Integrated nutrient management practices for sustainable production in cotton based cropping systems under assured rainfall conditions

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ABSTRACT

High and sustainable productivity of cotton is associated with balanced and sound nutrition. The declining trend in yields of cotton is related to nutritional problems, changes in cotton ecosystem, cropping sequence and management practices followed. The nutrient supply system can be improved by adopting integrated nutrient management practices for the cropping system used. Farm yard manure (FYM), vermicompost (VC) and crop residues (CR) are the best sources of organic manures. Besides, crop rotation is also an important aspect for better soil health and to obtain crop yields on a sustainable basis. With this background experiment was conducted during 1997 to 2001 on permanent site under rainfed conditions at ARS, Dharwad Farm to investigate the effects of organics and inorganics on the crop yields of cotton-based rotational cropping systems. The popular cropping system consisting of cotton followed by groundnut and rabi sorghum in one cycle of two years was used in the experiment. Mean results of 3 years experiments indicated that application of FYM at 10 000 kg/ha increased the yield of cotton significantly over other organics. The same trend was observed in all years. Combination of FYM at 3.3 tons, VC at 0.8 tons and CR at 1.6 tons /ha produced the next highest yield of cotton as compared to other treatments. Reduction in the application of the recommended dose of inorganic fertilizer (RDF) from 100 to 0% reduced the yield of cotton significantly. Similar observations were made even when organics were combined with fertilizers. It was noticed from the pooled data that combination of 100% RDF and FYM at 10 000 kg/ha has produced significantly higher yield of cotton (1594 kg/ha) compared with other treatments. Whereas rabi sorghum produced higher yield with combined application of CR at 5000 kg/ha and 50% RDF (2329 kg/ha) as against groundnut which produced higher yield with VC at 1250 kg and CR at 2500 kg/ha +100% RDF (692 kg/ha). Among the organic manures, FYM was more effective on cotton and FYM/CR were equally effective on Rabi sorghum, but a combination of these organic manures was better for groundnut to produce more yields. In general, the results clearly indicated that combination of RDF and organic manures has greater scope for upgrading crop yields on a sustainable basis in cotton-based rotational cropping systems. Further, this experiment is being continued on a permanent site to see the long-term effects of yearly application of organic and inorganic manures on crop yields and soil properties.

Introduction

The use of mineral fertilizers is the fastest and definite way to improve improving crop productivity. However, the increases in cost and associated environmental hazards as well as lack of sustainability in yields under application of such fertilizers are constraints in cotton production. Low soil organic matter coupled with deficiencies of nutrients and continuous cotton cropping and management practices are the main reasons for lack of sustainability. This has renewed the interest in the use of organic fertilizers along with inorganic fertilizers. High and sustainable productivity of cotton is associated with balanced nutrition and availability of nutrients in the soil. Nutrient supply systems can be improved by adopting Integrated Nutrient Management (INM) practices. Integration of organics and inorganics needs to be incorporated in cotton manurial schedule. Farmyard manure, which is a treasure house of nutrients, not only supplies major nutrients but also acts as a reservoir of micronutrients. It is both enhancing the organic matter content of soils, as well as the water holding capacity of the soil. In general, farmyard manure improves physical, biological and chemical properties of the soil. Crop residues, which is a low cost input and farm waste, acts as a nutrient supplier after decomposition. Man-made vermicompost is also an organic source with higher levels of nutrients. Integrated methods involving combination of organic and inorganic manures can sustain nutrient extraction and maintain the higher level of productivity and soil fertility on a long-term basis. With this background, long-term experiments on a permanent site were planned and executed to investigate the effects of INM practices on the yields of different crops and soil properties in a cotton-based cropping system.

Experimental procedure

A field experiment was conducted under assured rainfall condition (750 mm annual rainfall) on a permanent site in medium deep black soil at ARS, Dharwad farm, Karnataka, India. This experiment is being continued on a permanent site and every year the same treatment is imposed in a particular plot. The experiment was laid out in a split plot design with three replications. Cotton crop (first year) is rotated with groundnut in kharif and sorghum in rabi seasons (second year) in one cycle of two years. This experiment was initiated during 1997-98 and completed three cycles of two years rotation by 2002-03. Eight treatments consists of farmyard manure (FYM) at 10000 kg/ha, crop residue (CR) at 5000 kg/ha, vermicompost (VC) at 2500 kg/ha, FYM at 5000 kg/ha + CR at 2500 kg/ha, FYM at 5000 kg/ha + VC at 1250 kg/ha, CR at 2500 kg/ha + VC at 1250 kg/ha, FYM at 3300 kg/ha+ CR at 1870 kg/ha

