

## NITROGEN AND CARBON STATUS IN RELATION TO SOIL PRODUCTIVITY.

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Soil fertility is often gauged in terms of its nitrogen content. Indian soils are usually considered deficient in this component. The carbon content and its ratio with nitrogen are held to be related to soil fertility. Colloidal fraction and moisture holding capacity also play an important part in determining the productivity of soils.

This paper presents some interesting results obtained during the examination of certain typical soils from the tracts in Central India and Rajputana served by the Institute. During March and April, 1936, samples were collected in each region, horizon by horizon, in the soil profiles differing in fertility, both virgin and cultivated, up to a depth ranging between three and five feet. A detailed description is given of the soil profiles from each region (Appendix I) together with the normal monthly means of rainfall, percentage humidities and maximum and minimum temperatures (Figs. 1-3). The soil samples were examined for the following :—

Property	Method
1. Percentage sand-free portion and clay	.. Bouyoucos (1934).
2. Percentage carbon, nitrogen and their ratio	.. Robinson, McLean, and Williams (1929).
3. Percentage moisture holding capacity	.. Keen (1921).

The results are tabulated below :—

TABLE I.  
*Composition of regional soils  
Bundelkhand*

A.  
*Revenue class—Parua (Clay loam soil)*

Horizon	Thickness (inches)	% on oven-dry basis			% on air-dry basis		% on oven-dry basis
		Nitrogen	Carbon	C/N ratio	Sand-free portion	Clay	Moisture holding capacity
<i>Virgin</i>							
1	4	0.045	0.20	4.44	56.5	19.2	33.5
2	4	0.046	0.23	5.00	66.5	27.7	38.6
3	17	0.045	0.20	4.44	72.9	27.9	44.9
4	17	0.045	0.14	3.11	75.2	28.1	47.4
5	18	0.039	0.088	2.26	68.4	28.4	42.1

TABLE 1—concl'd.

Horizon	Thickness (inches)	% on oven-dry basis			% on air-dry basis		% on oven-dry basis
		Nitrogen	Carbon	C/N ratio	Sand-free portion	Clay	Moisture holding capacity
<i>Cultivated</i>							
1	4	0.037	0.18	4.86	71.6	26.4	32.5
2	4	0.044	0.20	4.54	66.5	27.9	40.1

B

Revenue class—Kabar (Clay soil)

<i>Virgin</i>							
1	2	0.098	0.70	7.14	70.1	26.5	43.8
2	5	0.058	0.42	7.24	76.8	29.1	43.6
3	13	0.041	0.26	6.34	76.7	27.3	45.5
4	12	0.042	0.24	5.71	76.9	29.8	45.0
5	12	0.036	0.14	3.89	76.0	30.4	47.9
6	16	0.024	0.061	2.54	77.2	30.4	50.8
<i>Cultivated</i>							
1	2	0.068	0.39	5.74	69.9	26.7	41.6
2	7	0.017	0.21	12.35	70.9	28.4	44.8

TABLE 2.

A

Malwa

Poor, black cotton soil (Clay soil)

Horizon	Thickness (inches)	% on oven-dry basis			% on air-dry basis		% on oven-dry basis
		Nitrogen	Carbon	C/N ratio	Sand-free portion	Clay	Moisture holding capacity
<i>Virgin</i>							
1	6	0.050	0.32	6.40	69.4	28.5	49.9
2	12	0.038	0.26	6.84	73.2	29.4	50.2
3	6	0.047	0.29	6.17	75.3	27.8	53.6
4	12	0.039	0.22	5.64	78.0	28.2	55.4

## B

*Rich black cotton soil (Clay soil)**(In the vicinity of a former village site)*

Hori- zon	Thickness (inches)	% on oven-dry basis			% on air-dry basis		% on oven-dry basis
		Nitrogen	Carbon	C/N ratio	Sand-free portion	Clay	Moisture holding capacity

*Virgin*

1	3	0.145	1.13	7.79	75.3	29.7	70.1
2	9	0.079	0.63	7.97	74.7	31.2	64.9
3	12	0.051	0.43	8.43	79.4	32.9	67.7
4	16	0.053	0.33	6.24	80.5	33.3	66.6
5	20	0.048	0.39	8.12	76.5	29.0	65.5

