EFFECT OF GROWING COTTON CONTINUOUSLY AND IN ROTATION WITH DIFFERENT CROPS ON THE FERTILITY OF BLACK COTTON SOIL

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IN a previous communication (Deshpande, Ballal and Kalamkar, 1955) the effects of growing cotton in rotation with different crops on the structure of Black Cotton Soil have been reported.* The observations indicated that the structural condition of the soil, though satisfactory, did not show significant differences under different rotations studied, in spite of the fact that they were in progress for over a period of 21 years. However, the yield data showed increased yields of cotton and juar in the Cotton-Juar-Groundnut rotation over the Cotton Continuous and Cotton-Juar Rotations. In view of these findings it was considered desirable to investigate into the comparative fertility of the soil under different rotations as revealed by the determinations of various total and available nutrients. The results obtained in this investigation are recorded in the present communication.

EXPERIMENTAL

In the previous study the soil samples used for structural analysis were collected from the plots under the following rotations:

Rotation A: Cotton grown year after year.

Rotation B: Cotton followed by juar in alternate years.

Rotation C: Three course rotation: First year cotton followed by juar in second year followed by groundnut in third year.

The same samples were used in the present work also. A composite surface soil sample for each plot was taken by mixing equal quantities of soil from ten different spots taken at random. Each block contained six plots under the above three rotations. Thus thirty samples were collected for three rotations for all the five blocks. The composite samples were air-dried, sieved and thoroughly mixed before being stored in closed glass jars.

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* This rotation experiment was conducted on the Government Experimental Farm, Akola, since 1931–32 in its revised form by the Economic Botanist for Cotton, Nagpur.

ANALYTICAL METHODS

Total nitrogen was determined by Kjeldahl method as modified by Bal (1925). Organic carbon was determined by Walkley and Black's Rapid Titration Method (1934). Nitrification Rates were determined by incubating 100 gm. samples of soil in glass jars at field moisture wetness at a temperature of 25° C. for a period of three weeks. Nitrates were determined at the end of the incubation period by the phenoldi-sulphonic acid method (A.O.A.C., 1930). Available phosphorus was determined by Truog method (1930).

Exchangeable calcium was determined by Hissink's method (1923). Exchangeable potassium was determined by leaching the soil with neutral ammonium acetate and then determining the potassium in it by volumetric cobaltinitrite method. A glass electrode was employed for soil reaction determination on suspensions of soil in carbon dioxide-free distilled water in a ratio of 1 : 2·5.

RESULTS

Total Nitrogen and Nitrification Rates.—The data on the total nitrogen content and also the Nitrification Rates of the samples used are presented in Tables I and II.

TABLE I

Total nitrogen

(Per cent. on oven-dry basis)

Treatment	Cotton continuous A	Cotton followed by juar B		Three-course rotation Cotton-Juar-Groundnut C		
Crop in the plot	Cotton	Cotton	Juar	Cotton	Juar	Groundnut
Block No.						
I	0·0390	0·0457	0·0463	0·0369	0·0450	0·0410
II	0·0360	0·0390	0·0410	0·0423	0·0410	0·0403
III	0·0360	0·0390	0·0369	0·0430	0·0423	0·0423
IV	0·0369	0·0373	0·0382	0·0393	0·0447	0·0453
V	0·0376	0·0373	0·0403	0·0403	0·0396	0·0400
Mean for Rotation	0·0375	0·0402		0·0416		

Statistical Analysis:

C.D. at 5 per cent. level for

AB ......0·0029

BC ......0·0025

AC ......0·0021

Result $\overline{C\,\underline{B}}\underline{\,A}$

TABLE II

Nitrification rates

(Milligrams per 100 gm. oven-dry soil)

Treatment	Cotton continuous A	Cotton followed by Juar B		Three course rotation Cotton-Juar-Groundnut C		
Crop in the plot	Cotton	Cotton	Juar	Cotton	Juar	Groundnut
Block No. I	2·0	2·3	2·0	3·1	3·5	4·2
II	2·0	2·3	2·1	4·2	4·3	4·0
III	1·9	2·5	3·2	3·0	2·3	2·3
IV	2·0	1·6	1·8	3·7	3·7	2·8
V	2·1	1·8	2·5	2·9	3·0	3·0
Mean for Rotation	2·0	2·2			3·2	

