

SPECIFIC ACTION OF ORGANIC COMPOUNDS IN MODIFYING PLANT CHARACTERISTICS; METHYL GLYCOCOLL VERSUS GLYCOCOLL

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(WITH FOUR FIGURES)

The effect on plant growth of a large number of soil organic compounds and other organic substances has been tested in this laboratory from time to time. The action of the two compounds glycocoll and methyl glycocoll on plants is very interesting, the former being beneficial, while the latter is harmful to growth and affects the plants in a peculiar way.

The utilization of certain nitrogenous compounds by plants, some having a beneficial effect and replacing nitrates in their action, and others having harmful effects, producing peculiar characteristics, leaves but little doubt that organic compounds in soils or nutrient solutions are absorbed directly by the roots of plants and enter into the cells, reacting with the cell contents and producing effects which differ according to the nature of the compound absorbed. The process is connected with and is a part of the general metabolic processes of plants. The absorbed material passes through the membranes possessing these properties of absorption, and reacts on the cell contents in a favorable or unfavorable manner, influencing the life processes of the plant itself. Glycocoll, a nitrogenous compound having a definite chemical structure, is shown to have been absorbed or used by the plant to build up its tissue, while the related compound, methyl glycocoll, also nitrogenous but having a different chemical structure, is absorbed by the plants and has an unfavorable influence, causing decreased growth, and a peculiar twisted lateral growth of the leaf of the plant.

The properties of plants of absorbing the mineral constituents from the nutrient or soil solution do not differ in respect to the absorption of the organic constituents from the solution. In the case of the methyl glycocoll the greatest harmful effect was noted

in those solutions where there was the greatest absorption of inorganic nutrients, and while no methods are available to study the absorption of this organic compound, it seems justifiable to assume that the cultures also absorbed a greater amount of organic constituent from the solution, while in other solutions where the absorption of nutrients was small the harmfulness of the methyl glycol was also only slight, indicating that a small amount was absorbed.

It has been shown in this laboratory and elsewhere that plant roots can affect organic substances externally, and it is therefore possible that organic substances may also influence the plant itself through this external action; however, in the majority of cases that have come under our observation the compounds have been absorbed, for in such cases as could be tested they disappeared from the solution and had their effects on the plant tops either favorably or unfavorably, as the case may be.

In the case of dihydroxystearic acid the normal metabolism is greatly disturbed.¹ This is shown by the difference in the absorption of the separate nutrients, phosphate, nitrate, and potash, a proportionately greater nitrate consumption being evident with the plants affected by dihydroxystearic acid. Such a change in metabolism could be explained only on the assumption that the compound produced a reaction within the plant after absorption from the solution.

The specific effects produced by organic compounds must also be taken into consideration. For instance, cumarin produces greatly stunted tops, with short, broad leaves and much distorted and thickened stems in the case of wheat plants. Quinone, on the other hand, produces long, slender, thin plants. The different reactions of the plants to these two compounds must be due to the direct absorption of the compound accompanied by a disturbed metabolism. Moreover, the cumarin-affected plants absorb relatively more phosphate, the quinone plants relatively more potash.²

Furthermore, plants grown in guanidine solutions develop small spots of a bleached appearance which grow and spread, producing

¹ SCHREINER, O., and SKINNER, J. J., Some effects of a harmful organic soil constituent. *BOT. GAZ.* 50:161. 1910.

² ———, The toxic action of organic compounds as modified by fertilizer salts. *BOT. GAZ.* 54:31. 1912.

a weakened plant, the leaves of which break at the stem, wilt, and die, the roots remaining unaffected.³ This is explainable only on the assumption of its absorption by the plant and its action on the plant protoplasm.

The cases cited of the beneficial and harmful action of organic compounds, many having specific characteristics, are sufficient to show that organic substances, like inorganic poisons, are absorbed and react with the protoplasm of the plant.

The effect of methyl glyocoll on plants has not previously been determined. In the early experiments⁴ of this laboratory glyocoll was shown to be beneficial to wheat seedlings in distilled water cultures. Concentrations of 1 to 1000 parts per million were used. The tops were increased in all the cultures; the roots were slightly injured by the higher amounts.

HANSTEEN⁵ showed that glyocoll was slightly harmful to *Lemna*, and that from it were produced proteins. In MOLLIARD's⁶ experiments beneficial results were secured in water cultures growing radishes. The experiments of HUTCHINSON and MILLER⁷ with water cultures were doubtful. One of their pea cultures showed that the nitrogen content of the plant was increased by the use of glyocoll, although a slight decrease was noticed in another culture.