*Cultivated*

1	2	0.125	1.13	9.04	76.1	31.3	65.4
2	7	0.081	0.56	6.91	75.3	25.9	65.0

## C

*Whitish grey adhan (Clay soil) \***Virgin*

1	2	0.150	1.40	9.33	70.7	29.2	58.7
2	10	0.100	0.82	8.20	68.6	28.0	53.5
3	6	0.076	0.59	7.76	75.1	31.7	61.6
4	12	0.057	0.39	6.84	77.2	33.6	69.1
5	10	0.056	0.41	7.14	69.7	29.1	71.8
6	20	0.062	0.55	8.87	72.6	27.1	63.4

*Cultivated*

1	2	0.124	1.00	8.06	67.3	26.8	61.2
2	6	0.102	0.82	8.04	73.4	26.6	61.0

\* Garden land usually low-lying heavily manured and intensively cultivated for generations.

TABLE 3.  
Rajputana, Jaipur State  
A  
Alkaline (Sandy loam soil)

Horizon	Thickness (inches)	% on oven-dry basis			% on air-dry basis		% on oven-dry basis
		Nitrogen	Carbon	C/N ratio	Sand-free portion.	Clay	Moisture holding capacity
<i>Cultivated</i>							
1	6	0.039	0.18	4.62	35.8	14.4	41.2
2	9	0.037	0.17	4.59	45.4	20.4	32.5
3	15	0.040	0.13	3.25	35.0	14.8	39.8
4	15	0.032	0.092	2.87	46.4	20.4	33.2

B  
Sweet (Sandy loam soil)  
*Cultivated*

1	6	0.061	0.19	3.11	24.6	11.0	30.5
2	9	0.040	0.15	3.75	35.0	15.8	38.1
3	15	0.034	0.18	5.29	36.6	14.4	40.9
4	15	0.039	0.17	4.36	35.2	14.8	39.3

TABLE 4.  
Rajputana, Bikaner State  
Gang Canal Colony  
A  
Medium (Clay loam soil)

Horizon	Thickness (inches)	% on oven-dry basis			% on air-dry basis		% on oven-dry basis
		Nitrogen	Carbon	C/N ratio	Sand-free portion	Clay	Moisture holding capacity
<i>Cultivated</i>							
1	6	0.047	0.22	4.68	45.2	17.2	33.3
2	6	0.037	0.20	5.40	48.5	19.9	38.7
3	12	0.059	0.20	3.39	47.8	19.0	38.9
4	12	0.043	0.15	3.49	43.3	17.0	38.8
5	12	0.038	0.13	3.42	43.8	16.8	36.2
6	12	0.031	0.12	3.87	44.8	18.1	36.4
7	12	0.032	0.11	3.44	48.8	18.4	38.1

## B

*Rich (Clay loam soil)*

Horizon	Thickness (inches)	% on oven-dry basis			% on air-dry basis		% on oven-dry basis
		Nitrogen	Carbon	C/N ratio	Sand-free portion	Clay	Moisture holding capacity
<i>Cultivated</i>							
1	6	0.045	0.17	3.77	44.2	15.5	33.2
2	6	0.039	0.15	3.84	49.2	20.6	37.4
3	12	0.039	0.15	3.84	44.0	19.2	35.3
4	12	0.034	0.14	4.11	45.5	18.0	35.5
5	12	0.031	0.13	4.19	50.1	18.0	36.3
6	12	0.030	0.14	4.67	50.4	19.2	36.9
7	12	0.036	0.16	4.44	73.2	28.2	39.1

TABLE 5.

