STUDIES IN THE ANALYSIS OF FERTILISER EFFECTS

II. Photosynthetic Efficiency of *Saccharum officinarum* Leaves as Influenced by Certain Manurial Treatments

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Introduction

While investigating the influence of different manurial treatments upon the growth and yield of plants it was felt necessary to have a complete physiological analysis of the fertilizer effect with respect to different economic crop plants. The investigations conducted in this direction have given ample evidence to the fact that the fertilisers influence the different physiological activities of plants, especially transpiration and water requirement,[6,8,11,14] respiration and photosynthesis,[1,2,7,9,12] carbohydrate and nitrogen metabolism in general.[3,4,5]

Direct evidences upon the photosynthetic activity of *Andropogon sorghum* as influenced by fertilizer treatments have been discussed in detail elsewhere.[15] In the following pages, however, the observations recorded on *Saccharum officinarum* grown under different treatments with inorganic fertilizer and organic bulky manure are presented.

The experiments were conducted under three distinct conditions, the medium of growth in all cases being the farm soil (sandy loam). In the first series the plants were grown in cemented pots 18″ × 12″ in size, and supplied with different inorganic fertilizers. In the second series dealing with organic bulky manures the sugarcane plants were grown in concrete tanks 6′ × 6′ × 6′ in size. In the third series, the treatments were all given under field conditions. Twenty-seven different combinations of nitrogen, phosphoric acid and potash with three levels of manuring in each case were confounded together. The lay-out in this series will be discussed in detail in a separate communication. The cane under each treatment covered 1/45 acre area.

Towards the stage of maturity, when the plants attained an age of 260 days, the third leaf from the top of the main (primary) shoot from each

of the treatments under consideration, was collected. The rate of assimilation of the leaves thus collected was studied under optimal conditions* of CO_2 (0·25–0·30%), temperature (31° C. ± 0·2) and light (1500 C.P. ½ W. Phillips bulb at 18 cm. distance). Continuous current method with Blackman's commutator was used for studies on assimilation and respiration. Chlorophyll content was estimated after Oltman.[10]

Sampling methods for the study of photosynthetic efficiency of leaves were tried separately.[17] It was found that in cases where the effect of age was not the primary consideration, the collection of third leaf from the top of the main shoot towards the period of maturity and the measurement of photosynthesis under optimal conditions in such leaves gathered from different treatments gave a more valid comparison of the effects of two or more treatments, as compared with at random selection of leaves from plants grown under varied fertilizer treatments. In view of this as also in view of the fact that a detailed study of age factor has already been reported earlier[16] no attempt was made to work out once again the effect of age on the assimilation rate of cane leaves. Three separate estimations were made of the photosynthetic efficiency of the leaves, and the significance of the values thus obtained, tested by the method of analysis of variance. The interaction effects of nitrogen, phosphoric acid, and potash and on assimilating efficiency, shall be dealt with in a subsequent contribution alongside the effect of similar treatments on growth and yield of plants.

In all these different series proper care was taken to grow the plants under as uniform condition of soil moisture as practicable, and to perform such other intercultural operations as hoeing, weeding, earthing, etc., whenever necessity was felt.

Details of Treatments

No. I. Pot Series—

(i) Control : supplied with no fertilizer.

(ii) N_2-fed plants : supplied with 6·0 gms. of ammonium sulphate per pot.

(iii) P_2O_5-fed plants : supplied with 2·0 gms. of double superphosphate per pot.

(iv) K_2O-fed plants : supplied with 2·0 gms. of potassium sulphate per pot.

* The optimal values for these factors were determined earlier in connection wit another series of investigations after the manner discussed in another paper.[13]

(v) N–K-fed plants : supplied with 6·0 gms. of ammonium sulphate and 2·0 gms. of potassium sulphate per pot.

(vi) N–P-fed plants : supplied with 6·0 gms. of ammonium sulphate and 2·0 gms. of double superphosphate per pot.

(vii) P–K-fed plants : supplied with 2·0 gms. of double superphosphate and 2·0 gms. of potassium sulphate per pot.

(viii) N–P–K-fed plants : supplied with 6·0 gms. of ammonium sulphate, 2·0 gms. of double superphosphate and 2·0 gms. of potassium sulphate per pot.

No. II. Concrete-tank Series—

(i) Control : no organic bulky manure was supplied.
(ii) Night-soil-fed plants.
(iii) Castor cake-fed plants.
(iv) Sheep-dung-fed plants.
(v) Cow-dung-fed plants.
(vi) Compost-fed plants.

In all these cases the quantity of different manures was calculated on nitrogen basis and supplied at the rate of 150 lbs. nitrogen per acre.

No. III. Field Series—

(i) Control : plots supplied with no artificial fertilizer.

Single fertilizer-fed plants :

(ii) N_2-fed plants : supplied with—
  (*a*) 75·0 lbs. of nitrogen per acre .. .. (N_1)
  (*b*) 150·0 lbs. of nitrogen per acre .. .. (N_2)

(iii) P_2O_5-fed plants : supplied with—
  (*a*) 40·0 lbs. of P_2O_5 per acre .. .. .. (P_1)
  (*b*) 80·0 lbs. of P_2O_5 per acre .. .. .. (P_2)

(iv) K_2O-fed plants : supplied with—
  (*a*) 40·0 lbs. of K_2O per acre .. .. .. (K_1)
  (*b*) 80·0 lbs. of K_2O per acre .. .. .. (K_2)

Double fertilizer-fed plants :

(v) N–P-fed plants : supplied with—
  (*a*) 75·0 lbs. of N_2 and 40·0 lbs. of P_2O_5 per acre (N_1P_1)
  (*b*) 75·0 lbs. of N_2 and 80·0 lbs. of P_2O_5 per acre (N_1P_2)
  (*c*) 150·0 lbs. of N_2 and 40·0 lbs. of P_2O_5 per acre (N_2P_1)
  (*d*) 150·0 lbs. of N_2 and 80·0 lbs. of P_2O_5 per acre (N_2P_2)

(vi) N–K-fed plants : supplied with—

(*a*) 75·0 lbs. of N_2 and 40·0 lbs. of K_2O per acre (N_1K_1)
(*b*) 75·0 lbs. of N_2 and 80·0 lbs. of K_2O per acre (N_1K_2)
(*c*) 150·0 lbs. of N_2 and 40·0 lbs. of K_2O per acre (N_2K_1)
(*d*) 150·0 lbs. of N_2 and 80·0 lbs. of K_2O per acre (N_2K_2)