The experiments of BOROWIKOW⁸ with *Helianthus* indicate that glyocoll retards growth. DACHNOWSKI and GORMLEY,⁹

³ SCHREINER, O., and SKINNER, J. J., The effect of guanidine on plants. Bull. Torr. Bot. Club 39:535. 1912.

⁴ SCHREINER, O., REED, H. S., and SKINNER, J. J., Certain organic constituents of soils in relation to soil fertility. Bull. 47. Bur. Soils, U.S. Dept. Agric. 1907.

⁵ HANSTEEN, B., Om Aeggehvidesynthese i den gronne phanerogame Plante. Vidensk. Skrift. no. 3. 1898; Über Eiweissynthese in grünen Phanerogamen. Jahrb. Wiss. Bot. 33:417. 1899.

⁶ MOLLIARD, M., Recherches sur le utilization par les plantes supérieures de diverses substances organiques azotées. Bull. Soc. Bot. France 10:541. 1910.

⁷ HUTCHINSON, H. B., and MILLER, N. H. J., The direct assimilation of inorganic and organic forms of nitrogen by higher plants. Centralbl. Bakt. 30:513. 1911.

⁸ BOROWIKOW, G. A., Über die Ursachen des Wachstums der Pflanzen. Biochem. Zeitschr. 50:119. 1913.

⁹ DACHNOWSKI, A., and GORMLEY, R., The physiological water requirements and growth of plants in glyocoll solutions. Amer. Jour. Bot. 1:174. 1914.

working with a number of plants in water cultures, have shown that glycocoll is generally beneficial. It is pointed out that the process of absorption of glycocoll is not connected with the transpirational water loss, but with the differential permeability of the absorbing root cells, with the efficiency of the nutrient metabolism characteristic of the plant, and the amount of water retained within the plants.

Glycocoll ($\text{CH}_2 \cdot \text{NH}_2 \cdot \text{COOH}$) is amidoacetic acid and is one of the simpler degradation products found where decomposition is occurring. This primary degradation product of protein appears in the decomposition of plant remains and exists in considerable quantities in the tissue and seed of many plants. It is obtained synthetically by chemical processes in a number of ways.

Methyl glycocoll ($\text{CH}_2 \cdot \text{NH} \cdot \text{CH}_3 \cdot \text{COOH}$) differs in its chemical structure from glycocoll, not only in that it contains the methyl group CH_3 , but also in that the amido group NH_2 is thereby changed to an imido group NH . Methyl glycocoll, as well as glycocoll, is a nitrogen-containing body; it is made synthetically and is not a simple protein body.

Effect of glycocoll

In this investigation the effect of glycocoll on growth in culture solutions was studied by growing wheat seedlings in solutions of calcium acid phosphate, sodium nitrate, and potassium sulphate. A large number of cultures was used; some consisted of the salts used singly, some of combinations of two salts, and others of all three salts used in different proportions. The total number of combinations used can be obtained from table IV, and from the discussion of the other tables. The composition of the solutions is given in the respective tables. Each solution was contained in a wide-mouth bottle holding 250 cc., and the solution was changed every three days, the old being replaced by fresh solution. The solutions were prepared by dissolving definite amounts of salts in carbon-treated distilled water. Two bottles of each solution were prepared, one to serve as a control, while to the other was added 50 ppm. of glycocoll. Each culture jar grew 10 wheat seedlings, supported in notched corks. The seedlings were placed in

the solutions when about 2 cm. tall, and grew for 12 days. The removal of salts was studied by analyzing the solutions for phosphate, nitrate, and potash, and the growth was observed and compared with its control, and the weight of green plants taken at the end of the experiment. The plants grew in these solutions from February 7 to February 19, 1914.

As the plants grew in the solutions, it was apparent that the glyocoll affected growth differently in the solutions containing different nutrient salts. The growth was increased much more by glyocoll in the solutions which contained no sodium nitrate than in those which contained large amounts of nitrate, as compared with the respective controls. This will be apparent from the weights of the green plants given in the accompanying tables.

TABLE I
EFFECT OF GLYCOCOLL IN CULTURE SOLUTIONS CONTAINING VARYING
AMOUNTS OF PHOSPHATES AND POTASH AND NO NITRATE

COMPOSITION OF CULTURE SOLUTIONS			GREEN WEIGHT	
P ₂ O ₅	NH ₃	K ₂ O	Without glyocoll	With 50 ppm. glyocoll
ppm.	ppm.	ppm.	gm.	gm.
80	0	0	1.01	1.05
72	0	8	1.26	1.55
64	0	16	1.53	1.85
56	0	24	1.50	1.95
48	0	32	1.55	2.05
40	0	40	1.47	2.00
32	0	48	1.39	2.05
24	0	56	1.50	1.95
16	0	64	1.65	1.70
8	0	72	1.40	1.90
0	0	80	1.37	1.65

Table I gives the green weight of the plants in solutions without and with glyocoll. The first three columns give the composition of each solution in parts per million P₂O₅ as calcium acid phosphate, NH₃ as sodium nitrate, and K₂O as potassium sulphate. The fourth column gives the green weight of the plants grown in solutions without glyocoll, and the last column the weight of the plants grown in solutions with 50 ppm. glyocoll.

