A CONTRIBUTION TO THE DEVELOPMENT OF TESTS FOR THE BIO-DYNAMIC PREPARATIONS

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Introduction

The use of specifically treated substances, called preparations, is an integral part of bio-dynamic agricultural management. There are two groups of these preparations: two sprays which are used on soils and plants (500 and 501), and six specifically fermented herbs which are administered to manures and composts (502 - 507). The making of these substances and their ingredients are described in Rudolf Steiner's *Agriculture;* additional details can be found in the bio-dynamic literature. Beneficial effects of the preparations have been found both by practitioners and by field experiments. Research has also been done in greenhouse and laboratory studies to help us both to understand the preparations conceptually, and to achieve further insight into their modes of action.

A recent review by W. Goldstein (1979), of which only part had been previously published or is accessible, surveyed experimental work done with the preparations. Pioneer work done with the preparations by E. and L. Kolisko (republished in 1978) has recently become available once more. M. Kuenzel (1954) applied the preparations as seed baths to numerous crops. She reported generally positive effects on growth, including a stronger root development. F. Lippert (1944) worked with seed baths, foliar sprays, and soil sprays of the preparations and observed stimulatory effects, higher yields, and increases in nodulation of legumes following treatment with 507 (made from valerian flowers). To some extent, similar results were induced by 500 (cow manure) and 503 (camomile). Also morphological distortions caused by exposing plants to ethylene were alleviated or arrested by preparations 501 (quartz), 503, 504 (stinging nettle) and 507. E. Pfeiffer (1935,1941) observed both that the preparations influenced potato tuber respiration and that 501 or 507 enhanced the correction of induced disturbances of root geotropism. I. Voegele (1977) found that treatment of wheat with 500, 503, and 505 caused a somewhat voluminous and bulky morphology, and that 501, 506 (dandelion) and 507 produced a more slender and vertically oriented type of growth.

Biodynamics, issue 142, 1982

In the works mentioned so far, no statistical analysis of the data was carried out.

In experimental work with the effects of the preparations on manure, E. Pfeiffer (1941) observed effects on the growth of molds, and on the nutrient levels and smells of manure composts. With three separate series of experiments, H. Heinze and E. Breda (1962) found statistically significant increases of the cation exchange capacity of the organic matter in composts, following treatment with prepations. U. Abele (1976) applied preparations to liquid manure (slurry) and demonstrated significant effects of this treatment on yields, crop quality and botanical composition of leys. The preparations also appeared to significantly decrease ammonia volatilization from the manures. H. Koepf (1966) experimented with the effects of prepared and unprepared liquid manure on wheat seedlings. With treated as opposed to untreated material, there were significant positive effects on the length and dry weight of roots.

W. Goldstein carried out experiments with preparations from 1977 to 1979, utilizing techniques similar to those used by H. Koepf (1966). In the following report these experiments will be described; their objective was to contribute to a seedling bioassay for investigative work with bio-dynamic preparations and manures.

Materials and Methods

Wheat seedlings of the cultivars "Diplomat," "Absolvent," "Probus" (winter wheats), and "Adler" (spring wheat) were pre-germinated in petrie dishes and transplanted to nutrient solutions soon after emergence of the first root. The plants grew at room temperature for 7-9 days on suspended, level gauze surfaces over 250 ml glass containers. Complete nutrient or nutrient-deficient Knop or Hoagland solutions were used at 100% or reduced concentrations. For each experimental treatment, three replicate containers were used, with fifteen plants per container. The containers were placed in a growth chamber, 60 cm under nine, 1.5 m, 80 w, Phillips "Atlas" grow-lux lamps. The light cycle was 12 hours light, 12 hours dark.

Herbal preparations or manure extracts were added to the nutrient solutions. The substances were extracted by incubating a given level of the material in 200 ml of aqua dest. at 25-30°C for 12 hours. After filtration the solutions were brought back up to 200 ml and aliquots were taken from them.

Liquid manure used was a mixture of 20% cow manure with water. 20 mg of each preparation were added to 250 ml of the slurry. Three replicates of each treatment were made and pooled samples were taken after incubation for the growth experiments.

Also, composts were made on a laboratory scale out of a mixture of fresh cow manure and 7% by weight of sieved peat. Each compost weighed 250 g initially, and if treated with preparations it received 20 mg of each of the preparations 502-507. After six months of composting, pooled samples were taken from three replicates of each treatment.

Morphology, length, weight, etc. of roots and leaves of the seedlings were recorded. The standard deviation s was used to indicate the variability found between individual plants belonging to a treatment group. Otherwise, analysis of the data was with variance analysis (completely randomized design), utilizing a protected l.s.d. test for multiple comparisons. If a series had only two treatments, analysis was with a pooled t-test. Regression and correlation analysis were used when appropriate. Asterisks are employed in the presentation in the usual manner to show significance. Attention was focussed on the morphology of the plants; the measurements were intended to support visual assessments. Thus in the space available, only a fraction of the data gathered will be presented.