+ VC at 830 kg/ha and control (without organics) were in the main plots for kharif crops only and inorganic fertilizers at 0.50 and 100 percent of recommended dose of fertilizers to each crop were in sub plots. The RDF applied to cotton, groundnut and rabi sorghum were 40:25:25, 25:30:25 and 50:25:0 NPK kg/ha, respectively. Organic manures were applied only to kharif crops every year 20 days before sowing and inorganic fertilizers were applied for all the crops at the time of sowing. Cotton was sown with Sahana (*G. hirsutum*) variety at 60 x 30 cm spacing during June-July and harvested during January-February. Groundnut (cv. TMV-2) is a kharif crop usually sown during June and harvested during September, and rabi sorghum variety M 35-1 was usually sown during October and harvested during February. FYM, crop residue and vermicompost were applied in furrows and covered with soil. Recommended plant protection measures were taken as and when required for control of pests in all crops. Observations for growth, yield parameters and yield were recorded at the time of harvesting. Soil samples were taken at the start of the experiment and after each cycle for the estimation of physical and chemical properties.

Results and Discussion

Response of cotton to application of organic manures

The mean of three cycles data for cotton (Table 1) indicated that FYM at 10000 kg/ha has produced significantly 13 to 38 percent higher (1398 kg/ha) yields over other organics and control. Similar trends were observed in all years. Little information is available on the effect of continuous manuring on crop yields. Such studies made by Khaini and More (1984) indicated that continuous application of FYM increased the organic carbon and available nutrients two-fold in cotton-sorghum rotation, and the yield of cotton was nearly doubled. Besides, addition of organic matter improved the physical properties of the soil. In another study, regular addition of FYM improved the organic carbon and increased the percentage of water-stable aggregates, and thereby improved the soil structure. Hence, there were increases in pore space, water holding capacity and microbial activity (Singh and Bhattacharya, 1989). In the present investigation, besides FYM at 10000 kg/ha, application of FYM at 3300 kg/ha + CR at 1670 kg/ha + VC at 830 kg/ha has also produced more kapas yield (1240 kg/ha), which was comparable with that of FYM at 5000 kg/ha + CR at 2500 kg/ha (1208 kg/ha). Similar results were obtained by Chandrashekhar *et al*. (1998) and they observed that combined application of FYM, CR and VC recorded the highest yield of cotton in INM studies for cotton-maize cropping system. However, application of crop residue at 5000 kg/ha or Vermicompost at 2500 kg/ha alone or their combination did not improve the yield of cotton. Similar trend was observed for most of the yield components (Tables 3 and 4). Earlier studies also indicated that crop residue application alone had no spectacular influence on the crop yield under rainfed agriculture (Chokhey, Singh and Wankhade, 1983) and the increase in yield was 35 to 110 kg/ha with 5000 kg/ha and 150 to 200 kg/ha with 10000 kg/ha. Under dryland conditions crop residue decomposition is generally too late or sometimes not possible. Same time the incorporated biomass may deplete the soil moisture by absorbing moisture from soil thus affects the crop growth. In this study also similar results were obtained with respect to cotton yield. However, the data show that application of any organic has numerical superiority in yield over control in all the cycles of cotton production. Among the organics, FYM alone followed by combination of FYM, VC and CR, as well as a combination of FYM and CR are found to improve the yield of cotton on a sustainable basis.

Response of cotton to application of inorganic fertilizers

Application of inorganic chemical fertilizers increased the yield of cotton significantly from control to 50% RDF and further to 100% RDF in all the cycles (Table 1). The mean data of 3 cycles indicated that cotton yield was related to the supply of nutrients to the cotton crop. Berger (1969) reported that cotton removes more nutrients to produce higher yield of cotton. Therefore, cotton yield depends upon the quantity of nutrients applied to the crop. Similar results were obtained by Das *et al*. (1991) and Mannikar (1993). Further, Chandrashekhar *et al*. (1998) reported that 10 to 30 percent of cotton and 17 to 45 percent of maize yields were lost due to the reduction in chemical fertilizers from 100 to 50 percent of the recommended dose of fertilizers. It was also find in this study that cotton yield at 100 percent RDF (1335 kg/ha) was significantly superior compared to 50 percent RDF (1174 kg/ha) and the control (931 kg/ha) where no fertilizer was applied and that yield increase was to the extent of 43 and 26 percent over control, respectively. The same trend was also noticed for yield parameters.