An examination of the table shows that glyocoll, in those solutions which contained no nitrate, but varying amounts of

phosphate and potash, produced an increased growth in every culture. The total weight of the 11 normal cultures was 15.63 grams, and the weight of the glycocoll cultures was 19.70 grams, an increase of 26 per cent.

In table II are given the cultures which were composed of 8 ppm. of NH_3 as nitrate, and varying amounts of phosphate and potash.

TABLE II

EFFECT OF GLYCOCOLL IN NUTRIENT SOLUTIONS CONTAINING VARYING AMOUNTS OF PHOSPHATE AND POTASH AND 8 PPM. OF NH_3 AS NITRATE

COMPOSITION OF CULTURE SOLUTIONS			GREEN WEIGHT	
P_2O_5	NH_3	K ₂ O	Without glycocoll	With 50 ppm. glycocoll
ppm.	ppm.	ppm.	gm.	gm.
72	8	0	1.48	1.65
64	8	8	1.73	2.05
56	8	16	2.20	2.09
48	8	24	2.40	2.43
40	8	32	2.37	2.70
32	8	40	2.34	2.35
24	8	48	1.30	1.45
16	8	56	2.20	2.25
8	8	64	2.35	2.40
0	8	72	1.90	2.05

The growth in this series of solutions was slightly better where glycocoll was added. An examination of the green weight columns of the table will show that nearly all the glycocoll cultures were slightly heavier. The total weight of the 10 cultures without glycocoll was 20.27 grams, against 21.42 grams for the cultures with glycocoll. This is an increase of 6 per cent.

The effect of glycocoll on growth in nutrient solutions containing still larger amounts of sodium nitrate is given in table III. These solutions, like the ones in the previous tables, are composed of varying amounts of phosphate and potash, but each contains 16 ppm. of NH_3 as nitrate.

In some of these solutions the glycocoll has slightly increased the growth, and in others the growth is slightly below the normal culture. The total weight of the 9 cultures without glycocoll was

20.75 grams, against 21.60 grams for the glycocoll, an average increase of only 4 per cent.

TABLE III
EFFECT OF GLYCOCOLL IN CULTURE SOLUTIONS CONTAINING VARYING
AMOUNTS OF PHOSPHATE AND POTASH AND
16 PPM. NH_3 AS NITRATE

COMPOSITION OF CULTURE SOLUTIONS			GREEN WEIGHT	
P_2O_5	NH_3	K ₂ O	Without glycocoll	With 50 ppm. glycocoll
ppm.	ppm.	ppm.	gm.	gm.
64	16	0	1.33	1.45
56	16	8	1.90	2.05
48	16	16	2.40	2.25
40	16	24	2.50	2.60
32	16	32	2.62	2.50
24	16	40	2.50	2.65
16	16	48	2.90	2.85
8	16	56	2.30	3.00
0	16	64	2.30	2.25

The beneficial effect of glycocoll in the solutions given in tables I, II, and III was most marked in those solutions containing no nitrate (table I). The effect was very slight in solutions containing 8 and 16 ppm. of NH_3 as nitrate, which indicates that the function of glycocoll in the nutrient solution is the same as that of nitrate; that is, that it seems to be absorbed by the plants and can take the place of nitrate in its effect on growth.

A large number of other solutions containing larger amounts of nitrate, up to 80 ppm., were employed in this experiment. No beneficial effect from glycocoll was observed in any of the cultures; on the other hand, some slight reductions in growth in some of these solutions was noted, but there was no marked harmful effect.

Absorption of nutrient salts as affected by glycocoll

The absorption of nutrients from the various solutions was determined, as mentioned before, by analyzing the cultures for nitrates immediately at the end of each 3-day period, and the phosphate and potassium on a composite of the solutions from the four changes. The colorimetric methods for determining small

amounts of salts, as described in Bulletin 70 of the Bureau of Soils, were employed in this investigation.