Results

1. Testing the nutrient solutions. As a first step, observations have been gathered on the growth of the wheat seedlings in different nutrient solutions.

Decreasing the concentration of a Knop nutrient solution makes roots grow in a more vertical fashion; the lengths of the first three seminal roots are increased, but the length of roots 2 and 3 are reduced relative to root 1 (see Table 1). Reducing the concentration leads to an increase in uniformity between individual plants for the length of any of the three initial seminal roots and to a reduction in the occurrence and length of side roots.

Plants grown in calcium-deficient Hoagland solutions had longer roots and a more vertical growth type than when they were grown in complete nutrient Hoagland solutions. Dropping the nutrient strength of the calcium-deficient solution to 50% increased the tendency towards vertical growth (see Table 2); in some cases the opposite tendency holds true for leaves.

TABLE 1

W. wheat "Diplomat" grown in Knop solutions of varying strength. Average lengths in mm followed by the standard errors.

Solution	*root 1*	*s*	*root 2*	*s*	*root 3*	*s*	*Sideroots*
60% Knop	60.1 ± 1.65	13.2	*62.7* ± 1.64	9.7	56.8 ± 1.58	10.7	0.7 ± 0.18
40% Knop	76.2 ± 2.34	10.3	70.2 ± 1.99	8.0	65.3 ± 1.88	7.8	1.7 ± 0.06
25% Knop	101.7 ± 1.77	5.7	85.9 ± 1.55	5.3	82.1 ± 1.28	4.9	0.2 ± 0.16

TABLE 2

Comparing the lengths of leaves and roots of w. wheat "Absolvent" in complete, 100% and 50% calcium-deficient Hoagland solutions. The numerical figure gives the difference A-B in mm. A > B means A was significantly longer than B.

Series	*Solution*	*Concentration*	*leaf 1*	*leaf 2*	*root 1*	*root 2*
1	Complete Ca-deficient	100% 100%	A_1 +5.76 B_1 A>B**	+7.27 A >B***	—16.44 B >A*	—14.46 B >A*
2	Ca-deficient Ca-deficient	100% 50%	A_2 +4.40 B_2 A>B*	+9.57 A >B***	—14.82 B >A*	—12.04 B >A***
3	Ca-deficient Ca-deficient	100% 50%	A_3 —10.0 B_3 B > A*	—9.04 B >A*	—23.28 B > A*	—17.99 B >A***

The results of twelve growth experiments can be summarized as follows: there basically exist two types of root development of a polar nature. These are shown in Diagram 1. Type 1 may be called horizontal; roots grow to become thick, short, and horizontal with long, thickly clustering root hairs. They often have curves and bends along their lengths and in extreme cases they loop. There is a large variation of root lengths between plants for any one of the first three seminal roots. The tap root (root 1) is often shorter than one or more of the other seminal roots. The growth of the second leaf is sometimes accelerated in its development. The leaf 1: root 1 ratio is high. The horizontal type is induced by high macronutrient levels. Raised calcium and nitrogen levels were found to be major agents inducing this development.

