as a source of nutrients but also through modifying soil physical behavior as well as increasing the efficiency of applied nutrients (Sahadevareddy and Aruna, 2008).

Materials and Methods

The long-term fertilizer experiment was initiated during the season *kharif* 1991 at Regional Agricultural Research Station, *Lam*, *Guntur*, 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 test crop was cotton, variety L-799. The crop was sown on 13-08-2013 and harvested on 09-03-2014 (Final picking). The initial (1991-92) soil characters were as following. The soil pH 8.4, E.C. 0.60 dSm^{-1}, organic carbon 0.37% and N, P_2O_5, K_2O 196, 23 and 392 kg ha^{-1}, respectively (Table 10). 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 treatments. 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 (Jackson, 1973). The E.C of soil samples was determined in 1: 2.5 soil water extract using electrical conductivity bridge (Jackson, 1973). Walkley and Black's "wet digestion method" as outlined by Jackson (1973) was followed to determine the organic carbon content of the soils. Available nitrogen content in the soils was determined by alkaline permanganate method (Subbiah and Asija, 1956). Available phosphorus in the soil samples was extracted with 0.5 M $NaHCO_3$ of pH 8.5 (Olsen *et al.,* 1954). Available potassium in soil was extracted using neutral normal ammonium acetate and potassium in the extract was determined flame photometrically gien by Muhr *et al.*, 1965.

The content of nitrogen in cotton plants was estimated by micro Kjeldahl method (Piper, 1966). Phosphorus in the di-acid extract of plant samples was estimated by vanado molybdo phosphoric yellow colour method using spectrophotometer at 420 nm as described by Jackson (1973). Potassium in the di-acid extract of plant sample was determined using flame photometer as per the method described by Jackson (1973).

Results and Discussion

Soil pH

The pH of the soil was not influenced at different stages (initial, flowering and harvest) of crop growth by different treatments in both the surface and subsurface soil. A glance of the data in table 1 revealed that soil pH was slightly increased from initial to harvest stage. There was a reduction in soil pH when compared to the initial (1991-92) value of 8.4. However, the treatment differences were non-significant.

Irrespective of nutrient management provided to cotton crop, the soil pH at different stages of crop growth decreased with increasing level of NPK (Table 1) from 50 to 200% but not at significant level. Those findings were in consonance with the work of Sinha *et al.*, (1997) and Prasad *et al.,* (2010a) who reported that the continuous use of urea fertilizer to both crops could able to decrease the pH after harvest of maize crop.

Electrical conductivity (dS m^{-1})

The EC of the soil was not significantly influenced by different treatments in the surface and subsurface soil. The EC of surface and subsurface soils ranged from 0.18 to 0.30 dS m^{-1} at various stages. The highest 0.30 dS m^{-1} was recorded in 200% RD of NPK (T_{10}) initial at surface soils and the lowest value 0.18 dS m^{-1} was recorded in the treatment control (T_1) harvest at subsurface soils. The trend of variation in EC of the soil between the treatments in both the soil layers was almost negligible and statistically non-significant (Table 2). There was considerable decrease in the soluble salt content of soil which was relatively less compared to the initial (1991-92) value of 0.60 dS m^{-1}.

The electrical conductivity decreased from initial to harvest stage 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. Low electrical conductivity in cotton growing soils, attesting to intense ion leaching was reported by Giora *et al.*, (2010).

Soil organic carbon

The glance of the data (Table 3, Fig. 1) 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% of 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 increase in organic carbon content in the surface soil as compared to the subsurface soil was mainly due to the accumulation of organic residues over a period of time.

Available nitrogen

The highest value (202 kg ha^{-1}) of available nitrogen was recorded with 100% RD of NPK + FYM @ 10 t ha^{-1} (T_7) treated plot (flowering stage, surface soil) followed by 150% RD of NPK (T_4) treated plot (198 kg ha^{-1}) (flowering stage, surface soil) followed by chemical fertilizers (100% RD of NPK) with the combination of gypsum (T_{11}), Zinc (T_8) and $MgSO_4$ (T_9) (Table 4). The highest value of available N due to incorporation of FYM 10 t ha^{-1} along with balanced fertilizer application once in year over a period of time might be attributed to enhanced mineralization and accumulation of N in surface soil layer. The surface soil samples had relatively high nitrogen content compared to sub-surface soils (Table 4, Fig. 2). The decrease of nitrogen availability with depth might be due to the low organic matter in the sub-surface (Bandyopadhyay *et al.*, 2004).