Considering first the absorption of phosphate, the entire set of cultures containing no glycocoll absorbed 177.5 mg. of P_2O_5 , while the similar set of cultures with glycocoll absorbed 233 mg. The relative absorption of potash was somewhat similar. In the solutions without glycocoll, 613.7 mg. of K_2O was removed, while from the cultures with glycocoll 623.5 mg. was absorbed. With both phosphate and potash, the glycocoll cultures removed more than the normal cultures, which was to be expected, as the glycocoll cultures made a larger growth. However, the absorption of nitrate was less by the glycocoll than the normal cultures. The set of cultures containing no glycocoll removed 544.7 mg. NH_3 , and the cultures with glycocoll only 320.5 mg. NH_3 . The removal of less nitrate from solutions containing glycocoll is also contributing evidence that the plants use the glycocoll in building tissue, as it would use the nitrate in this particular function.

The effect of glycocoll seems to be the same as that of creatinine,¹⁰ creatine, histidine, arginine,¹¹ asparagine,¹² xanthine, hypoxanthine, and nucleic acid,¹³ all nitrogenous compounds and shown to be beneficial to growth, especially in the absence of any other form of nitrogen. These compounds replace the effect of nitrates on plants and are used as such by the plant.

In recent years it has been demonstrated that plants not only use nitrogen in the form of nitrates and ammonia, but that they can also use nitrogen in the form of complex organic compounds.¹⁴ The

¹⁰ SKINNER, J. J., Beneficial effect of creatinine and creatine on growth. *BOT. GAZ.* **54**:152. 1912.

¹¹ ———, Effect of histidine and arginine as soil constituents. *Eighth Internat. Cong. Applied Chem.* **15**:253. 1912.

¹² ———, and BEATTIE, J. H., Effect of asparagine on absorption and growth. *Bull. Torr. Bot. Club* **39**:429. 1912.

¹³ SCHREINER, O., and SKINNER, J. J., Experimental study of the effect of some nitrogenous soil constituents on growth. Nucleic acid and its decomposition products. *Plant World* **16**:45. 1913.

¹⁴ SCHREINER, O., Symposium on soils at the 1911 meeting of the A.A.A.S. *Science* **36**:577. 1912.

HUTCHINSON, H. B., and MILLER, N. H. J., The direct assimilation of inorganic and organic forms of nitrogen by higher plants. *Centralbl. Bakt.* **30**:513. 1911.

SCHREINER, O., and SKINNER, J. J., Nitrogenous soil constituents and their bearing on soil fertility. *Bull. 87. Bur. Soils, U.S. Dept. Agric.* 1912.

action of these and a number of other nitrogenous compounds has been tested in this laboratory, and it has been found that these compounds are used as a source of nitrogen for the plant, without any transformation into ammonia, nitrites, or nitrates, and that the plant absorbs and uses them in preference to nitrate.

Effect of methyl glyocoll

The effect of methyl glyocoll on growth was studied in a similar way as was glyocoll; that is, wheat plants were grown in nutrient culture solutions composed of fertilizer salts, used singly and in combination of two and three salts. The methyl glyocoll was used in the cultures in amounts of 50 ppm., the same concentration as in the glyocoll experiments. The composition of the 66 nutrient solutions used are given in table IV, together with the green weight of the plants, grown in the solutions without and with methyl glyocoll. The plants grew from January 14 to January 26; within this time the solutions were changed and replaced by fresh solutions of the same composition four times in 3-day periods.

By an examination of table IV it will be seen that the methyl glyocoll, unlike the glyocoll, caused a decrease in growth. This is true in the entire set of cultures except four. The total green weight of the 66 cultures containing nutrient salts, but no methyl glyocoll, was 128.03 grams; while the total green weight of the similar set of cultures containing methyl glyocoll was 99.3 grams, a reduction in growth of 33 per cent.

The root growth of the plants in the methyl glyocoll solutions was shorter and did not have as healthy an appearance as the roots of the plants in the solutions which contained only the nutrient salts.

The tops, aside from being lighter in weight, were abnormal in appearance. The tops did not stand upright, but were twisted and grew in a lateral direction. This was true of each culture in the entire set, regardless of its content of nutrient salts. These physiologically disturbed plants had a pale green color, in contrast to the dark green of the normal cultures. The effect of this substance resembles somewhat that of cumarin,¹⁵ which causes

¹⁵ SCHREINER, O., and SKINNER, J. J., The toxic action of organic compounds as modified by fertilizer salts. BOT. GAZ. 54:31. 1912.