Statistical Analysis:

C.D. at 5 per cent. level for

AB ......0·3
BC ......0·5
AC ......0·4

Result $C\ \overline{B\ A}$

The data (Table I) show clearly that there is a significant difference between the total nitrogen contents of the soil under different rotations, rotation C having raised the nitrogen content of the soil significantly higher than rotation A and rotation B being better than rotation A. When Continuous Cotton was grown the nitrogen content of the surface foot of soil was 7 and 11% lower than the nitrogen content of the two course and three course rotations respectively.

As regards nitrification rates, it will be seen from Table II that the rate of nitrification in rotation C plots is significantly higher than those under other rotations. Rotation B also shows a slight increase over rotation A but the rate is not significantly higher. It is interesting to note that whereas rotation C shows as high as 60% greater nitrification rate over rotation A, rotation B shows 10% increase only.

TABLE III. *Organic carbon*

(Per cent. on oven-dry soil)

Treatment	Cotton continuous A	Cotton followed by Juar B		Three-course rotation Cotton-Juar-Groundnut C		
Crop in the plot	Cotton	Cotton	Juar	Cotton	Juar	Ground-nut
Block No.						
I	0·498	0·510	0·517	0·475	0·505	0·483
II	0·486	0·522	0·488	0·507	0·550	0·522
III	0·488	0·476	0·452	0·552	0·534	0·529
IV	0·476	0·529	0·502	0·509	0·531	0·531
V	0·452	0·448	0·462	0·472	0·474	0·488
Mean for Rotation	0·480	0·491		0·511		

Statistical Analysis:

C.D. at 5 per cent. level

AB ......0·026
BC ......0·024
AC ......0·022

Result $\underline{C\ \overline{B}}\overline{\ A}$

TABLE IV. *Carbon-Nitrogen Ratio*

Treatment	Cotton continuous A	Cotton followed by Juar B		Three-course rotation Cotton-Juar-Groundnut C		
Crop in the plot	Cotton	Cotton	Juar	Cotton	Juar	Ground-nut
Block No.						
I	12·8	11·1	11·1	12·9	11·2	11·8
II	13·6	13·4	11·9	12·0	13·4	12·9
III	13·7	12·2	12·2	12·8	12·6	12·5
IV	12·0	14·2	13·1	12·9	11·9	11·7
V	12·0	11·7	11·5	11·7	11·9	12·2
Mean for Rotation	12·8	12·2		12·3		

Statistical Analysis:

C.D. at 5 per cent. level for

AB ......1·1
BC ......0·8
AC ......0·9

Result $\overline{A\ C\ B}$

The data presented in Table III show that the plots under rotation C show a significantly higher carbon content than the plots under rotation A. Though not significant, the carbon content in the plots under rotation B is slightly higher as compared to plots under rotation A. However, in spite of the incease in the organic mratter in rotations C and B, the carbon-nitrogen ratios (Table IV) of the soils are nearly the same as in the plots under rotation A (Holtz and Vandecavaye, 1938; Acharya and others, 1953).

TABLE V

Available phosphorus

(Milligrams per 100 gm. oven-dry soil)

Treatment	Cotton continuous A	Cotton followed by Juar B		Three-course rotation Cotton-Juar-Groundnut C		
Crop in the plot	Cotton	Cotton	Juar	Cotton	Juar	Groundnut
Block No.						
I	3·7	3·5	3·3	5·6	6·0	4·9
II	4·7	5·3	4·5	5·5	5·7	5·3
III	5·5	2·7	3·6	5·4	5·5	6·2
IV	4·2	3·8	4·5	4·4	4·2	4·3
V	4·0	3·3	3·3	4·1	3·4	5·1
Mean for Rotation	4·4	3·8		5·0		

Statistical Analysis:

C.D. at 5 per cent. level for

AB ......0·7
BC ......0·7
AC ......0·8

Result $\overline{C\;\underline{A}}\;\underline{\;B}$

It will be seen from the above table that the quantity of available phosphorus is not the same in all the rotations. The available phosphorus content is significantly higher in rotation C than in rotation B and is better than in rotation A. As regards rotations A and B, though the difference between their mean values is not statistically significant, the quantity of available phosphorus in rotation B is appreciably lower than that in A. The available phosphorus content in rotation B is approximately 13% and 31% lower than in rotations A and C respectively. It seems, therefore, that the three course rotation which includes a legume, tends to increase the availability of phosphorus while the two-course rotation which includes juar crop reduces the amount of available phosphorus in the soil. The results by Lad and Patel (1955) are, however, at variance with these results.