*Rajputana, Bikaner State*  
*Gangasarowar Colony*

## A

*Medium (Sandy)*

Horizon	Thickness (inches)	% on oven-dry basis			% on air-dry basis		% on oven-dry basis
		Nitrogen	Carbon	C/N ratio	Sand-free portion	Clay	Moisture holding capacity
<i>Virgin</i>							
1	5.5	0.063	0.12	1.90	11.4	4.9	28.4
2	7.5	0.089	0.12	1.35	18.0	9.5	27.2
3	7.0	0.084	0.10	1.19	21.0	10.0	30.5
4	5.3	0.081	0.16	1.98	21.0	10.5	32.8
5	5.0	0.089	0.16	1.80	21.0	9.0	32.5
6	5.0	0.102	0.09	0.88	18.9	8.4	31.3
7	4.0	0.083	0.11	1.33	18.9	8.8	31.2

## B

*Rich (Sandy)**Virgin*

1	2.7	0.019	0.14	7.37	18.9	6.3	26.8
2	11.8	0.019	0.14	7.37	24.2	10.2	31.4
3	12.0	0.018	0.08	4.44	24.8	9.8	31.1
4	10.4	0.018	0.06	3.44	23.4	9.4	31.0

The values for carbon and nitrogen content were on the whole lower than those usually found in soils in temperate regions. They also widely differed between themselves. The C/N ratios exceeded ten only for the second horizon of cultivated *kabar* land. Very low ratios predominated. No consistent relation could be found between the carbon and nitrogen contents and their ratios and the other properties determined, i.e. sand-free portion, clay and their ratio and moisture holding capacity, nor with the temperatures, humidities or rainfalls characteristic of each region (Figs. 1-3). It was the same when the percentage of carbon and nitrogen were calculated on sand-free basis. Highest values for carbon and nitrogen and narrow C/N ratios were not confined to the surface horizons, most influenced by light and temperature. It seems hazardous to predict the productivity of these soils from such values. This is supported by the results of lysimeter experiments at Indore in 1933. The same cotton varieties were grown under the same conditions in lysimeters containing profile blocks of the sandy Jaipur soil, Badnawar (Dhar) whitish grey *adhan* soil and Indore medium black cotton soil.

The yields are given below :—

TABLE 6.  
Yields of Seed-cotton in gms. in lysimeters, 1933  
(Area 48 sq. ft.)

Variety	Jaipur profile (sandy)	Badnawar profile (whitish grey <i>adhan</i> )	Indore profile, Field 31. (Black cotton soil)
Cambodia Indore 1 ..	139	639	53
Malvi 9 ..	215	573	102

The carbon and nitrogen contents and their ratios in different horizons of these soils are given below :—

TABLE 7.  
Percentages of carbon, nitrogen and their ratios, in the soil profiles contained in lysimeters,  
used for 1933 tests

Horizon.	Jaipur profile			Badnawar profile (whitish grey <i>adhan</i> )			Indore profile, Field 31. (Black cotton soil)		
	Carbon	Nitro- gen	C/N ratio	Carbon	Nitro- gen	C/N ratio	Carbon	Nitro- gen	C/N ratio
1	0.15	0.053	2.83	0.54	0.11	4.90	0.38	0.069	5.50
2	0.12	0.043	2.79	0.57	0.14	4.07	0.43	0.072	5.97
3	0.19	0.047	4.04	0.38	0.18	2.10	0.40	0.059	6.79
4	0.15	0.036	4.16	0.44	0.13	3.46	0.39	0.062	6.29
5	....	....	....	0.32	0.06	3.53	0.23	0.053	4.33

The yields and nitrogen contents do not appear to be correlated.

Nitrogen deficient soils usually respond to the application of nitrogenous manures. This does not seem to be always true of these soils.

TABLE 8.

*Crop-response to nitrogen on different soils. Yields of seed cotton, lbs. per acre*

## A

Dhar, 1934

Varieties	No treatment	Nicifos 22/18	Safflower cake	P	Sig. diff.
Malvi bulk ..	630	692	541	<0.05	126.2
Cambodia bulk ..	403	391	474	<0.05	62.2

## B

Jaipur, 1934

*Variety—Cambodia Indore 1*

Sowing dates	Plant spacings	No treatment	Nicifos 17/45
22nd April .. ..	12"	813	949
	18"	1092	537
15th May .. ..	12"	696	537
	18"	722	337
2nd July (rains) .. ..	12"	303	305
	18"	281	313

$P < 0.05$ ; Sig. diff. = 329.