Available phosphorus

The available phosphorus content of soil also increased with maturity of the crop and similar to available nitrogen. Table 5 and figure 3 showed that there was a build-up of available P_2O_5 (except T_1 and T_6) over the initial value of 23 kg P_2O_5 ha^{-1}. Application of

FYM @ 10 t ha^{-1} along with RDF (T_7) recorded the highest amount of available phosphorus at initial, flowering and harvest as compared to rest of the treatments while, the lowest was recorded with T_1 (control). The available P was higher in the surface soils compared to sub-surface soils.

The highest available P_2O_5 was observed in T_7 treatment. Organic matter on the surface favoured the solubilisation of insoluble phosphorus releasing more quantity to the surface (Chaudhary *et al.,* 2006) and also due to the confinement of crop cultivation to the rhizosphere and supplementing of the depleted phosphorus through external sources *i.e.,* fertilizers.

Available potassium

Available K content of the soil increased (Table 6, Fig. 4) in all the treatments studied during *kharif* 2013-14 compared to the initial status (392 kg K ha^{-1}) of the year 1991. Surface soil samples had higher available potassium content when compared to sub-surface soil. This could be due to more intense weathering, release of K from organic residues, application of K fertilizers and upward translocation of potassium from lower depth along with capillary raise of ground water (Hirekurabar *et al.,* 2000).

Seed cotton yield

The data represented in table 7 and figure 5 indicated that among the treatments, FYM treated plot (T_7, RDF+FYM @ 10 t ha^{-1}) recorded significant increase in seed cotton yield along with T_4 (150% of RDF) over T_3 (100% RDF). The comparison of treatment T_3 (100% RDF) with T_8 (100 per cent RD of NPK+$ZnSO_4$ @ 50 kg ha^{-1}), T_9 (100% RD of NPK+$MgSO_4$ @ 50 kg ha^{-1}) and T_{11} (100% RD of NPK + gypsum @ 5 q ha^{-1}), did not show any marked effect on seed cotton yield. The yield reduction was 11.9 and 19.4 per cent in T_5 and T_6, respectively over T_3.

The highest seed cotton yield was observed in T_7 treatment, due to the use of organic manures like FYM. It attributed to increased microbial activity which in turn helped in transformation of nutrients making them more available to plants. Similar observations were reported by Lalithakumari *et al.,* (2010).

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 (dS m^{-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)	NS	NS	NS	NS	NS	NS
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 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.4 Effect of long-term use of manures and fertilizers on soil Available nitrogen content (kg ha^{-1})

Treatments	Surface			Sub-surface		
	Initial	**Flowering**	**Harvest**	**Initial**	**Flowering**	**Harvest**
T_1: Control	154	165	159	151	163	154
T_2: 50% RD of NPK	159	176	162	157	173	157
T_3: 100% RD of NPK	163	180	167	161	176	164
T_4: 150% RD of NPK	172	198	181	171	192	178
T_5: 100% RD of NP	161	179	166	160	176	162
T_6: 100% RD of N	161	178	165	158	175	159
T_7: T_3 + FYM @10 t ha^{-1}	182	202	189	181	200	184
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	163	182	169	162	180	164
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	163	182	169	162	178	164
T_{10}: 200% RD of NPK	168	186	175	164	184	173
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	167	185	173	164	182	172
SEm±	5.11	5.42	4.24	5.22	5.54	5.20
CD (0.05)	15.1	15.9	12.5	NS	16.3	15.3
CV (%)	5.9	5.1	5.2	5.5	5.3	5.4

Table.5 Effect of long-term use of manures and fertilizers on soil Available phosphorus (kg P_2O_5 ha^{-1})

Treatments	Surface			Sub-surface		
	Initial	**Flowering**	**Harvest**	**Initial**	**Flowering**	**Harvest**
T_1: Control	20.4	21.2	20.6	17.5	20.0	19.7
T_2: 50% RD of NPK	33.8	41.2	38.2	31.1	38.0	36.7
T_3: 100% RD of NPK	36.3	47.7	43.3	33.8	44.6	41.1
T_4: 150% RD of NPK	45.4	52.8	48.6	42.9	49.5	46.0
T_5: 100% RD of NP	36.0	46.5	43.2	34.6	44.7	40.6
T_6: 100% RD of N	21.9	23.5	22.2	19.0	22.1	20.4
T_7: T_3 + FYM @10 t ha^{-1}	51.8	62.8	56.4	48.2	60.8	52.9
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	37.3	49.3	43.6	35.8	44.9	42.2
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	37.4	49.1	43.8	36.4	45.0	41.5
T_{10}: 200% RD of NPK	48.4	56.5	53.0	43.4	52.6	50.6
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	40.9	51.5	48.2	39.5	49.3	45.5
SEm±	2.3	2.1	2.3	1.7	2.2	2.5
CD (0.05)	6.7	6.3	6.8	4.9	6.6	7.4
CV (%)	10.6	8.1	9.5	8.3	9.0	10.9