TABLE VI

Exchangeable calcium

(Milliequivalents per 100 gm. oven-dry soil)

Treatment	Cotton continuous A	Cotton followed by Juar B		Three-course rotation Cotton-Juar-Groundnut C		
Crop in the plot	Cotton	Cotton	Juar	Cotton	Jaur	Groundnut
Block No.						
II	57·3	58·8	59·9	54·0	55·9	58·7
III	58·9	55·8	54·9	57·1	59·5	60·5
IV	51·3	57·3	55·7	53·9	57·2	54·5
V	52·3	50·3	49·5	49·8	53·4	48·3
Mean for Rotation	55·0	55·3		55·3		

Statistical Analysis:
C.D. at 5 per cent. level for AB ......5·0
BC ......3·6
AC ......4·6

Result $\overline{\text{B C A}}$

The data presented in Tables VI and VII indicate that there are no significant differences in exchangeable calcium and exchangeable potassium.

TABLE VII

Exchangeable potassium

(Milliequivalents per 100 gm. oven-dry soil)

Treatment	Cotton continuous A	Cotton followed by Juar B		Three-course rotation Cotton-Juar-Groundnut C		
Crop in the plot	Cotton	Cotton	Juar	Cotton	Juar	Ground-nut
Block No.						
I	1·34	1·68	1·61	1·63	1·65	1·67
II	1·29	1·08	1·03	1·05	1·11	1·03
III	1·29	1·10	1·18	1·30	1·34	1·39
IV	1·51	1·34	1·36	1·69	1·74	1·67
V	1·39	1·50	1·54	1·63	1·56	1·68
Mean for Rotation	1·38	1·33			1·47	

Statistical Analysis:

C.D. at 5 per cent. level for

AB.. ....0·18
BC ......0·19
AC ......0·16

Result $\overline{C\ A\ B}$

TABLE VIII

pH values

Treatment	Cotton continuous A	Cotton followed by Juar B		Three-course rotation Cotton-Juar-Groundnut C		
Crop in the plot	Cotton	Cotton	Juar	Cotton	Juar	Ground-nut
Block No.						
I	7·9	8·0	7·9	7·9	8·1	8·0
II	8·1	7·9	8·0	8·1	8·0	8·1
III	7·9	8·1	8·1	8·1	8·1	8·1
IV	8·0	7·9	8·0	8·0	8·0	7·9
V	7·9	8·1	8·0	8·1	7·9	7·9
Mean for Rotation	7·9	8·0			8·0	

The data presented in Tables VIII indicate that the pH values in different rotations are almost the same and obviously, therefore, they do not differ significantly.

TABLE IX

*Average yields of cotton, juar and groundnut for 21 years**

(Pounds per acre)

Treatment	Cotton continuous A	Cotton followed by Juar B		Three-course rotation Cotton-Juar-Groundnut C		
Crop in the plot	Cotton	Cotton	Juar	Cotton	Juar	Groundnut
	306	286	1091	508	1179	1215

Statistical Analysis: t values

Crop		Comparison for rotations	'*t*' values as calculated 40 d. f.	Remarks
Cotton	..	A and B	0·51	Not significant
		B and C	> 3	Significant at 1%
		C and A	> 3	Significant at 1%
Juar	..	B and C	< 1	Not significant

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* The yields of the crops in different years are given in Appendix A.

It will be seen from Table IX that the inclusion of groundnut in rotation C has significantly raised the mean yield of cotton over those in rotations A and B. It has also increased the mean yield of juar, though this increase is not statistically significant. Significant difference is also not noticed in the mean yield of cotton in rotations A and B.