## C

*Sri Ganganagar, Bikaner State, 1934*

Varieties and treatments				Manures		
Varieties	Sowing dates	Irrigation	Plant spacings	No treatment	Nicifos 17/45	Castor cake
<i>Mollisoni</i> P. 289F. <i>Mollisoni</i>	May	Moderate	12"	746	679	1031
	June	Moderate	6"	647	878	551
	June	Heavy	6"	1140	1153	1294

$P < 0.05$ ; Sig. diff. = 166.

Similar results have been obtained in other parts of India (Sahasrabudde, 1934; Vaidyanathan, 1934).

Dhar (1935) concluded that the C/N ratios of soils in different regions widened as the prevailing temperatures increased. Jenny (1929) drew exactly the opposite inference and found that the nitrogen contents decreased with increasing temperatures quantitatively. McLean (1930) found the C/N ratios constant for a region and that they became wider as the prevailing temperatures increased or when the soil was under grass. He did not find any consistent correlation between C/N ratios and fertility but he concluded that for soils of the same area the carbon and nitrogen content increased with fertility. He also found a consistent decrease of C/N ratio with depth in soil profiles. The data presented above show that the inferences drawn by these workers only partially represent real conditions.

The following results were obtained from a comparison of soils from patches of high and low productivity in a barley field in Jaipur and poor and rich tea soils and *patana* soils from Portswood, Ceylon:—

TABLE 9.  
*Nitrogen and Carbon contents and their ratios in productive and poor soils.*

Localities	Soils	Horizons (inches)	% Nitrogen	% Carbon	C/N Ratio
Jaipur (1936) ..	Productive barley patch ..	{ 0 6	0.054	0.14	2.66
		{ 6 15	0.056	0.19	3.45
	Poor barley patch ..	{ 0 6	0.040	0.13	3.32
Ceylon (1935) ..	Rich tea soil ..	{ 6 15	0.037	0.12	3.30
		{ 0 6	0.620	6.17	9.95
	Poor tea soil ..	{ 6 15	0.460	4.21	9.15
		{ 0 6	0.220	1.64	7.45
	Patana tea soil ..	{ 6 15	0.170	1.08	6.34
		{ 0 6	0.520	5.34	10.26
		{ 6 15	0.340	3.94	11.59

The surface layer of the rich Ceylon tea soil gave the following results after the application of manures.

TABLE 10.  
*The effect of manuring of rich Ceylon tea soil on the nitrogen and carbon contents and their ratios—Ceylon, 1935*

Manure	% Nitrogen	% Carbon	C/N Ratio
<i>Applied in October, 1934—</i>			
Green manure+pruning mixture ..	0.73	6.10	8.35
Compost .. ..	1.01	7.74	7.66
<i>Applied in December, 1934—</i>			
Compost .. ..	0.89	7.37	8.28

NOTE.—Samples of soils were taken in April, 1935.

The carbon-nitrogen ratio was wider for the poor patch in the same field at Jaipur, while it was narrower for poor Ceylon soil when two different soils



were compared. Similarly, between the two Ceylon soils higher carbon and nitrogen contents were found with increased fertility. Between the poor and rich patches in the same field at Jaipur they were also higher. The differences between the second horizons were much greater than those between the first. The effect of addition of carbon and nitrogen by manuring rich Ceylon tea soil, however, varied according to the manure and the interval between manuring and sampling. The wider carbon-nitrogen ratio of the *patana* soil may be the effect of being under grass or simply a field difference. Between adjacent cultivated and virgin (under grass) portions of the same field the reverse was sometimes found (Table 1A and B and Table 2B; surface horizons of *parua* and rich black cotton soils and the second of *kabar*). Evidently the influence of other factors, not yet adequately studied, on the nitrogen and carbon contents in soils and their ratios interfere with the accuracy of inferences.