(vii) P–K-fed plants : supplied with—

(*a*) 40·0 lbs. of P_2O_5 and 40·0 lbs. of K_2O per acre (P_1K_1)
(*b*) 40·0 lbs. of P_2O_5 and 80·0 lbs. of K_2O per acre (P_1K_2)
(*c*) 80·0 lbs. of P_2O_5 and 40·0 lbs. of K_2O per acre (P_2K_1)
(*d*) 80·0 lbs. of P_2O_5 and 80·0 lbs. of K_2O per acre (P_2K_2)

Three fertilizer-fed plants :

(viii) N–P–K-fed plants : supplied with—

(*a*) 75·0 lbs. of N_2, 40·0 lbs. of P_2O_5 and 40·0 lbs. of K_2O per acre .. .. .. ($N_1P_1K_1$)
(*b*) 150·0 lbs. of N_2, 40·0 lbs. of P_2O_5 and 40·0 lbs. of K_2O per acre .. .. .. ($N_2P_1K_1$)
(*c*) 75·0 lbs. of N_2, 80·0 lbs. of P_2O_5 and 40·0 lbs. of K_2O per acre .. .. .. ($N_1P_2K_1$)
(*d*) 75·0 lbs. of N_2, 80·0 lbs. of P_2O_5 and 80·0 lbs. of K_2O per acre .. .. .. ($N_1P_2K_2$)
(*e*) 150·0 lbs. of N_2, 40·0 lbs. of P_2O_5 and 80·0 lbs. of K_2O per acre .. .. .. ($N_2P_1K_2$)
(*f*) 150·0 lbs. of N_2, 80·0 lbs. of P_2O_5 and 40·0 lbs. of K_2O per acre .. .. .. ($N_2P_2K_1$)
(*g*) 75·0 lbs. of N_2, 40·0 lbs. of P_2O_5 and 80·0 lbs. of K_2O per acre .. .. .. ($N_1P_1K_2$)
(*h*) 150·0 lbs. of N_2, 80·0 lbs. of P_2O_5 and 80·0 lbs. of K_2O per acre .. .. .. ($N_2P_2K_2$)

The three fertilizer ingredients, *viz.*, nitrogen, phosphoric acid and potash, were added in the form of neutral ammonium sulphate (20·0% N), double superphosphate (40·0% P_2O_5) and potash sulphate (48·0% K_2O), and added in two instalments once after germination and secondly before first earthing the cane.

Experimental Results

No. I Pot Series :

The application of different fertilizers in pots is found to influence the rate of photosynthesis (both apparent and real) in a characteristic way. The data obtained give indication to the view that the rate of apparent assimilation increases substantially in response to different treatments

(Fig. 1, Table I). Of the single fertilizer treatment, plants supplied with potash sulphate show the maximum rate of photosynthesis (Expt. 4). In the double fertilizer group, plants receiving both nitrogen and potash exhibit the highest photosynthetic rate (Expt. 5) followed by those treated with PK and NP (Expts. 7 and 6). Plants receiving all three manurial ingredients, however, although assimilate more (Expt. 8) than those receiving PK

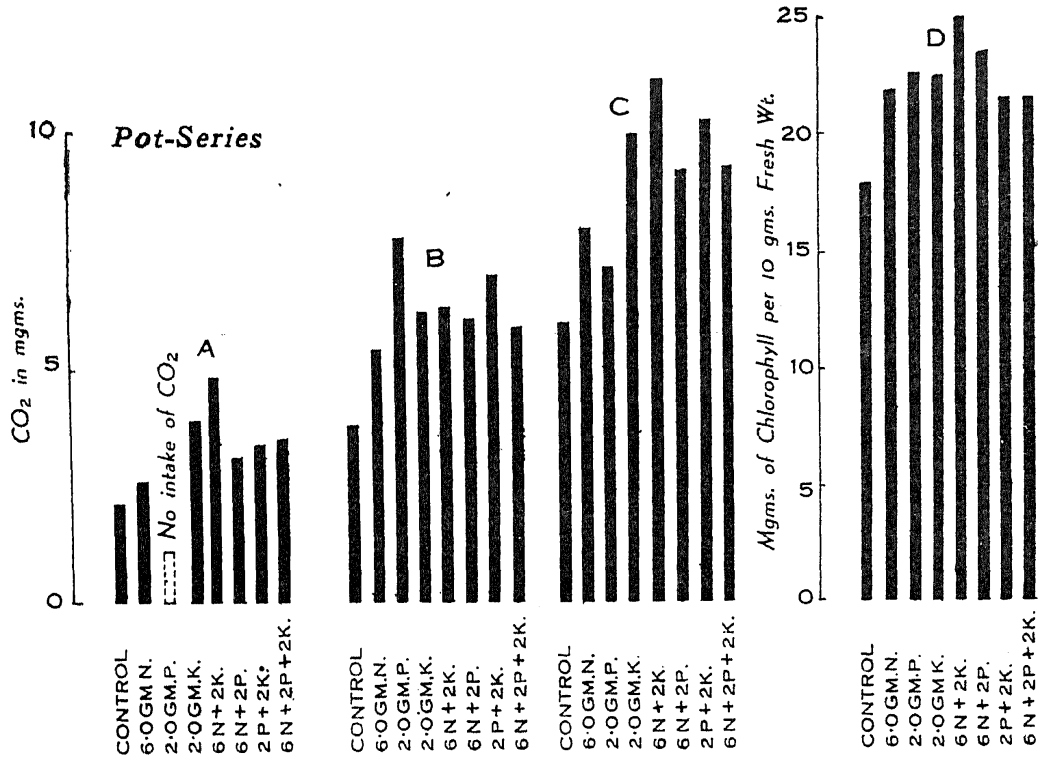

FIG. 1

The rate of photosynthesis (apparent and real), respiration and chlorophyll content of potted plants of *Saccharum officinarum*

Pot-Series

A.—Apparent-Assimilation-Rate
B.—Respiration-Rate
C.—Real-Assimilation-Rate
D.—Chlorophyll-Content

(Expt. 7) do not show the same high efficiency as that recorded for potash alone (Expt. 4). In response to phosphate in the single fertilizer treated plants there is practically no intake of CO_2 (Expt. 3).