DISCUSSION

The scrutiny of the data presented in this paper points out that fertility has been built up in the Cotton-Juar-Groundnut (Rotation C) rotation plots as shown by their higher nutrient status. The fertility of the plots under Cotton Continuous (Rotation A) and Cotton-Juar (Rotation B) rotations seems to be almost at the same level. This explains the higher yields of cotton and juar obtained in rotation C over the yields of cotton and juar in the other two rotations. The average yield of cotton during the period of 21 years in the plots under rotation C is 508 lb. per acre while it is 306 lb. in the plots under rotation A and 286 lb. per acre in case of rotation B. The average yield of juar in the plots under rotation C is 1,179 lb. per acre while it is 1,091 lb. per acre in rotation B (Table IX). It will thus be observed that the inclusion of the groundnut crop in the rotation has steadily maintained the soil at a reasonably higher fertility level and as a result higher yields of cotton and juar have been obtained.

It will be interesting to examine further what particular nutrient or nutrients have contributed towards the attainment of these higher yields. As regards total nitrogen the quantity, if calculated as pounds per acre in the top six inches of the soil (assuming it to be two million pounds), comes to 750, 804 and 832 lb. in the plots under rotations A, B and C respectively. In other words, there seems to be an increase of 54 pounds of nitrogen in plots under rotation B over those in rotation A and an increase of 28 pounds in rotation C over rotation B. The differences of 54 and 28 pounds of nitrogen, however, have not been found statistically significant and as such the plots under rotation A and B and those under B and C seem to be more or less on the same footing in respect of total nitrogen content. These results are in agreement with the results obtained by Bal (1942).

As regards Cotton Continuous and Cotton-Juar-Groundnut rotation plots there is an accumulation of 82 lb. of nitrogen more in the latter plots than in the former and this difference is statistically significant. It thus appears that the inclusion of groundnut, a leguminous crop, in the rotation has helped in increaing substantially the total nitrogen content of the soil over the Cotton Continuous rotation. However, the increase of 82 lb. cannot be attributed only to groundnut crop because this rotation also includes juar crop and if it is taken into consideration that there is already an increase of 54 lb. in Cotton-Juar rotation over continuous cotton which presumably can be considered as due to juar, the increase due to groundnut crop comes to 28 lb. only during a period of 21 years. In other words the contribution of groundnut in the rotation seems to be surprisingly less than the one of juar crop. Views expressed by different workers in this respect are rather conflicting. Virtanen (1938), Thornton and Nicol (1934) and Acharya, Jain and Jha (1953) have reported excretion of nitrogen from the roots of legume crops and consequent increase in soil nitrogen. Several others including Swanson (1917), Swanson and Latshaw (1919), Wright (1920), Mooers (1926), Mirchandani (1938), Greaves and Jones (1950) and Desai and Sen (1952), in their studies on alfalfa, clover, vetch, soyabeans, peas, etc., however, did not find any increase in the content of this element in the soil. The present observations do not seem to support the former view.

Though the groundnut crop in rotation does not seem to increase substantially the total nitrogen content, it has remarkably improved its nitrifying capacity. While the nitrification rates in case of Cotton Continuous and Cotton-Juar rotations are almost similar, it is 50% higher in Cotton-Juar-Groundnut rotation than in the other two. Taking into consideration the improtant role of this element in crop production in Black Cotton Soil, it is more likely that the higher yields of cotton and juar obtained in the three-course rotation are a result more of constant higher availability of nitrogen during the growth of the crop than the higher total amount present in the soil. Joshi and Joshi (1953) have also found that the productivity of the soil as measured by the yields of crop in the field is directly correlated with the microbial activity of the soil as determined by the laboratory methods in so far as bacterial numbers and nitrifying capacity are concerned.

However, availability of nitrogen cannot be considered as the only factor responsible for the higher yields, important though it is. Side by side, with enhancing the rate of nitrification the groundnut crop also seems to have facilitated the availability of phosphorus. Nevertheless, it is not on par with that of nitrogen in this rotation.

Since the soil reaction of all the plots under the rotations is almost similar and there is very little variation in exchangeable calcium and exchangeable potassium, it can be presumed that the higher nitrification rate together with better availability of phosphorus are responsible for higher yields of cotton and juar in the three-course rotation.