TABLE IV

EFFECT OF METHYL GLYCOCOLL ON GROWTH OF WHEAT SEEDLINGS IN CULTURE SOLUTIONS OF CALCIUM ACID PHOSPHATE, SODIUM NITRATE, AND POTASSIUM SULPHATE

No.	COMPOSITION OF CULTURE SOLUTIONS			GREEN WEIGHT	
	P ₂ O ₅	NH ₃	K ₂ O	Without methyl glycoll	With 50 ppm. methyl glycoll
	ppm.	ppm.	ppm.	gm.	gm.
1.....	80	0	0	1.02	0.95
2.....	72	0	8	1.27	1.30
3.....	72	8	0	1.32	1.20
4.....	64	0	16	1.32	1.25
5.....	64	8	8	1.47	1.45
6.....	64	16	0	1.20	1.20
7.....	56	0	24	1.35	1.30
8.....	56	8	16	1.80	1.55
9.....	56	16	8	1.85	1.45
10.....	56	24	0	1.35	1.20
11.....	48	0	32	1.15	1.30
12.....	48	8	24	1.95	1.40
13.....	48	16	16	2.25	1.70
14.....	48	24	8	1.75	1.45
15.....	48	32	0	1.60	1.10
16.....	40	0	40	1.47	1.25
17.....	40	8	32	2.07	1.55
18.....	40	16	24	2.19	1.75
19.....	40	24	16	2.14	1.40
20.....	40	32	8	1.95	1.50
21.....	40	40	0	1.60	1.15
22.....	32	0	48	1.52	1.35
23.....	32	8	40	2.12	1.50
24.....	32	16	32	2.42	1.75
25.....	32	24	24	2.44	1.70
26.....	32	32	16	2.02	1.72
27.....	32	40	8	1.90	1.60
28.....	32	48	0	1.40	1.30
29.....	24	0	56	1.42	1.32
30.....	24	8	48	2.09	1.82
31.....	24	16	40	2.44	1.84
32.....	24	24	32	2.22	1.80
33.....	24	32	24	2.42	1.80
34.....	24	40	16	2.32	1.70
35.....	24	48	8	1.89	1.40
36.....	24	56	0	1.49	1.42
37.....	16	0	64	1.47	1.32
38.....	16	8	56	2.30	1.42
39.....	16	16	48	2.55	1.70
40.....	16	24	40	2.54	1.59
41.....	16	32	32	2.54	1.70
42.....	16	40	24	2.24	1.60
43.....	16	48	16	2.37	1.55
44.....	16	56	8	1.97	1.57
45.....	16	64	0	1.70	1.40
46.....	8	0	72	1.57	1.37
47.....	8	8	64	2.07	1.59

TABLE IV—*Continued*

No.	COMPOSITION OF CULTURE SOLUTIONS			GREEN WEIGHT	
	P ₂ O ₅	NH ₃	K ₂ O	Without methyl glyocoll	With 50 ppm. methyl glyocoll
	ppm.	ppm.	ppm.	gm.	gm.
48.....	8	16	56	2.34	1.89
49.....	8	24	48	2.54	1.70
50.....	8	32	40	2.90	1.70
51.....	8	40	32	2.42	1.65
52.....	8	48	24	2.45	1.60
53.....	8	56	16	2.22	1.70
54.....	8	64	8	2.32	1.70
55.....	8	72	0	1.52	1.45
56.....	0	0	80	1.32	1.43
57.....	0	8	72	1.95	1.45
58.....	0	16	64	2.29	1.50
59.....	0	24	56	2.27	1.55
60.....	0	32	48	2.30	1.65
61.....	0	40	40	2.25	1.65
62.....	0	48	32	2.20	1.67
63.....	0	56	24	2.32	1.67
64.....	0	64	16	1.96	1.50
65.....	0	72	8	1.76	1.40
66.....	0	80	0	1.35	1.28

distorted stems and produces broad twisted leaves. Cumarin, however, does not cause a pale green leaf when grown in similar nutrient solution as does the methyl glyocoll. A set of normal and methyl glyocoll cultures is shown in figs. 1 and 2. The characteristic action is distinctly shown in the plants in fig. 2; the leaves are twisted and broad, which is in striking contrast to the straight upright plants of the normal cultures in fig. 1.

In analyzing the green weight figures given in table IV, it is interesting to note that the methyl glyocoll has reduced growth more in some of the cultures than in others, which will be brought out in the tables that follow. A close examination shows that the reduction was most in those solutions which normally produce the largest growth; that is, the difference between the green weight of specific cultures of some compositions without and with methyl glyocoll is greater where the growth is greater in the solutions containing only the nutrient salts.