The rate of real assimilation varies in practically the same order (Fig. 1, Table I) as the rate of apparent assimilation. Plants treated with potash alone show greater rate of real assimilation (Expt. 4), as compared to nitrogen and phosphoric acid treated plants following in order (Expts. 2 and 3). Maximum photosynthetic activity is again noted in plants supplied with nitrogen and potash (Expt. 5). In plants receiving all the three fertilizers assimilation neither reaches the level attained by plants treated

TABLE I

Variations in photosynthetic rate (apparent and real), respiration, and chlorophyll content of Saccharum officinarum *in response to different fertilizer treatments*

Temperature = 31° C. ± 0·2

CO_2 concentration = 0·25 to 0·30

Illumination, 1,500 C.P., Half-watt Philips bulb at 18 cm. distance

Expt. No.	Treatment*	CO_2 in mgms. per 100 sq. cm. leaf			Chlorophyll in mgms. per 10 gms. fresh weight
		Apparent assimilation	Respiration	Real assimilation	
	No. 1 Pot series experiments				
1	Control ..	2·171	3·876	6·047	18·0
2	6·0 gms. N per pot ..	2·567	5·455	8·022	21·9
3	2·0 gms. P per pot ..	− 0·545	7·816	7·271	22·5
4	2·0 gms. K per pot ..	3·854	6·209	10·063	22·5
5	6·0 gms. N + 2·0 gms. K per pot ..	4·741	6·376	11·117	25·1
6	6·0 gms. N + 2·0 gms. P per pot ..	3·156	6·115	9·271	23·5
7	2·0 gms. P + 2·0 gms. K per pot ..	3·322	7·013	10·335	21·7
8	6·0 gms. N + 2·0 gms. P + 2·0 gms. K per pot ..	3·450	5·934	9·384	21·7
	No. 2—Concrete-tank series experiments				
9	Control	2·786	10·511	13·297	15·2
10	Night-soil	2·795	13·429	16·224	16·4
11	Castor-cake	8·540	7·117	15·657	17·5
12	Sheep-dung	7·508	9·630	17·138	16·0
13	Cow-dung	7·799	8·496	16·295	18·1
14	Compost	7·263	8·928	16·191	18·0

N.B.—The data in these columns are the average of three separate estimations.

* For details of the treatments see pp. 134–36.

TABLE I (*Contd.*)

Expt. No.	Treatment*	CO_2 in mgms. per 100 sq. cm. leaf			Chlorophyll in mgms. per 10 gms. fresh weight
		Apparent assimilation	Respiration	Real assimilation	
	No. 3—Field series experiments				
15	Control	1·191	1·667	2·858	11·25
16	75 N	1·340	4·306	5·646	18·60
17	150 N	3·935	4·155	8·090	22·50
18	40 P	2·616	3·139	5·755	18·75
19	80 P	4·556	2·122	6·678	25·00
20	40 K	6·786	1·068	7·854	13·50
21	80 K	3·998	2·666	6·664	26·0
22	75 N + 40 P	1·419	2·998	4·417	20·00
23	75 N + 80 P	2·449	0·874	3·323	16·60
24	150 N + 40 P	5·571	3·203	8·774	25·00
25	150 N + 80 P	3·293	3·911	7·204	25·00
26	75 N + 40 K	1·356	2·304	3·660	25·00
27	75 N + 80 K	(− 1·663)	2·216	0·553	20·00
28	150 N + 40 K	3·877	1·399	5·276	20·00
29	150 N + 80 K ..	3·757	1·878	5·635	25·00
30	40 P + 40 K	2·843	4·314	7·157	26·0
31	40 P + 80 K	6·847	3·423	10·270	26·5
32	80 P + 40 K	7·591	2·137	9·728	22·0
33	80 P + 80 K	0·864	1·752	2·616	11·2
34	75 N + 40 P + 40 K ..	6·172	10·319	16·491	21·6
35	150 N + 40 P + 40 K ..	5·812	1·746	7·555	25·0
36	75 N + 80 P + 40 K ..	1·913	2·423	4·336	20·0
37	75 N + 80 P + 80 K ..	5·526	1·745	7·271	26·0
38	150 N + 40 P + 80 K ..	7·850	2·685	10·535	18·75
39	150 N + 80 P + 40 K ..	(− 0·636)	1·092	0·729	13·75
40	75 N + 40 P + 80 K ..	2·799	3·089	5·888	25·0
41	150 N + 80 P + 80 K ..	1·568	3·051	4·619	23·75

with potash alone or both nitrogen and potash supplied together (Expts. 8, 4 and 5). That the differences under varying fertilizer treatments are highly significant is shown by the results of statistical analysis (Tables II to VI).

TABLE II

Analysis of variance due to artificial fertilizers (Pot Series)

Due to	D.F.	S.S.	Mean S.S.
Block	2	0·025	0·0125
Treatment	7	100·707	14·3867 V_1
Error	14	2·476	0·177 V_2
Total	23	103·208	

V_1/V_2 = 81·281 (Significant at 1% level). C.D. = 0·686

	6·0 N	2·0 P	2·0 K	6·0 N + 2·0 K	6·0 N + 2·0 P	2·0 P + 2·0 K	6·0 N + 2·0 P + 2·0 K
Control ..	+	+	+	+	+	+	+
6·0 N ..			+	+	+	+	+
2·0 P ..			+	+	+	+	+
2·0 K ..				+			
6·0 N + 2·0 K ..						+	
6·0 N + 2·0 P ..						+	
2·0 P + 2·0 K ..							

+ Indicates significant differences.

TABLE III

Analysis of variance due to organic fertilizers (Concrete-tank Series)

Due to	D.F.	S.S.	Mean S.S.
Block	2	0·515	0·258
Treatment	5	22·931	4·586 V_1
Error	10	15·113	1·511 V_2
Total	17	38·559	

V_1/V_2 = 3·035 (not significant both at 1 and 5%). C.D. = 2·00306.

TABLE III—(*Contd.*)

	Night-soil	Castor-cake	Sheep-dung	Cow-dung	Compost
Control ..	+	+	+	+	+
Night-soil ..					
Castor-cake ..			+		
Sheep-dung ..					
Cow-dung ..					

+ Indicates significant differences.

TABLE IV

Analysis of variance due to single fertilizer series (Field Series)

Due to	D.F.	S.S.	Mean S.S.
Block	2	0·122	0·061
Treatment	6	56·051	9·343 V_1
Error	12	1·473	0·123 V_2
Total	20	57·646	

V_1/V_2 = 75·943 (significant at 1% level).

C.D. = 0·592.

	75 N	150 N	40 P	80 P	40 K	80 K
Control	+	+	+	+	+	+
75 N		+		+	+	+
150 N						
40 P				+	+	+
80 P						
40 K						

+ Indicates significant differences.

TABLE V

Analysis of variance due to double fertilizer (Field Series)

Due to	D.F.	S.S.	Mean S.S.
Block	2	0·064	0·032
Treatment	12	36·415	3·034 V_1
Error	24	0·257	0·0171 V_2
Total	38	36·736	

V_1/V_2 = 178·4 highly significant at 1% level. C.D. = 0·214.