It appears that the absolute nitrogen and carbon contents of fertile soils may not necessarily be high because they only represent a state of equilibrium resulting from the combined action of all the external and internal factors governing the oxidation or reduction of soil organic matter—the carrier of its nitrogen. The factor actually operating is the internal environment of each horizon in the profile during the annual seasonal cycle as regards moisture, air, temperature and the dissolved material. The external climatic factors influence only indirectly just in the same way as is done by the parent rock or the adjacent horizons. Every soil thus seems to possess its own characteristic maximum possible level of carbon and nitrogen content usually reflected under virgin conditions in its surface horizon. Cultivation seems to change it even in the continuously manured *adhan* land as shown below:—

TABLE 11.  
*Changes in virgin soil due to cultivation*

Differences between cultivated and virgin soils in	Bundelkhand				Malwa			
	<i>Parua</i>		<i>Kabar</i>		<i>Rich</i>		<i>Adhan</i>	
	Horizons							
	1	2	1	2	1	2	1	2
% Nitrogen	-0.08	-0.02	-0.03	-0.041	-0.02	+0.02	-0.026	+0.02
% Carbon	-0.02	-0.03	-0.31	-0.21	0.00	-0.07	-0.40	0.00
C/N ratio	+0.42	-0.46	-1.40	+5.11	+1.25	-1.06	-1.27	-0.16
% Sand-free portion	+15.1	0.0	-0.2	-5.9	+0.8	+0.6	-3.4	+4.8
% Clay ..	+7.2	+0.2	+0.2	-0.7	+1.6	-5.3	-2.4	-1.5
% Moisture holding capacity	-1.0	+1.5	-2.2	-1.2	-4.7	+0.1	+2.5	+7.5

Nitrogen content was lowered by cultivation in the surface horizons; the lowering appeared to be inversely proportional to the content of sand-free portion in the virgin soils. In the second horizon nitrogen content was lowered in Bundelkhand soils in proportion to their content of sand-free portion, but in those of Malwa it rose equally for both rich and *adhan* soils. The carbon contents were also lowered in both horizons of Bundelkhand soils, while they were lowered only in the second horizon of the rich soil and the first of the *adhan*. The result was that the carbon-nitrogen ratio became wider in the first horizons of the *parua* and the Malwa rich soils and the second horizon of the *kabar* soil but was narrowed in the others. Such changes were also accompanied by those in other properties. The behaviour of the second horizon seemed to differ from that of the first, which sometimes worked in an opposite direction. The only outstanding difference in the composition, after cultivation of the highly productive manured *adhan* land from other soils, seemed to be the narrowing of C/N ratio and increase of moisture holding capacity in *both* horizons. It may be noted here that the second horizon of the productive patch in the Jaipur field is equally rich as the first in nitrogen and carbon. The first two horizons of other soils did not show this degree of uniformity.

Apparently the actual differences in the content of nitrogen and carbon or their ratios necessary to increase soil productivity may be slight, as shown by the composition of the heavily manured *adhan* land. Differences in productivity seem to depend chiefly on the extent to which the supply of nitrogen and moisture is similarly maintained by, at any rate, the first two horizons of a soil. Wide differences between or opposite behaviour, one way or the other, of the two horizons adversely affects fertility. Probably a prolonged existence of favourable environment during the life of the crop is a much more potent factor than anything else.

Thus, the differences in the absolute values for the nitrogen and carbon contents of soils or their ratios may not show any correlation with the differences in their fertility. Comparisons based on them seem to have a limited value.

#### SUMMARY.

Nitrogen and carbon contents and their ratios for typical soils of Bundelkhand, Malwa and Rajputana were found to be low and differed widely between soils and between horizons.

Apparently no correlation existed between them and single factors like region, prevailing temperatures, rainfall, humidities, moisture holding capacities of soils, the proportion of sand-free portion, clay and their ratios.

Absolute values were usually maximum under virgin conditions in surface layers. Cultivation changed them according to soil 'variety' and horizon.

Even continuous application of farmyard manure did not maintain the absolute values to virgin levels.

When soil fertility is increased by the application of bulky organic manures, the differences produced in its nitrogen and carbon content may not always be as great as are found when two soils are compared.

Neither the yield of cotton in lysimeters nor its response in the field to nitrogenous manuring was proportionate to the nitrogen contents of soils used. Better crops seem to depend more on the degree of uniformity in the upper soil layers than on their nitrogen content.