Table.6 Effect of long-term use of manures and fertilizers on soil Available potassium (kg K_2O ha^{-1})

Treatments	Surface			Sub-surface		
	Initial	Flowering	Harvest	Initial	Flowering	Harvest
T_1: Control	461	480	470	448	465	459
T_2: 50% RD of NPK	512	522	515	496	492	503
T_3: 100% RD of NPK	549	559	530	533	526	517
T_4: 150% RD of NPK	628	663	644	621	633	633
T_5: 100% RD of NP	535	537	528	506	521	512
T_6: 100% RD of N	479	515	510	456	507	482
T_7: T_3 + FYM @10 t ha^{-1}	695	712	664	679	649	648
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	558	570	532	542	535	520
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	563	580	555	549	524	537
T_{10}: 200% RD of NPK	618	653	634	603	626	619
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	599	638	619	581	617	594
SEm±	16.39	17.58	19.55	16.49	18.87	15.38
CD (0.05)	48	51	57	48	55	45
CV (%)	5.0	5.6	6.5	5.2	5.9	5.2

Table.7 Effect of long-term use of manures and fertilizers on yield of cotton

Treatments	Seed cotton yield kg ha^{-1}	% increase over control	% increase (or) decrease over T_3	Stalk yield	Biological yield	HI (%)
				kg ha^{-1}		
T_1: Control	939	-	-45.9	1836	2775	33.8
T_2: 50% RD of NPK	1370	46.0	-21.0	2696	4066	33.7
T_3: 100% RD of NPK	1735	84.8	-	3434	5169	33.5
T_4: 150% RD of NPK	2135	127.4	23.0	4228	6363	33.5
T_5: 100% RD of NP	1527	62.6	-11.9	3026	4553	33.5
T_6: 100% RD of N	1399	49.0	-19.4	2765	4164	33.6
T_7: T_3 + FYM @10 t ha^{-1}	2181	132.3	25.7	4330	6511	33.5
T_8: T_3+$ZnSO_4$ @50 kg ha^{-1}	1806	92.3	4.0	3586	5393	33.5
T_9: T_3+$MgSO_4$ @50 kgha^{-1}	1797	91.4	3.6	3560	5359	33.5
T_{10}: 200% RD of NPK	1980	110.9	14.1	3913	5893	33.6
T_{11}: T_3+gypsum @ 5 q ha^{-1}	1862	98.3	7.3	3686	5548	33.5
SEm±	104.9	-	-	173.8	260.7	0.02
CD (0.05)	316	-	-	512	769	NS
CV (%)	11.2	-	-	8.9	8.9	0.08

Table.8 Effect of long-term use of manures and fertilizers on nutrient content (%) of cotton

Treatments	Nitrogen		Phosphorus		Potassium	
	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
T_1: Control	2.36	2.22	0.36	0.26	2.83	2.28
T_2: 50% RD of NPK	2.55	2.30	0.44	0.32	2.90	2.43
T_3: 100% RD of NPK	2.66	2.45	0.51	0.40	3.09	2.50
T_4: 150% RD of NPK	2.82	2.63	0.60	0.47	3.22	2.65
T_5: 100% RD of NP	2.60	2.42	0.50	0.38	3.02	2.44
T_6: 100% RD of N	2.48	2.40	0.47	0.34	2.97	2.38
T_7: T_3 + FYM @10 t ha^{-1}	3.00	2.77	0.63	0.50	3.31	2.73
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	2.68	2.48	0.53	0.42	3.14	2.53
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	2.69	2.47	0.52	0.41	3.10	2.51
T_{10}: 200% RD of NPK	2.78	2.60	0.57	0.44	3.15	2.60
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	2.70	2.52	0.54	0.40	3.17	2.54
SEm±	0.08	0.08	0.02	0.03	0.09	0.09
CD (0.05)	0.25	0.23	0.06	0.09	0.26	NS
CV (%)	5.5	5.4	6.9	13.4	5.1	5.9

Table.9 Effect of long-term use of manures and fertilizers on nutrient uptake

Treatments	Nitrogen		Phosphorus		Potassium	
	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
T_1: Control	42.7	61.5	6.5	7.0	50.7	63.1
T_2: 50% RD of NPK	67.5	93.8	11.6	13.1	76.8	99.0
T_3: 100% RD of NPK	90.3	126.9	17.3	20.7	104.7	129.4
T_4: 150% RD of NPK	118.2	171.8	25.1	30.3	134.6	171.9
T_5: 100% RD of NP	76.9	110.1	14.7	17.2	90.9	110.5
T_6: 100% RD of N	67.4	99.8	12.7	14.1	80.9	99.2
T_7: T_3 + FYM @10 t ha^{-1}	128.7	176.5	26.9	31.6	141.9	173.9
T_8: T_3 + $ZnSO_4$ @ 50 kg ha^{-1}	94.9	133.7	18.7	22.1	111.1	136.5
T_9: T_3 + $MgSO_4$ @ 50 kg ha^{-1}	94.7	132.4	18.3	21.9	109.0	134.6
T_{10}: 200% RD of NPK	107.5	153.5	22.1	25.7	121.8	152.9
T_{11}: T_3 + gypsum @ 5 q ha^{-1}	98.4	140.1	19.6	22.7	115.5	141.1
SEm±	5.01	8.30	1.03	1.87	6.43	6.98
CD (0.05)	14.8	24.5	3.0	5.5	18.9	20.6
CV (%)	9.7	11.3	10.1	15.7	10.8	9.4