	75 N + 40 P	75 N + 80 P	150 N + 40 P	150 N + 80 P	75 N + 40 K	75 N + 80 K	150 N + 40 K	150 N + 80 K	40 P + 40 K	40 P + 80 K	80 P + 40 K	80 P + 80 K
Control	+	+	+	+	+		+	+	+	+	+	
75 N + 40 P			+	+			+	+	+	+	+	
75 N + 80 P			+	+			+	+	+	+		
150 N + 40 P									+	+		
150 N + 80 P									+	+		
75 N + 40 K							+	+	+	+		
75 N + 80 K							+	+	+	+	+	
150 N + 40 K								+	+	+		
150 N + 80 K								+	+	+		
40 P + 40 K												
40 P + 80 K												
80 P + 40 K												

+ Indicates significant differences.

TABLE VI

Analysis of variance due to three fertilizers (Field Series)

Due to	D.F.	S.S.	Mean S.S.
Block	2	187·807	93·904
Treatment	8	328·587	41·072 V_1
Error	16	126·933	7·933 V_2
Total	26	643·327	

V_1/V_2 = 5·1 significant at 1% level.
C.D. = 4·598.

	75 N +40 P +40 K	150 N +40 P +40 K	75 N +80 P +40 K	75 N +80 P +80 K	150 N +40 P +80 K	150 N +80 P +40 K	75 N +40 P +80 K	150 N +80 P +80 K
Control ..	+	+		+	+			
75 N + 40 P + 40 K ..								
150 N + 40 P + 40 K ..								
75 N + 80 P + 40 K ..								
75 N + 80 P + 80 K ..					+			
150 N + 40 P + 80 K ..								
150 N + 80 P + 40 K ..								
75 N + 40 P + 80 K ..								

+ Indicates significant differences.

The rate of respiration is also increased much beyond the value recorded for the untreated plants (Fig. 1). Of all the treatments the rate of respiration is maximum in case of phosphoric acid treated plants (Expt. 3) and minimum in case of plants receiving nitrogen alone (Expt. 2). In other cases the rate of respiration fluctuates within a narrow range.

The chlorophyll content of leaves of treated series is always higher than the control (Fig. 1). Maximum chlorophyll content is noted in cultures supplied with both nitrogen and potash (Expt. 5) followed by those supplied with nitrogen and phosphoric acid (Expt. 6).

No. II. Concrete-Tank Series:

Apparent Assimilation:—The rate of apparent assimilation in response to the organic manures supplied at the rate of 150·0 lbs. N_2 per acre, in each case, does not show as characteristic differences (Fig. 2) as noted in the

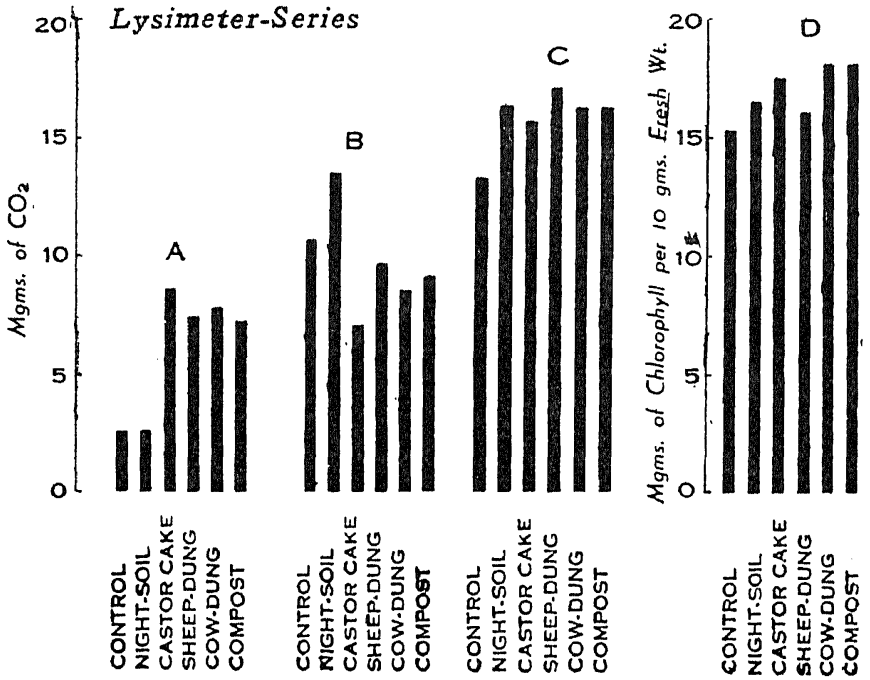

FIG. 2

The rate of photosynthesis (apparent and real), respiration and chlorophyll content of leaves gathered from *Saccharum officinarum* plants growing in concrete tanks

A.—Apparent-Assimilation-Rate
B.—Respiration-Rate
C.—Real-Assimilation-Rate
D.—Chlorophyll-Content

previous case. Leaves from manured plants, however, usually have photosynthetic efficiency much higher than that recorded for the control (Expts. 9–14). In the night-soil treated plants no augmentative effect is, however,

noted (Expt. 10). Castor-cake increases the photosynthetic rate to a maximum extent (Expt. 11) followed by leaves from cow-dung, sheep-dung, and compost treated plants (Expts. 13, 12 and 14).

Respiration :—While the rate of apparent assimilation is greatly increased in majority of the manures, that of respiration is definitely retarded (Fig. 2). Night-soil, however, increases the rate of respiration (Expt. 10) beyond the level attained by the control (Expt. 9).

Real Assimilation :—The rate of real assimilation does not vary much from treatment to treatment (Fig. 2, Table I) although the treated plants in general show a higher photosynthetic efficiency than the control. The variations due to treatments (Table III) are however not significant.

Chlorophyll Content :—Chlorophyll content of leaves too behaves in a similar manner in response to different bulky organic manures (Fig. 2).

These evidences indicate in general that in response to different bulky organic manures (i) the rate of real assimilation and chlorophyll content does not exhibit marked variations from treatment to treatment although the treated plants are definitely better in these regards as compared to control and (ii) the respiratory intensity (night-soil treated plants excepted) is definitely decreased in response to application of organic manures.

No. III. Field Series :

The rate of assimilation (both apparent and real), respiration and chlorophyll also undergo characteristic variations from treatment to treatment (Figs. 3, 4, 5 and 6 ; Table I).

Apparent Assimilation.—The observations indicate that in the single fertilizer series, out of the different treatments given to the plants the greatest acceleration is obtained in plants receiving 40·0 lbs. of potash per acre alone (Expt. 20). An increase in the supply of potash to 80·0 lbs. per acre, however, diminishes the rate of apparent assimilation (Expt. 21). In contrast to this, however, acceleration is obtained under higher dozes of nitrogen (150·0 lbs. per acre) and double superphosphate (80·0 lbs. per acre) (Expts. 17 and 19). This indicates that whereas an increase in potash beyond 40·0 lbs. is deleterious in so far as apparent assimilation is concerned, similar increase in nitrogen or phosphates increases photosynthesis markedly.