Response of cotton to combination of organic and inorganic manures

Interaction effects were significant. Application of FYM at 10000 kg/ha with 100 percent RDF produced significantly higher yields compared to the other treatments (Table 1). Yield increase was significant for each of the applied organic fertilizers when fertilizer doses were increased from 0 to 50 percent and further to 100 percent RDF. This study clearly shows that cotton yields were increased to a greater extent when organic plus inorganic manures were applied to the cotton. Similar results were obtained by Solaiappan (2002) and he found that combined application of organic manure and recommended level of inorganic fertilizer gave significantly and consistently higher seed cotton and sorghum grain yield. In this study cotton yield with FYM at 10000 kg/ha alone (1187 kg/ha) was comparable with 100 percent RDF alone (1228 kg/ha). Cot-

ton yield was 1187 kg/ha with 10000 kg/ha of FYM and it was 1228 kg/ha with 100 percent RDF. These yields were increased to 1594 kg/ha when both were applied and improvement in yield was to the extent of 30 to 34 percent. Similar trends were noticed in all the years of cotton production. Therefore, these results clearly indicated that enhancement of cotton yield on a sustainable basis is possible if nutrient supply is made through application of inorganic plus organic manures.

Effect of INM practices on the yield of groundnut, sorghum and equivalent yield of cotton

Rabi sorghum produced highest yield (Table 2) with combined application of 50 percent RDF and crop residue at 5000 kg/ha (2329 kg/ha), as against groundnut which produced higher yield with VC at 1.25000 kg/ha+ CR at 25000 kg/ha with 100 percent RDF (692 kg/ha). The effect of combination of crop residue with VC and fertilizers was more convincing with groundnut and sorghum than cotton production. It is also clear from the data that like cotton production, response to inorganic fertilizers irrespective of different organics yield was increased with increasing levels of fertilizers both in groundnut and sorghum crops. Though the response to organics was very meager in groundnut production, sorghum responded better to crop residue and FYM applications. Increasing the level of fertilizers from 0 to 100 percent improved the yield of all the crops irrespective of the source of organics added. Total cotton equivalent yield (Table 5) reflects the effect of crop rotation and response to INM practices for production of one cycle cropping system of two years. It is evident from the yield data that FYM at 10000 kg/ha (2298 kg/ha) is best among all the organics followed by FYM at 5 t + CR at 25000 kg/ha (2087 kg/ha). The data show that the effect of crop residue with fertilizer and VC was greater on groundnut and sorghum than on cotton, thus producing best yield of cotton equivalent in one cycle of two years. Further, the effect of inorganic fertilizers was also quite convincing to increase the yield of cotton when fertilizer dose was increased from 0 to 50 and further to 100 percent RDF. Cotton equivalent yield of only FYM at a 10000 kg/ha application (1944 kg/ha) was on par with 100 percent RDF application (2028 kg/ha). Highest yield was obtained only when FYM at 10000 kg/ha along with 100 % RDF was applied (2620 kg/ha). From the data of three cycles it is concluded that in a rotational cropping system of cotton –groundnut (kharif) – sorghum (rabi) in two years, application of FYM at 10000 kg/ha with 100 percent RDF followed by application of FYM at 5 t + CR at 25000 kg/ha with 100 percent RDF was optimum for higher yields under assured rainfall conditions. Wherever FYM is in short supply farmers can supplement the organics with crop residues to boost crop yields.

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Table 1. *Cotton yield (kg/ha) as affected by integrated nutrient management practices in cotton based cropping system.*