The 66 cultures given in table IV permit of better discussion when they are arranged according to the triangular scheme upon which their composition depends. This scheme has been fully



FIG. 1.—Wheat plants growing in nutrient solutions

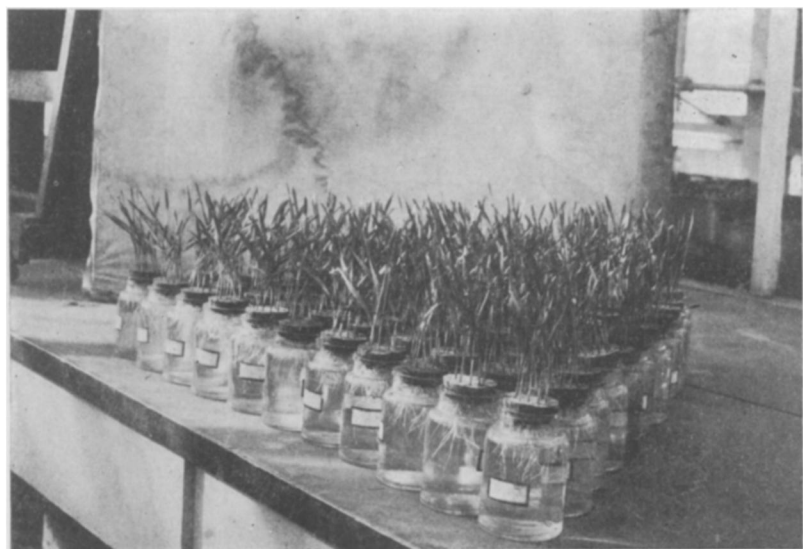


FIG. 2.—Wheat plants growing in nutrient solutions with 50 ppm. of methylglycine.

presented in an earlier paper¹⁶ and needs no further exposition here. As shown in this earlier paper, the maximum growth takes place in the middle region of the lower part of the diagram; that is, in those cultures which contain phosphate between the limits 8–24 ppm., and nitrate and potash between the limits 24–48 ppm. These are the cultures represented by group *a* in fig. 3, which is here

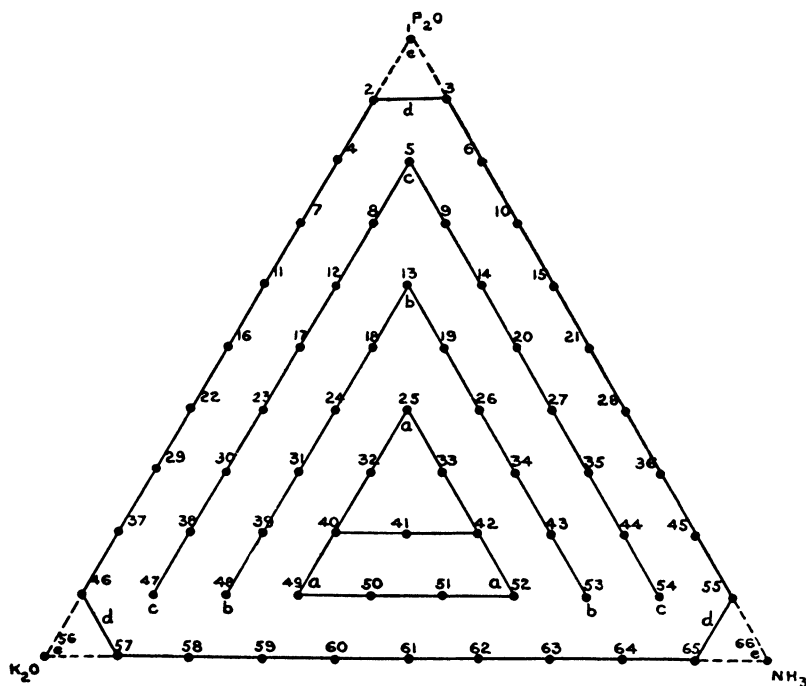


FIG. 3.—The arrangement of the culture solutions in groups: *a*, *b*, *c*, three fertilizer element groups; *d*, two fertilizer element group; *e*, one fertilizer element group.

again reproduced to make the discussion clear. It has been shown that this group *a* has the largest growth, and the greatest absorption of nutrients by the growing plants also takes place in this group. Both growth and absorption become less successively in groups *b*, *c*, and *d*. The latter group contains only two of the fertilizer elements in any one solution, and the growth in these is

¹⁶ SCHREINER, O., and SKINNER, J. J., Ratio of phosphate, nitrate, and potassium on absorption and growth. BOT. GAZ. 50:1. 1910.

considerably poorer than in those containing three of the fertilizer elements.

If we consider now the results of table IV in the light of these facts and in the same groupings, some interesting facts regarding the effect of the methyl glyocoll are revealed.

In table V are given the cultures of group *a*, which as a group normally produces the largest growth and the greatest absorption. The number of the culture is given in the first column; the third, fourth, and fifth columns give the composition of the solution; the sixth the green weight of plants grown in solution without methyl glyocoll; and the last column the green weight of plants with methyl glyocoll. There is considerable difference in growth in these two sets of cultures, as is seen in the table.