In the ' double fertilizer ' series maximum rate of photosynthesis is observed in plants receiving 80·0 lbs. of phosphates and 40·0 lbs. of potash per acre (Expt. 32 ; Fig. 3) next in order being those receiving 40·0 lbs. of phosphates and 80·0 lbs. of potash per acre (Expt. 31). Plants receiving

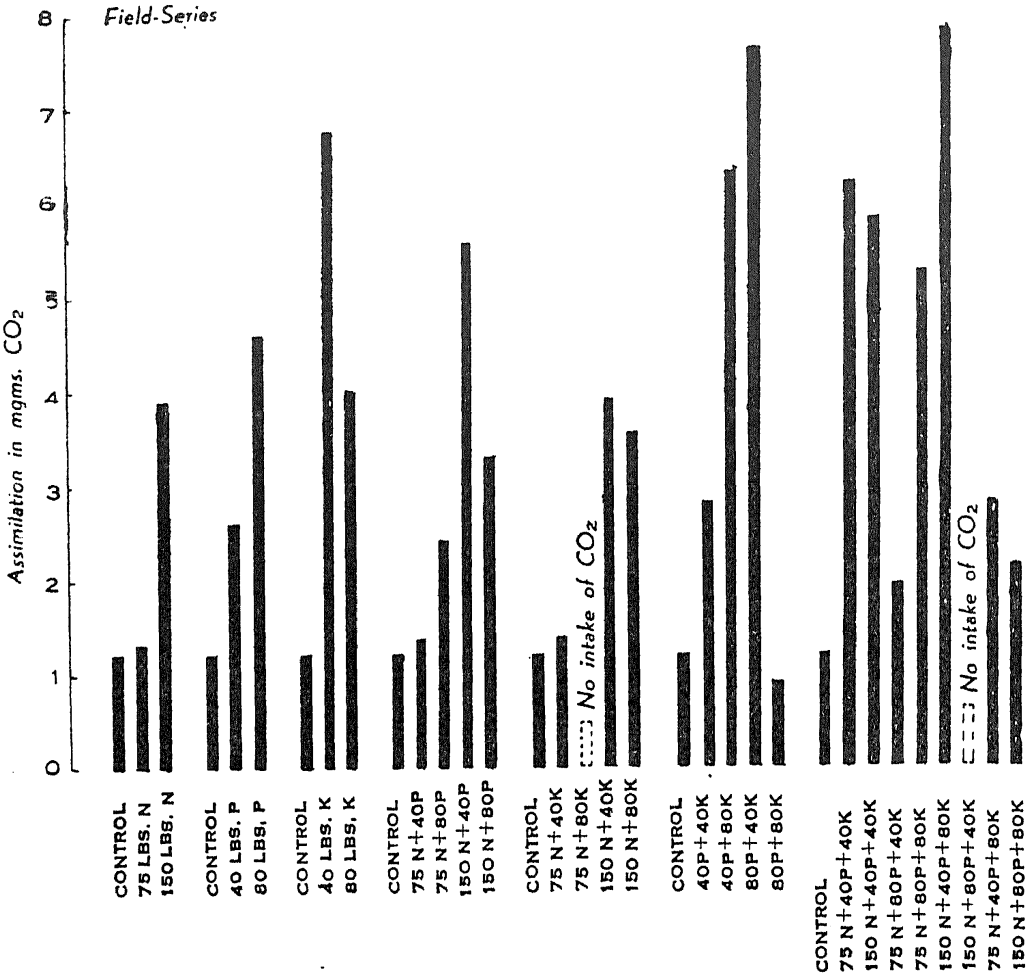

FIG. 3

Fertiliser effect on the apparent assimilation rate of leaves of *Saccharum officinarum* plants

Apparent-Assimilation-Rate

75·0 lbs. of nitrogen and 80·0 lbs. of potash do not take up any CO_2 from the atmosphere, the rate of apparent assimilation exhibiting negative values (Expt. 27).

In the three-fertilizer series maximum rate of apparent assimilation is observed in plants receiving 150·0 lbs. of nitrogen, 40·0 lbs. of phosphates and 75·0 lbs. of potash (Expt. 38 ; Fig. 3). This is followed by plants grown under $N_1P_1K_1$, $N_2P_1K_1$ and $N_1P_2K_2$ treatments (Expts. 34, 35, 37 ; Fig. 3). In this group as well plants receiving 150·0 lbs. N_2—80·0 lbs. P_2O_5—40·0 lbs. K_2O per acre exhibit negative values (Expt. 39) there being no intake of CO_2 from the atmosphere.

Respiration (*Fig. 4*).—Contrary to the observations recorded for apparent assimilation an increase in potash is associated with increase in respiratory activity (Expts. 20 and 21), whereas increase in nitrogen and phosphoric

acid alone to the soil decreases the rate of respiration (Expts. 16, 17, 18 and 19).

In the 'single fertilizer' series plants receiving 75·0 lbs. of nitrogen per acre have the maximum rate of respiration (Expt. 16), while those receiving 40·0 lbs. of potash exhibit the least respiration (Expt. 20).