Carbon and nitrogen contents represent an equilibrium reached by organic matter under the influence of the prevailing moisture, aeration, temperatures and dissolved material in the soil. Productivity increases whenever the total intake by crop-roots becomes greater.

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## APPENDIX I.

*Description of regional soil profiles**Region—Bundelkhand**Revenue class—Parua (Clay loam) Virgin*

Horizon	Depth (inches)	Description
1.	0-4	Reddish brown colour, lumps friable, roots of grasses in abundance, gritty to touch.
2.	4-8	Similar to above, less roots, a lot of <i>nagar-motha</i> ( <i>Cyperus scariosus</i> ) roots.
3.	8-25	Similar to above, a few dead roots.
4.	25-42	Similar to above, very few dead roots.
5.	42-60	Similar to above.

*Cultivated*

1.	0-4	Similar to that of virgin soil but less lumps and roots, looser soil.
2.	4-8	Similar to virgin soil but less compact and lumps, more friable.

*Revenue class—kabar (Clay soil) virgin*

Horizon	Depth (inches)	Description
1.	0-2	Grey with yellowish and blackish tinge, many grass roots, small semi-friable lumps, soft to touch.
2.	2-7	Similar to above but in bigger lumps, a few <i>nagar-motha</i> roots.
3.	7-20	Colour slightly darker than the upper or lower layers, similar to above in other respects.
4.	20-32	Lighter colour than the upper layer a few <i>kankar</i> nodules.
5.	32-44	A lot of <i>kankar</i> nodules, colour a mixture of upper grey and lower light yellow.
6.	44-60	Colour light yellow, in other respects similar to above.

*Cultivated*

1.	0-2	Similar to virgin soil but slightly looser, less roots.
2.	2-7	Similar to virgin, but looser.

*Region—Malwa**Poor (Clay soil), virgin*

1.	0-6	Black with slight yellow tinge, a few <i>kankar</i> nodules, lumps semi-friable, a few dead roots.
2.	6-18	Similar to above with some black hard concretions (iron).
3.	18-24	Slightly more yellow, similar to above in other respects.
4.	24-36	Similar to above, <i>murrum</i> and <i>kankar</i> below three feet.

*Rich (Clay soil), virgin*

1.	0-3	Light grey, slightly loose, forming small friable lumps, large number of roots, many <i>kankar</i> nodules and a few hard, dark brown concretions (iron).
2.	3-12	Light-grey, more compact, less roots, large number of <i>kankar</i> nodules, very few dark brown concretions, chiselled face smooth and glossy.
3.	12-24	Similar to above, more compact, a few roots.
4.	24-40	Similar to above, less compact, deeper grey colour.
5.	40-60	Less compact, cleavage surface smooth and shining, tendency to form angular blocks of irregular shape, very few dark brown concretions, <i>kankar</i> nodules less than in the above, very few roots.

*Cultivated*

1.	0-2	Light grey, loose, small friable lumps, few dark brown concretions, <i>kankar</i> nodules, a few roots.
2.	2-9	Slightly deeper in colour, more compact forming bigger lumps, large number of small <i>kankar</i> nodules, very few roots, dark brown concretions.

*Adhan (Clay soil), virgin*

1.	0-2	Light grey soil, semi-friable, smooth, dark brown concretions (iron), large number of dead roots.
2.	2-12	Light grey, very few cracks, concretions similar to above, soil friable, chiselled face rough and dull.

Horizon	Depth (inches)	Description
3.	12-18	Grey colour, darker, vertical streaks, in other respects similar to above.
4.	18-30	Slightly deeper colour, streaks narrowing, similar to above in other respects.
5.	30-40	Deeper colour, chiselled face smoother, <i>murrum</i> pockets here and there.
6.	40-60	Similar to above, irregularly mottled with yellowish earth.

*Cultivated*

1.	0-2	Light grey, slightly whitish, ashy appearance, loose, small friable lumps, large number of dark brown concretions, very few dead roots.
2.	2-8	Semi-friable lumps, dark brown concretions, a few brick pieces, some <i>kankar</i> nodules, lighter-coloured vertical streaks, irregular vertical cracks.