Table.10 Data of initial soil samples (1991)

S. No.	Soil Properties	Soil values
1	pH	8.4
2	EC dS m^{-1}	0.60
3	OC (%)	0.37
4	Available nitrogen (kg ha^{-1})	196
5	Available phosphorus (kg P_2O_5 ha^{-1})	23
6	Available potassium (kg K_2O ha^{-1})	392

Stalk yield and biological yield (kg ha^{-1})

The data (Table 7 and Fig. 6) indicated that different nutrient treatments significantly influenced the stalk yield of cotton crop. Control plot (T_1) showed a drastic reduction in the stalk yield due to the removal and depletion of nutrients with continuous cropping without fertilization (Bharadwaj and Omanwar, 1994). The treatments T_8, T_9 and T_{11} were on par with each other and recorded significantly lower stalk yield than T_7. The highest stalk yield recorded in T_7 due to better nutrition of crop plants influenced FYM application which might have increased the photosynthesis rate (Rajarajan *et al.*, 2005).

The biological yield (table 7) (kapas yield + stalk yield) was significantly influenced by application of 100% RD of NPK+FYM @ 10 t ha^{-1} (T_7) over control. The highest biological yield was observed in T_7 followed by T_4 and T_{10}. Overall, the highest biological yield recorded in combined treatment was attributed to the synergistic interaction primarily effect between FYM and inorganic fertilizers. FYM (farm yard manure) might have acted as a source of additional nutrients and moisture retention.

Nitrogen, phosphorus and potassium content in cotton at harvest stages

At harvest stage, the highest N, P and K content in plant (Table 8) was noticed in T_7 (100% NPK + 10 t FYM ha^{-1}) but N and P content were found at par with 150% RD of NPK and 200% RD of NPK treatments. Increasing dose of inorganic fertilizers showed enhanced primary nutrient content in cotton upto 150% RD of NPK. The treatments 100% NPK+$ZnSO_4$ @ 50 kg ha^{-1} (T_8), 100% NPK+$MgSO_4$ @ 50 kg ha^{-1} (T_9) and 100% RD of NPK + gypsum 5 q ha^{-1} (T_{11}) recorded more nitrogen content in cotton plant over 100% RD of NPK treatment (T_3). The higher nutrient content resulted on integrated management of organic and inorganic sources (T_7) might be the cause for increased concentration of nutrients mainly nitrogen in cotton (Nawlakhe and Mankar, 2011).

Phosphorus content in cotton was highest (0.50%) in treatment T_7 that received (100% RD of NPK + FYM @ 10 t ha^{-1}). The increased content of phosphorus with conjunctive use of FYM and inorganics might be due to the formation of phosphohumic complexes, which were more easily assimilated by the plants.

The highest K content was recorded in the treatment T_7 (100 per cent recommended dose of NPK+FYM @ 10 t ha^{-1}) with 2.73 per cent followed by T_4 (150 per cent recommended dose of NPK) with 2.65 per cent.

Continuous manuring and fertilization at the same site for long period affected the soil fertility and there by uptake of nutrient by crop (Table 9). In this present study increasing trend in uptake of NPK by cotton was observed with increasing fertilizer levels from 50 to 150 per cent of RDF and slightly decreased at 200% RDF. The highest uptake of N, P and K (176.5, 31.6 and 173.9 kg ha^{-1} respectively) were recorded with the application of 100% RD of NPK + FYM 10 t ha^{-1} followed by 150% RD of NPK (T_4).

The lowest total uptake of N, P and K were observed i.e. 61.5, 7.0 and 63.1 kg ha^{-1} respectively by cotton in control treatment. Application of super optimal dose ($T_{4,}$ 150% RD of NPK) of treatment showed significant increase in N, P and K uptake by cotton over 50%, 100% RDF and control.

Finally, it can be concluded that combined use of organics and inorganics can help not only in increasing the yield and uptake of nutrients but also in improving soil organic carbon, available nutrient status and thereby increasing the nutrient supplying capacity of soil, which in turn help in sustainable crop production.

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