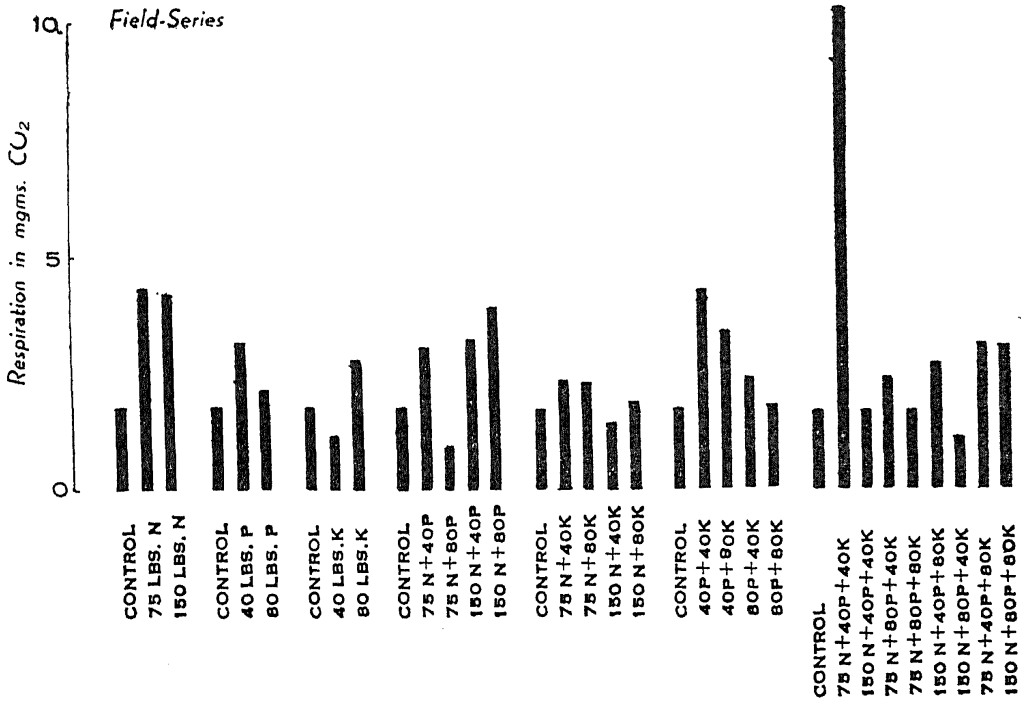

FIG. 4

Fertiliser effect on the respiration rate of leaves of *Saccharum officinarum* plants

Respiration-Rate

In the 'double fertilizer' series associations of any two mineral ingredients is useful when applied in certain combination and concentration, whereas in others it is definitely deleterious. Increasing application of phosphoric acid has a deleterious effect on respiration when applied in combination with 75·0 lbs. of nitrogen per acre (Expt. 23). Under heavier dressings of nitrogen similar increase in potash increases respiration rate (Expt. 29). In combination with phosphorus increase in potash definitely retards respiration at both the levels of phosphoric acid application. Maximum rate of respiration is noted in plants receiving both 40·0 lbs. of potash and 40·0 lbs. of phosphates per acre (Expt. 30). Those receiving 75·0 lbs. of nitrogen and 80·0 lbs. of phosphates exhibit least respiration (Expt. 23).

In the 'three fertilizer' series maximum rate of respiration is observed in plants receiving 75·0 lbs. N_2—40·0 lbs. P_2O_5—40·0 lbs. K_2O (Expt. 34)

followed by those grown under $N_2P_2K_2$ and $N_1P_1K_2$ treatments (Expts. 41 and 40). Minimum rate of respiration is observed in plants receiving 150·0 lbs. N_2—80·0 lbs. P_2O_5—40·0 lbs. K_2O per acre (Expt. 39).

Real Assimilation (*Fig. 5*).—In the ' single fertilizer ' series the rate of real assimilation varies practically in the same order as the rate of apparent assimilation. The best result is obtained in case of plants receiving 150·0 lbs. of nitrogen followed by those receiving 40·0 lbs./acre of potash alone (Expts. 17 and 20).

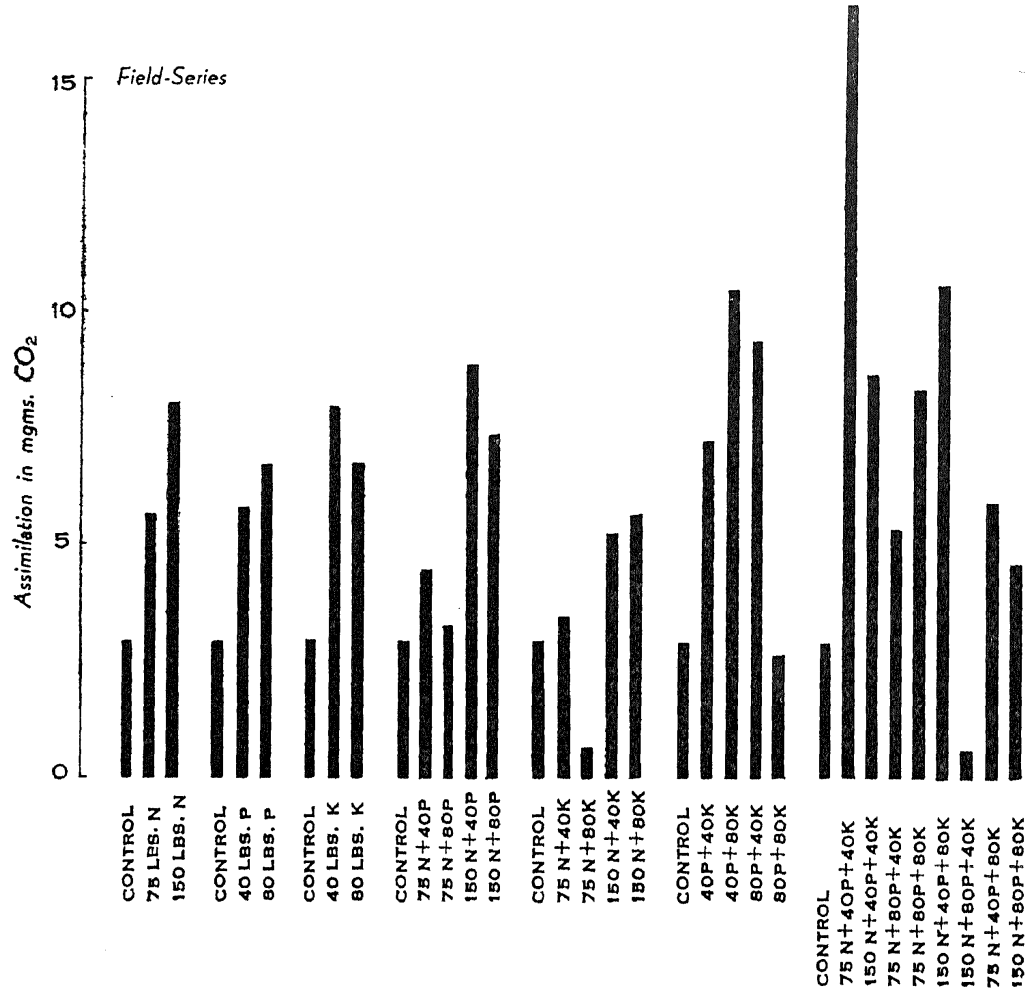

FIG. 5

Fertiliser effect on the real photosynthetic rate of *Saccharum officinarum* leaves

Real-Assimilation-Rate

In the ' double fertilizer ' series the maximum rate of real assimilation is observed in plants receiving 40·0 lbs. of P_2O_5 and 80·0 lbs. of potash (Expt. 31). This is followed by those supplied with 80·0 lbs. phosphate and 40·0 lbs. potash (Expt. 32). Like the rate of apparent assimilation

minimum rate of real assimilation is obtained in plants receiving N_1K_2 treatment (Expt. 27).

In association with both higher and lower doses of nitrogen (75·0 lbs. and 150·0 lbs. per acre) increase in supply of phosphorus decreases photosynthesis (Expts. 23 and 25).