*Region—Rajputana, Jaipur State**Alkaline (Sandy loam soil), cultivated*

1.	0-6	Yellowish brown, slightly deeper in the interior of lumps, gritty, small hard lumps, a few <i>kankar</i> nodules.
2.	6-15	Similar to above but slightly lighter colour, a few dead roots.
3.	15-30	Similar to above, but no <i>kankar</i> nodules.
4.	30-45	Lighter colour, full of stiff lumps.

*Sweet (Sandy loam soil), cultivated*

1.	0-6	Reddish yellow colour, lighter than the above-mentioned saline soils, no <i>kankar</i> nodules, lumps stiff, similar to above in other respects.
2.	6-15	Similar to above, a few <i>kankar</i> nodules.
3.	15-30	Similar to above, a few dead roots.
4.	30-45	Similar to above but without <i>kankar</i> nodules or dead roots.

*Region—Rajputana, Gang Canal Colony, Bikaner State**Soils under cultivation since 1928**Medium (Sandy loam)*

1.	0-6	Yellowish grey, gritty, full of very small friable lumps.
2.	6-12	Similar to above but slightly bigger lumps.
3.	12-24	Similar to above but slightly stiffer lumps.
4.	24-36	Similar to above but less number of lumps.
5.	36-44	Similar to above but a few <i>kankar</i> nodules.
6.	44-60	Similar to above.

*Rich (Sandy loam)*

The descriptions of the horizons are similar to above-mentioned medium soil except that the bottom layer (44"-60") is softer to touch.

NOTE.—The horizons of soil in this region were not clearly demarcated in the lower depths, therefore samples were taken for every foot.

*Region—Rajputana, Gangasarowar Colony, Bikaner State**Virgin soils**Medium (Sandy soil)*

Horizon	Depth (inches)	Description
1.	0-5.5	Greyish yellow, no lumps, a few plant residues, some <i>kankar</i> nodules and gravel.
2.	5.5-13	Similar to above, but a few lumps.
3.	13-20	Similar to above but no lumps.
4.	20-25.3	Similar to above.
5.	25.3-30.3	Similar to above but a few hard lumps.
6.	30.3-35.3	Similar to above but a few <i>kankar</i> nodules.
7.	35.3-39.3	Same as above.

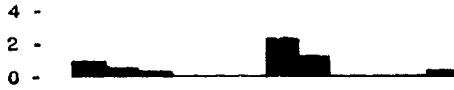
*Rich (Sandy soil)*

1.	0- 2.7	Greyish yellow, no lumps, small quantity of plant residues and gravel.
2.	2.7-14.5	Greyish yellow, hard lumps and plant residues (especially roots) and gravel.
3.	14.5-26.5	Greyish yellow, big lumps, dead roots, <i>kankar</i> nodules and gravel.
4.	26.5-36.9	Greyish yellow, big hard lumps, dead roots and gravel, moist soil at the bottom.

**RAJPUTANA-BIKANER STATE,  
GANGASAROWAR COLONY**



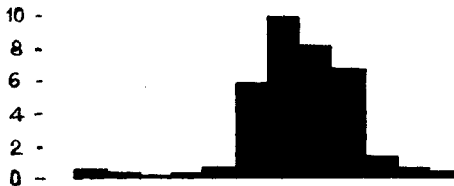
**RAJPUTANA-BIKANER STATE,  
GANG CANAL COLONY**



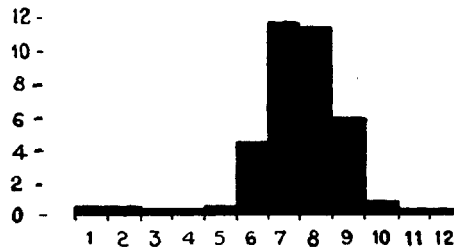
**RAJPUTANA-JAIPUR STATE.**



**MALWA**



**BUNDELKHAND**



MONTHS - JANUARY TO DECEMBER.

FIG. 1. Monthly normal rainfall, inches.