TABLE V

GROWTH OF WHEAT PLANTS IN THE BEST CULTURE SOLUTIONS OF GROUP *a* WITHOUT AND WITH METHYL GLYOCOLL

No.	COMPOSITION OF CULTURE SOLUTIONS			GREEN WEIGHT	
	P ₂ O ₅	NH ₃	K ₂ O	Without methyl glyocoll	With methyl glyocoll
	ppm.	ppm.	ppm.	gm.	gm.
25.....	32	24	24	2.44	1.70
33.....	24	24	32	2.22	1.80
34.....	24	32	24	2.42	1.80
40.....	16	24	40	2.54	1.59
41.....	16	32	32	2.54	1.70
42.....	16	40	24	2.24	1.60
49.....	8	24	48	2.54	1.70
50.....	8	32	40	2.90	1.70
51.....	8	40	32	2.42	1.65
52.....	8	48	24	2.45	1.60

The total green weight of the 10 cultures without methyl glyocoll was 24.71 grams, against 16.84 grams for the methyl glyocoll cultures, a reduction of 32 per cent. It is also interesting to compare the absorption of phosphate, nitrate, and potassium in these two sets of cultures. The 10 normal cultures absorbed 28.9 mg. of P₂O₅, NH₃, and K₂O, and the 10 cultures with the methyl glyocoll absorbed 20.8 mg. That is, the methyl glyocoll cultures absorbed 28 per cent less nutrients than the normal cultures.

We will next consider the solutions of group *b*, which contained more unequal ratios and which have previously proved to have a poorer physiological influence on plants as manifested by the growth. The composition of these solutions together with the green weights of the two sets of cultures is given in table VI.

TABLE VI

GROWTH OF WHEAT PLANTS IN CULTURE SOLUTIONS OF GROUP *b* WITHOUT AND WITH METHYL GLYCOCOLL

No.	COMPOSITION OF CULTURE SOLUTIONS			GREEN WEIGHT	
	P ₂ O ₅	NH ₃	K ₂ O	Without methyl glycoll	With methyl glycoll
	ppm.	ppm.	ppm.	gm.	gm.
13.....	48	16	16	2.25	1.70
18.....	40	16	24	2.19	1.75
19.....	40	24	16	2.14	1.40
24.....	32	16	32	2.42	1.75
26.....	32	32	16	2.02	1.72
31.....	24	16	40	2.44	1.84
34.....	24	40	16	2.32	1.70
39.....	16	16	48	2.55	1.70
43.....	16	48	16	2.37	1.55
48.....	8	16	56	2.34	1.89
53.....	8	56	16	2.22	1.70

The figures show that methyl glycoll produced less growth than the normal solutions. The green weight of the 11 normal cultures was 26.10 grams, against 18.70 grams total green weight for the methyl glycoll cultures, a reduction of 29 per cent due to the methyl glycoll. The 11 normal cultures absorbed 27.43 mg. of P₂O₅, NH₃, and K₂O, while the methyl glycoll cultures absorbed 19.45 mg., a reduction of 22 per cent in nutrients absorbed. It is interesting to note that methyl glycoll reduced both the growth and absorption less in these cultures of group *b* than in those of group *a* given in table V.

In table VII is given the effect of methyl glycoll in the solutions of group *c*, which have been shown to be not as suitable for plant development as those given in the two preceding tables.

The total green weight of the 15 cultures without methyl glycoll was 29.50 grams, and the total green weight of the same solutions containing methyl glycoll was 22.95 grams, a reduction

of 22 per cent in growth. The absorption of P_2O_5 , NH_3 , and K_2O from these solutions for the 15 normal cultures was 18.2 mg., against 15.5 mg. for the total number of cultures containing methyl glycoll, a reduction of 15 per cent. Again it is seen that in these cultures where absorption and growth is small the methyl glycoll is less harmful.

TABLE VII

GROWTH OF WHEAT PLANTS IN CULTURE SOLUTIONS OF GROUP *c* WITHOUT AND WITH METHYL GLYCOLL

No.	COMPOSITION OF CULTURE SOLUTIONS			GREEN WEIGHT	
	P_2O_5	NH_3	K_2O	Without methyl glycoll	With methyl glycoll
	ppm.	ppm.	ppm.	gm.	gm.
5.....	64	8	8	1.47	1.45
8.....	56	8	16	1.80	1.55
9.....	56	16	8	1.85	1.45
12.....	48	8	24	1.95	1.40
14.....	48	24	8	1.75	1.45
17.....	40	8	32	2.07	1.55
20.....	40	32	8	1.95	1.50
23.....	32	8	40	2.12	1.50
27.....	32	40	8	1.90	1.60
30.....	24	8	48	2.09	1.82
35.....	24	48	8	1.89	1.40
38.....	16	8	56	2.30	1.42
44.....	16	56	8	1.97	1.57
47.....	8	8	64	2.07	1.59
54.....	8	64	8	2.32	1.70

In table VIII are given the green weights of plants grown in solution containing only two nutrient salts (group *d*), with and without methyl glycoll. Solutions containing only two salts produce less growth than solutions containing three salts, in any proportion.