Increase in potash from 40·0 lbs. per acre in association with lower doses of nitrogen is much more harmful (Expt. 27) than similar increase in phosphorus (Expt. 23).

In association with heavy doses of nitrogen (150·0 lbs. per acre), potash when supplied to the extent of 80·0 lbs. per acre has a beneficial influence on photosynthesis (Expt. 29).

Similar increase in the quantity of potash has a useful influence when applied with 40·0 lbs. P_2O_5 per acre (Expt. 31). Under heavier doses of P_2O_5 there is, however, a definite harmful effect (Expt. 33).

In the 'three fertilizer' series maximum rate of real assimilation is noted in case of plants receiving 75·0 lbs. N_2—40·0 lbs. P_2O_5—40·0 lbs. K_2O per acre (Expt. 34). Next in order of efficiency being plants grown under $N_2P_1K_2$ treatment (Expt. 38).

The minimum rate of photosynthesis is found in plants receiving 150·0 lbs. N_2—80 lbs. P_2O_5—40·0 lbs. K_2O per acre (Expt. 39). The statistical analysis of results (Tables IV–VI) indicates that the variation in assimilation rate from treatment to treatment in all the three series are significant at 1% level.

Chlorophyll Content (*Fig. 6*).—In the 'single fertilizer' series increase in the quantity of either nitrogen, phosphoric acid or potash increases the chlorophyll content of leaves (Expts. 15–21). The values in all cases are higher than the control. Maximum chlorophyll content is obtained in plants grown under 80·0 lbs. of potash followed by those grown under similar doses of phosphates (Expts. 21 and 19). In the 'double fertilizer' series increase in phosphorus in association with lower doses of nitrogen appears to be harmful from the point of view of chlorophyll content (Expt. 23). In association with heavier dozes of nitrogen of the order of 150·0 lbs. per acre this deleterious influence is overcome, chlorophyll content remaining constant (Expts. 24 and 25).

Increase in potash in association with lower doses of nitrogen has the same effect as phosphorus (Expt. 27). When applied with higher doses of nitrogen 150·0 lbs. per acre increase in potash decidedly increases the chlorophyll content (Expt. 29).

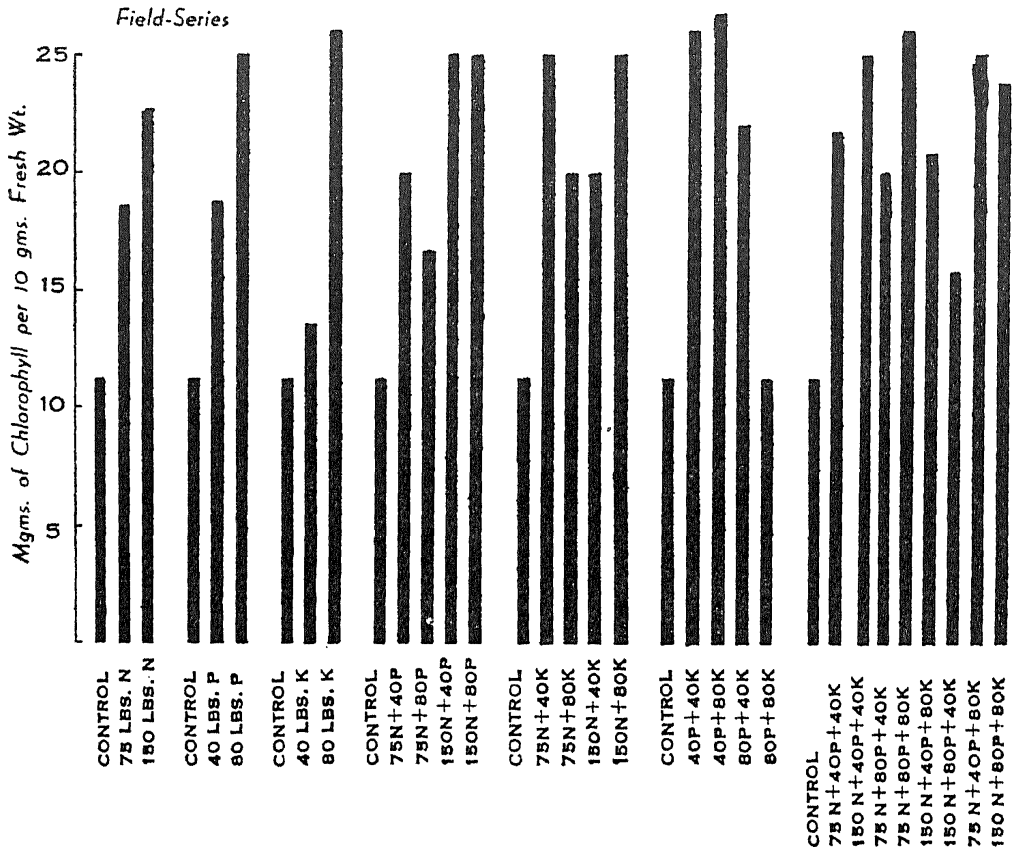

FIG. 6
Fertiliser effect on the chlorophyll content
of *Saccharum officinarum* leaves
Chlolophyll-Content

Phosphorus and potash when applied at the rate of 40·0 lbs. and 80·0 lbs. per acre respectively increases the chlorophyll content beyond the values recorded for other combinations of P_2O_5 and K_2O (Expt. 31). In association with lower doses of phosphorus increase in potash increases the chlorophyll content (Expt. 31) whereas when applied with heavier dressings (80·0 lbs. per acre) of phosphorus similar increase in potash has a definite deleterious effect on the chlorophyll content (Expt. 33).

In the 'three fertilizer' series plants grown under $N_1P_2K_2$ treatment (Expt. 37) have the highest chlorophyll content while those receiving $N_2P_2K_1$ treatment possesses the least chlorophyll content (Expt. 39). Under other combinations the chlorophyll content varies between 1·8 mgms. to 2·5 mgms. per gm. fresh weight.

Discussion

From what has been narrated in the previous pages, it is evident that application of manures either singly or in combination, greatly influences

the rate of assimilation (real and apparent) and respiration as also the chlorophyll content of the leaves. It is significant to note that in response to bulky manures (Expts. 10–14) such as night-soil, sheep-dung, cow-dung. compost, etc., supplied at the rate of 150·0 lbs. nitrogen to an acre, photosynthesis does not show well-marked variations from treatment to treatment. On the other hand, application of artificial fertilizer either singly or in different combinations induces wide fluctuations in the photosynthetic efficiency of leaves (Expts. 2–8). In response to potassium either applied singly or in combination with nitrogen or phosphorus, photosynthesis is augmented much beyond the value recorded for treatments lacking in potassium.