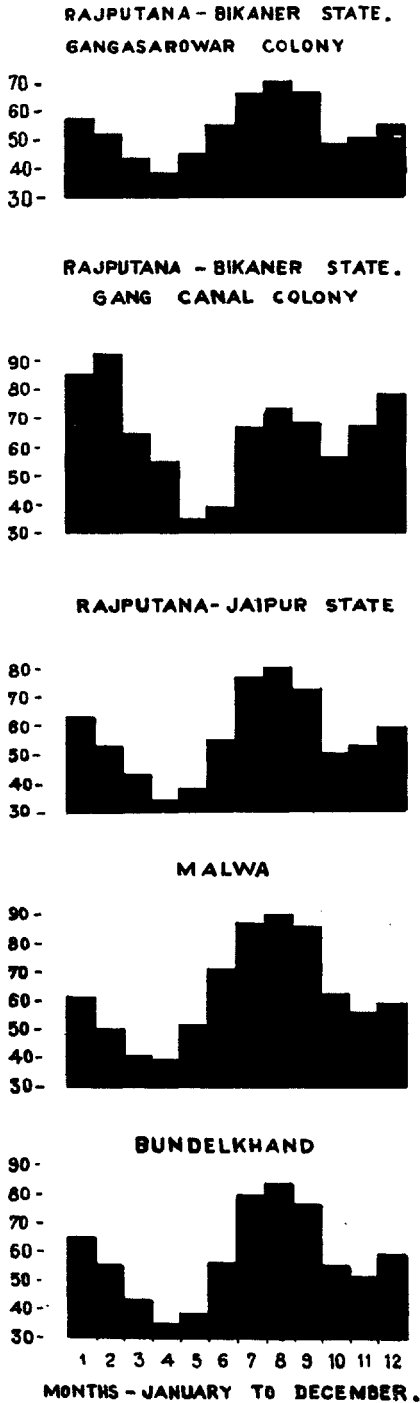


Fig. 2. Monthly normal humidities per cent.

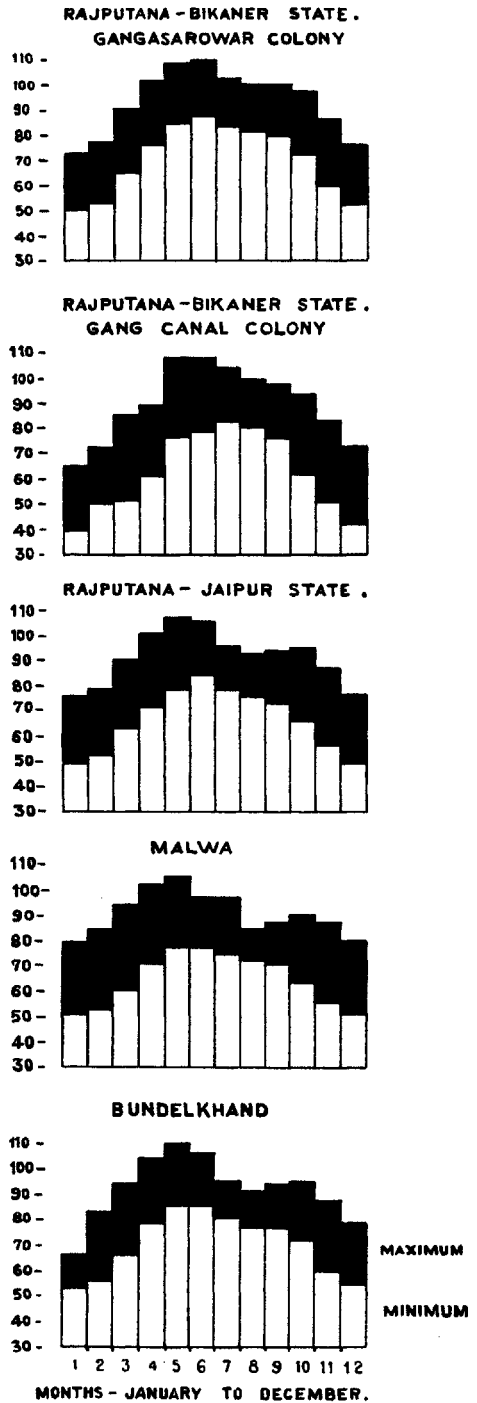


Fig. 3. Monthly normal maximum and minimum temperature.