Organic manures	1997				1999				2001				Mean of 3 cycles			
	Control	50% RDF	100% RDF	Mean	Control	50% RDF	100% RDF	Mean	Control	50% RDF	100% RDF	Mean	Control	50% RDF	100% RDF	Mean
FYM 10000 kg/ha	804	995	1208	1002	1970	2336	2612	2306	787	910	964	887	1187	1414	1594	1398
Vermicompost 2500 kg/ha	564	724	917	735	1167	1833	1873	1624	534	774	904	737	755	1110	1231	1032
Crop residue 5000 kg/ha	588	726	894	736	1186	1923	2152	1754	555	795	887	746	777	1148	1311	1078
FYM 5000 kg/ha +VC 1250 kg/ha	791	907	1012	900	1806	1875	2045	1908	538	706	715	653	1042	1163	1257	1154
FYM 5000 kg/ha +CR 2500 kg/ha	689	832	1052	858	1776	1919	2023	1906	765	830	985	860	1077	1194	1354	1208
VC 1250 kg/ha + CR 2500 kg/ha	587	757	902	749	1199	1791	1970	1653	655	742	848	748	814	1097	1240	1050
FYM 3300 +VC 800 +CR 1600 (kg/ha)	844	1042	1144	1010	1414	1874	2278	1856	705	892	969	855	988	1270	1464	1240
Control	557	696	843	698	1204	1537	1984	1575	666	753	859	759	809	995	1228	1011
Mean	677	835	996		1465	1886	2117		650	800	891		931	1174	1335	
For comparing means	SEm ±	CD at 5%	CV %		SEm ±	CD at 5%	CV %		SEm ±	CD at 5%	CV %		SEm ±	CD at 5%	CV %	
Organic manures (O)	112.7	NS	8.7		53.6	163	8.3		57.3	NS	9.5		30.4	85.2	13.8	
Fertilizer levels (F)	14.9	42.8			30.8	89			15.1	43.6			18.6	52.2		
'F' at same level of '0'	--	NS			87.1	251			42.8	123.3			--	--		
'0' at same or different level of 'F'	--	NS			80.1	241			67.1	NS			52.7	147.6		

Table 2. *Groundnut and* Rabi *Sorghum yield as affected by integrated nutrient management practices in cotton based cropping system (means of 1998-99 and 2000-01).*

	Chemical fertilizers							
	Ground nut yield (kg/ha)				Sorghum yield (kg/ha)			
Organic manures	Control	50% RDF	100% RDF	Mean	Control	50% RDF	100% RDF	Mean
FYM 10000 kg/ha	447	496	619	520	1434	1830	1921	1728
Vermicompost 2500 kg/ha	410	535	628	524	1352	1614	1844	1603
Crop residue 5000 kg/ha	395	432	643	489	1462	2329	2016	1936
FYM 5000 kg/ha +VC 1250 kg/ha	414	559	632	535	1125	1447	1719	1430
FYM 5000 kg/ha +CR 2500 kg/ha	443	478	597	506	1265	1776	2032	1691
VC 1250 kg/ha + CR 2500 kg/ha	482	560	692	578	1020	1695	1886	1534
FYM 3300 +VC 800 +CR 1600 (kg/ha)	434	516	592	514	1021	1380	1620	1340
Control	418	485	525	476	896	1164	1412	1158
Mean	430	507	616		1197	1654	1807	

Table 3. *Growth parameters as affected by integrated nutrient management practices in cotton based cropping system (mean of 3 years).*

Organic manures	Plant height (cm)				Number of monopodials/plant				Number of sympodials/plant			
	Control	50% RDF	100% RDF	Mean	Control	50% RDF	100% RDF	Mean	Control	50% RDF	100% RDF	Mean
FYM 10000 kg/ha	75.06	78.78	88.12	80.65	1.9	2.2	2.8	2.3	12.9	12.6	13.8	13.1
Vermicompost 2500 kg/ha	68.00	73.30	76.97	72.76	1.3	1.8	2.1	1.7	12.8	12.7	12.8	12.8
Crop residue 5000 kg/ha	69.18	75.12	77.76	74.02	1.4	1.8	2.5	1.9	13.1	13.2	12.7	13.0
FYM 5000 kg/ha +VC 1250 kg/ha	74.98	71.18	78.07	74.74	1.7	2.3	2.5	2.2	12.8	11.9	12.6	12.4
FYM 5000 kg/ha +CR 2500 kg/ha	73.96	74.62	78.24	75.61	1.8	1.7	2.6	2.0	11.9	12.9	12.6	12.5
VC 1250 kg/ha + CR 2500 kg/ha	70.49	70.56	77.36	72.80	1.4	1.8	2.0	1.7	12.4	12.6	13.2	12.7
FYM 3300 +VC 800 +CR 1600 (kg/ha)	74.53	75.99	79.62	76.72	1.9	2.2	2.4	2.1	13.5	13.1	13.6	13.4
Control	64.96	73.86	81.38	73.40	1.5	2.4	2.3	2.1	11.9	12.4	13.6	12.7
Mean	71.39	74.18	79.69		1.6	2.0	2.4		12.7	12.7	13.1	
For comparing means	SEm ±	CD at 5%	CV %		SEm ±	CD at 5%	CV %		SEm ±	CD at 5%	CV %	
Organic manures (O)	2.09	NS	9.94		0.12	0.33	29.94		0.34	NS	9.84	
Fertilizer levels (F)	0.88	2.43			0.07	0.20			0.15	0.41		
'0' at same or different level of 'F'	4.31	NS			0.35	NS			0.73	NS		