The experiments further reveal that when the quantity of potash is increased from 40·0 lbs. to 80·0 lbs. an acre photosynthesis decreases from 7·854 mgms. to 6·664 mgms., *i.e.*, 0·85 times (Expts. 20 and 21). When a dressing of 75·0 lbs. of nitrogen is also supplied with potash, doubling the quantity of potash alone decreases the rate of photosynthesis from 3·660 mgms. to 0·553 mgms., *i.e.*, 0·15 times (Expts. 26 and 27). In association with high concentration of nitrogen of the order of 150·0 lbs. an acre the deleterious effect is not evident even when the quantity of potash is increased from 40·0 to 80·0 lbs. an acre (Expts. 28 and 29). When applied in association with phosphates the photosynthetic response to potash is altogether different. In plots supplied with 40·0 lbs. of phosphates an increase in potash application from 40·0 lbs. to 80·0 lbs. increases the rate of assimilation from 7·157 mgms. to 10·270 mgms., *i.e.*, 1·43 times (Expts. 30 and 31). In association with 80·0 lbs. of phosphorus similar increase in potash definitely retards the photosynthetic rate by 0·51 times (Expts. 32 and 33).

In association with both nitrogen and phosphorus supplied at the rate of 75·0 lbs. and 40·0 lbs. respectively, increase in potash from 40·0 lbs. to 80·0 lbs. per acre again decreases photosynthesis from 16·491 to 5·88 mgms., *i.e.*, 0·36 times (Expts. 34 and 40). But with richer dressings of nitrogen of the order of 150·0 lbs. of nitrogen, phosphorus being maintained at the same level (40·0 lbs. per acre) increase in potash definitely increases the photosynthetic rate from 7·555 mgms. to 10·535 mgms., *i.e.*, 1·39 times (Expts. 35 and 38). When phosphorus is also increased side by side with nitrogen upto a level 80·0 lbs. and 150·0 lbs. respectively, increase in potash by two times again increases photosynthetic rate from 0·729 mgms. to 4·61 mgms., *i.e.*, 6·32 times (Expts. 39 and 41).

More or less similar variations are observed in response to nitrogen and phosphorus application as well, photosynthesis under certain treatments exhibiting an increase while under others showing a definite decline.

These evidences lead to the generalisation that the photosynthetic response to the application of different manurial ingredients greatly depends upon the presence or absence of other fertilizer ingredients. Thus the augmentative effect of potash is marred under certain fertilizer combinations (Expts. 27 and 39) when the presence of other complementary factors phosphorus and nitrogen inhibits the fullest acceleration in CO_2 intake. No direct proportionality between the quantities of fertilizers applied and the photosynthetic rate is observed in different series. This in itself indicates that the response to any of the fertilizers does not rigidly depend upon the concentration of one ingredient alone but differs from treatment to treatment.

If the different series of cultures are compared, plants grown under organic manures have higher photosynthetic efficiency than the plants grown in other series not supplied with any superficial dressings of organic matter. Such beneficial effect of organic manures in general might well be attributed to (1) the beneficial effect of organic matter in inducing favourable variations in texture and water-holding capacity of the soil which indirectly influences growth and metabolism; (2) the presence of majority of mineral ingredients essential for normal functioning of the plant machinery; and (3) the presence of the organic nitrogen compounds which have a general stimulating effect upon the plant.

Summary

Evidences on the influence of artificial fertilizers and organic manures upon the photosynthetic efficiency, respiration rate, and chlorophyll content of leaves have been discussed in the previous pages. The data lead to the conclusion that the influence of potash, phosphorus, and nitrogen upon the photosynthetic activity of leaves greatly depends on the presence or absence of other complementary factors. Potash thus when applied singly at the rate of 40·0 lbs. per acre increases photosynthesis to a greater extent than heavier dozes (Expts. 20 and 21).

In association with both higher and lower doses of nitrogen (75·0 lbs. to 150·0 lbs. per acre), increase in supply of phosphorus decreases photosynthesis (Expts. 23 and 25).

Increase in potash from 40·0 lbs. to 80·0 lbs. per acre in association with lower doses of nitrogen is much more harmful (Expt. 27) than similar increase in phosphorus (Expt. 23).

In association with heavy doses of nitrogen (150·0 lbs. per acre) potash when supplied even to the extent of 80·0 lbs. per acre has a beneficial influence on photosynthesis (Expt. 29).

Similar increase in the quantity of potash has a beneficial influence on photosynthesis when applied with 40·0 lbs. of P_2O_5 per acre (Expt. 31); under heavier doses of P_2O_5 there is, however, a definite harmful effect (Expt. 33).

Plants receiving 75·0 lbs. of nitrogen and 40·0 lbs. of phosphate and 40·0 lbs. potash per acre exhibit maximum photosynthetic rate, next in order being plants receiving 150·0 lbs. of nitrogen, 40·0 lbs. of P_2O_5 and 80·0 lbs. of K_2O per acre.

In response to different organic fertilizers the rate of real assimilation does not vary to any significant extent from treatment to treatment, although it is definitely increased beyond the value recorded for the control.

Increasing application of phosphates has a deleterious effect on respiration when applied in combination with 75·0 lbs. of nitrogen per acre (Expt. 23). Under heavier dressings of nitrogen similar increase in potash increases respiration rate (Expt. 29). In combination with phosphorus increase in potash definitely retards respiration at both the levels of phosphoric acid application (Expts. 31 and 32).

Maximum rate of respiration is observed in plants treated with 75·0 lbs. of nitrogen, 40·0 lbs. P_2O_5 and 40·0 lbs. K_2O (Expt. 34).

Increase in phosphorus in association with lower doses of nitrogen appears to be harmful from the point of view of chlorophyll content (Expt. 23). In association with heavier doses of nitrogen of the order of 150·0 lbs. per acre this deleterious influence is overcome, chlorophyll content (Expts. 24 and 25) remaining constant.

Increase in potash in association with lower doses of nitrogen has the same effect as phosphate (Expt. 27) when supplied with higher doses of nitrogen (150·0 lbs. per acre) increase in potash decidedly increases the chlorophyll content (Expt. 29).

Phosphorus and potash when applied at the rate of 40·0 lbs. and 80·0 lbs. per acre respectively increases the chlorophyll content (Expt. 31) beyond the values recorded for other combinations of P_2O_5 and K_2O. In association with lower doses of phosphorus increase in potash increases the chlorophyll content (Expt. 31) whereas when applied with heavier dressings (80·0 lbs. per acre) of phosphorus similar increase in potash has a definite deleterious effect on the chlorophyll content (Expt. 33).

Maximum chlorophyll content is obtained in plants grown under 40·0 lbs. P_2O_5 and 80·0 lbs. K_2O.

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