The total growth of the 27 cultures without methyl glycoll was 44.72 grams green weight, against 37.32 grams for the cultures with methyl glycoll, a reduction of only 16 per cent.

From tables V, VI, VII, and VIII it is apparent that growth was greatest in the cultures of group *a*, and that the greatest amount of absorption took place in these solutions. The harmful effect of methyl glycoll was also most marked in this group of solutions. A comparison of tables VI, VII, and VIII shows that those solutions

in which less absorption took place and less growth was produced, the effect of the organic compound was also less.

TABLE VIII

GROWTH OF WHEAT PLANTS IN CULTURE SOLUTIONS OF GROUP *d* COMPOSED OF TWO FERTILIZER ELEMENTS, WITHOUT AND WITH METHYL GLYCOCOLL

No.	COMPOSITION OF CULTURE SOLUTIONS			GREEN WEIGHT	
	P ₂ O ₅	NH ₃	K ₂ O	Without methyl glycoll	With methyl glycoll
	ppm.	ppm.	ppm.	gm.	gm.
2.....	72	0	8	1.27	1.30
4.....	64	0	16	1.32	1.25
7.....	56	0	24	1.35	1.30
11.....	48	0	32	1.15	1.30
16.....	40	0	40	1.47	1.25
22.....	32	0	48	1.52	1.35
29.....	24	0	56	1.42	1.32
37.....	16	0	64	1.47	1.32
46.....	8	0	72	1.57	1.37
57.....	0	8	72	1.95	1.45
58.....	0	16	64	2.29	1.50
59.....	0	24	56	2.27	1.55
60.....	0	32	48	2.30	1.65
61.....	0	40	40	2.25	1.65
62.....	0	48	32	2.20	1.67
63.....	0	56	24	2.32	1.67
64.....	0	64	16	1.96	1.50
65.....	0	72	8	1.76	1.40
55.....	8	72	0	1.52	1.45
45.....	16	64	0	1.70	1.40
36.....	24	56	0	1.49	1.42
28.....	32	48	0	1.40	1.30
21.....	40	40	0	1.60	1.15
15.....	48	32	0	1.60	1.10
10.....	56	24	0	1.35	1.20
6.....	64	16	0	1.20	1.20
3.....	72	8	0	1.32	1.20

In another experiment the wheat plants grew in solutions of glycoll and methyl glycoll, side by side at the same time, from February 22 to March 4. In this test only 11 different nutrient solutions were employed. One set of 11 cultures was used as a control; to each culture of the second set of 11 cultures 50 ppm. of glycoll was added, and to the third set methyl glycoll in the same amounts was added. The result of this test was very much the same as observed in the preceding experiments. The glycoll produced increased growth in those solutions which contained no

nitrate and in those which had a small amount of nitrate, but only a very small increase in the solutions which contained larger amounts of mineral nitrate. The methyl glycooll produced a stunted growth and a peculiar twisting and lateral growth of the top of the plant, as before noted. There was a 25 per cent decrease in growth from the control cultures.

Effect of calcium carbonate on the action of methyl glycooll

An experiment was made to study the effect of methyl glycooll under alkaline conditions. In this case 11 nutrient solutions were



FIG. 4.—Effect of glycooll and methyl glycooll on wheat plants in a nutrient solution containing 8 ppm. P_2O_5 , 22 ppm. NH_3 , and 48 ppm. K_2O ; no. 1, nutrient solution; no. 2, same with glycooll; no. 3, same with methyl glycooll and calcium carbonate.

used, as in the experiment just recorded; one set of 11 was used as a control; another set contained glycooll; and a third set methyl glycooll with calcium carbonate. The physiological effect of the methyl glycooll, in solutions with calcium carbonate, was the same as in the solutions already discussed. The effect of both the

glycocoll and methyl glycocoll is shown in fig. 4. The effect of the compounds was not materially different in the solutions of different composition. No. 1 is the control culture, no. 2 in addition to the nutrient salts contains 50 ppm. of glycocoll, and no. 3 contains 50 ppm. of methyl glycocoll with calcium carbonate. It will be observed that the plants in the glycocoll cultures are slightly larger than culture no. 1, the control. The characteristic effect of methyl glycocoll is shown in the third culture. The photograph shows the growth to be smaller and the stems twisted and leaves growing almost horizontally. The growth in the 11 cultures containing methyl glycocoll was 27 per cent less than in the control set, which shows that lime has not changed its physiological action.

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