Table 4. *Yield parameters as affected by integrated nutrient management practices in cotton based cropping system (means of 3 years).*

Organic manures	Number of bolls/plant				Boll weight (g)				Yield/plant (g)			
	Control	50% RDF	100% RDF	Mean	Control	50% RDF	100% RDF	Mean	Control	50% RDF	100% RDF	Mean
FYM 10 000 kg/ha	10.9	11.5	11.7	11.4	3.9	3.9	4.0	3.9	30.4	38.3	35.5	34.7
Vermicompost 2500 kg/ha	7.2	8.7	9.2	8.4	3.7	3.8	3.9	3.8	19.8	28.9	27.2	25.3
Crop residue 5000 kg/ha	8.0	10.4	11.1	9.8	3.7	3.8	3.8	3.8	23.7	31.7	33.3	29.6
FYM 5000 kg/ha +VC 1250 kg/ha	8.5	8.5	10.8	9.3	3.8	3.8	4.0	3.8	24.4	27.5	35.6	29.2
FYM 5000 kg/ha+ CR 2500 kg/ha	8.8	10.1	10.4	9.8	3.8	3.8	3.9	3.8	23.7	28.8	34.1	28.9
VC 1250 kg/ha +CR 2500 kg/ha	9.3	10.8	9.5	9.9	3.8	3.9	4.0	3.9	28.1	32.4	44.1	34.9
FYM 3300 + VC 800 +CR 1600 (kg/ha)	10.1	10.5	9.9	10.1	3.9	3.9	4.0	3.9	29.3	31.7	35.9	32.3
Control	8.3	9.3	10.1	9.2	3.6	3.7	3.8	3.7	20.9	28.6	34.1	27.9
Mean	8.9	10.0	10.4		3.8	3.8	3.9		25.1	31.0	35.0	
For comparing means	SEm ±	CD at 5%	CV %		SEm ±	CD at 5%	CV %		SEm ±	CD at 5%	CV %	
Organic manures (O)	0.65	NS	24.39		0.06	NS	7.42		3.07	NS	31.76	
Fertilizer levels (F)	0.28	0.78			0.03	0.09			1.14	3.15		
'0' at same or different level of 'F'	1.37	NS			0.17	NS			5.56	NS		

Table 5. *Cotton equivalent yield of groundnut and rabi sorghum and total yield of cotton per cycle of two years as affected by cotton based cropping system as influenced by INM practices.*

Organic manures	Cotton equivalent yield of ground nut, kg/ha				Cotton equivalent yield of sorghum, kg/ha				Total yield of cotton/cycle			
	Control	50% RDF	100% RDF	Mean	Control	50% RDF	100% RDF	Mean	Control	50% RDF	100% RDF	Mean
FYM 10000 kg/ha	291	322	402	338	466	595	624	562	1944	2331	2620	2298
Vermicompost 2500 kg/ha	267	348	408	341	439	524	599	521	1461	1982	2238	1894
Crop residue 5000 kg/ha	257	281	418	318	475	757	655	629	1509	2186	2384	2025
FYM 5000 kg/ha +VC 1250 kg/ha	269	363	411	348	366	470	559	465	1677	1996	2227	1967
FYM 5000 kg/ha+ CR 2500 kg/ha	288	311	388	329	411	577	660	550	1893	2082	2402	2087
VC 1250 kg/ha +CR 2500 kg/ha	313	364	450	376	331	551	613	498	1458	2012	2303	1924
FYM 3300 + VC 800 +CR 1600 (kg/ha)	282	335	385	334	332	448	526	435	1602	2053	2375	2009
Control	272	315	341	309	291	378	459	376	1372	1688	2028	1696
Mean	280	329	400		389	537	587		1600	2040	2322	