It will be seen from Table IX that the yield of cotton in the Cotton-Juar rotation is less than that of cotton under Cotton Continuous. Though the difference is not statistically significant, the position seems rather inconsistent especially when it is considered that the nutrient status of the plots under both the rotations is almost similar. So far as nitrification rate and total nitrogen are concerned the position appears a little better in the Cotton-Juar rotation. Regarding the low yield of cotton some workers (Hawkins, 1925 and Sewell, 1923) have expressed the view that juar leaves some toxins in the soil due to the harmful effects of which the yield of succeeding crop of cotton is adversely affected. However, if this is true, the same type of result should have also been obtained in the case of cotton crop in the Cotton-Juar-Groundnut rotation. But as stated earlier quite contrary is the case. It is possible that the deleterious effects of juar crop either might have been suppressed or rendered ineffective by the succeeding groundnut crop and the cotton crop coming after it had all the advantages of a leguminous crop *minus* the disadvantages of juar. Apart from this consideration the other reason which also appears to be likely from the data presented, is that the cotton crop has very little available phosphorus at its disposal in the Cotton-Juar rotation. It will be seen from Table V that in all the three rotations the available phosphorus is least in this particular rotation and hence appears to be a probable cause of reduction in the yield of cotton.

SUMMARY

The yield data of the Rotation Experiment at Government Experimental Farm, Akola, for 21 years revealed that highest yields of cotton and juar were obtained in the Cotton-Juar-Groundnut rotation over Cotton-Juar and Cotton Continuous. The present work is an attempt in correlating the higher yields with the fertility of the plots.

The following determinations were carried out: Total nitrogen, nitrification rate, organic carbon, available phosphorus, exchangeable calcium, exchangeable potassium and soil reaction.

No significant differences were observed in respect of exchangeable calcium and exchangeable potassium and there has been practically no change in soil reaction as a result of different rotations.

The different rotations did not alter the carbon-nitrogen ratio of the soil.

There has been no significant difference in total nitrogen between (*i*) Cotton Continuous and Cotton-Juar rotations and (*ii*) Cotton-Juar and Cotton-Juar-Groundnut rotations. However, Cotton-Juar-Groundnut rotation shows significantly higher total nitrogen over Cotton Continous.

The contribution of groundnut appears less than that of juar in increasing the total nitrogen of the soil. The nitrification rate on the other hand has been substantially increased in the plots in which groundnut was grown in rotation. It has also increased the availability of phosphorus, and the higher yields of cotton and juar in the Cotton-Juar-Groundnut rotation are attributed to these beneficial effects.

The fertility of the plots under Cotton Continuous and Cotton-Juar rotations was found more or less similar, available phosphorus, however,

being less in the latter. It is suggested that the low availability of phosphorus may be responsible for lower yield of cotton in Cotton-Juar rotation as compared to Cotton Continuous.

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APPENDIX A

Average yields in pounds per acre of Cotton, Juar and Groundnut for each year under different rotations

(From 1931–32 to 1951–52)

Rotation	Cotton Continuous	Cotton followed by Juar		Three-course rotation Cotton-Juar-Groundnut		
Crop	Cotton	Cotton	Juar	Cotton	Juar	Groundnut
Year						
1931–32	168	160	1120	180	1220	1680
1932–33	368	364	1988	736	2036	1368
1933–34	460	360	1660	648	1680	1396
1934–35	460	308	1344	716	1392	1112
1935–36	290	336	1448	540	1424	1032
1936–37	416	336	818	595	936	1432
1937–38	180	204	1276	324	1352	784
1938–39	175	224	938	386	954	1116
1939–40	489	356	874	648	973	1094
1940–41	397	367	1296	592	1312	1916
1941–42	415	371	644	722	906	1624
1942–43	182	209	648	306	796	1452
1943–44	261	232	1052	425	998	1664
1944–45	241	276	887	395	1142	1496
1945–46	230	256	980	342	1050	1224
1946–47	215	206	1133	315	1225	681
1947–48	311	391	1089	789	1446	1058
1948–49	62	121	866	216	895	970
1949–50	177	213	1549	236	1679	780
1950–51	241	177	182	656	178	491
1951–52	679	537	1134	906	1168	1260

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