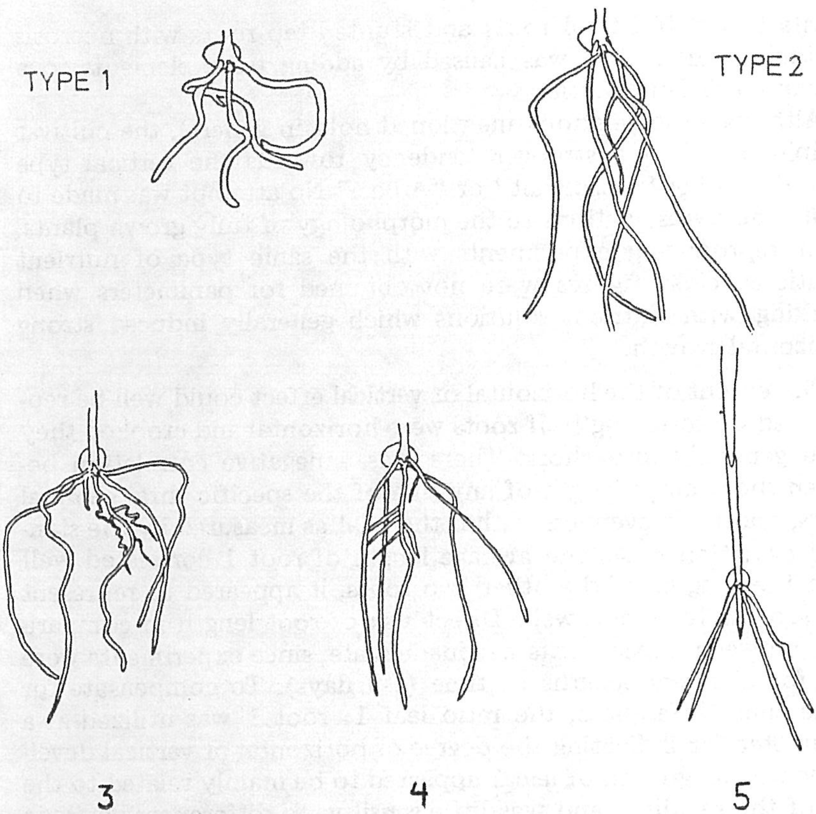

Diagram 1. Forms of wheat roots induced by different nutrient solutions; see text for explanation.

Type 2 may be called the vertical type. Roots grow to be long, slender and vertical. The lengths of the first three seminal roots of the plants in a trial show greater uniformity. Root hairs are more sparsely spaced along the roots. The formation of the second leaf is sometimes held back.

The vertical type was induced either by using lowered macronutrient levels, by using calcium or nitrogen-deficient solutions, or by adding trace elements and ferric citrate (in accordance with Bidwell, 1974). Number 3 and 4 in Diagram 1 show the roots of winter wheat in complete and nitrogen-deficient Hoagland solutions, respectively. Both had trace elements and ferric citrate added. Number 5 shows an extreme case of the vertical type.

Plants had stiff lateral roots and stunted tap roots with necrosis at their apices. This was caused by adding trace elements to a calcium-deficient solution.

Although the relations mentioned hold in general, the cultivar "Diplomat" had a stronger tendency towards the vertical type than did either "Absolvent" or "Adler." No attempt was made to relate these observations to the morphology of fully grown plants.

In reproducing experiments with the same type of nutrient solutions, close figures were not obtained for parameters when working with nutrient solutions which generally induced strong horizontal growth.

The extent of the horizontal or vertical effect could well be represented by root length. If roots were horizontal and crooked they were generally also short. There was a negative correlation between the average length of any one of the specific three seminal roots, and their evenness within the trial as measured by the standard deviation s. As the average length of root 1 correlated well with the lengths of the other two roots, it appeared to represent the growth tendency well. Direct use of root length in comparisons between experiments was inadequate, since experiments were run for different lengths of time (7-9 days). To compensate for these time differences, the ratio leaf 1: root 1 was utilized as a parameter for indicating the degree of horizontal or vertical development. The growth of leaf 1 appeared to be mainly related to the age of the seedlings and was little sensitive to differences between nutrient solutions relative to the roots. The leaf 1: root 1 ratio correlated (allometrically) with the average lengths of root 1 and root 2. All the correlations mentioned above were significant at the $\alpha = 1\%$ level.

2. Experiments with preparation 507 (valerian). When added at a rate of 0.1%, this preparation (which comes as a liquid) induced the vertical type of root development. The effect was relatively larger when the concentration of the nutrient solution favored the horizontal type as shown in Table 3. With few exceptions, the preparation induced less variability in the lengths of specified roots.

Similar trials with the cultivar "Absolvent" produced similar results only when calcium-deficient nutrient solutions were used (see Table 4). When grown in complete nutrient solutions, "Absolvent" showed a significant exception to the general 507 effect.

TABLE 3

W. wheat "Diplomat" grown in Knop nutrient solutions of different concentrations, with and without 0.1% preparation 507; no trace elements were added. Average lengths and standard errors are given in mm. Sideroots were graded on a developmental scale of 1-4. The standard deviation s values are given below for the different treatments.

Treatment	*Nutrient Solution Concentration*	*leaf 1*	*leaf 2*	*root 1*	*root 2*	*root 3*	*sideroots*
Control A_1	60%	112.8 ± 0.89	51.4 ± 1.53	60.6 ± 1.65	62.7 ± 1.64	59.1 ± 1.58	0.72 ± 0.18
+ 507 B_1	60%	120.0	55.4	98.4	86.4	83.0	2.72
signif. $B_1 > A_1$		***	—	***	***	***	***
Control A_2	40%	124.8 ± 1.76	58.3 ± 1.25	76.2 ± 2.32	70.2 ± 1.49	65.3 ± 1.88	1.70 ± 0.06
+ 507 B_2	40%	131.9	65.7	104.8	92.4	89.4	3.0
signif. $B_2 > A_2$		*	*	***	***	***	***
Control A_3	25%	101.4 ± 1.16	40.8 ± 0.55	101.7 ± 1.77	85.9 ± 1.55	82.0 ± 1.28	0.17 ± 0.16
+ 507 B_3	25%	111.7	49.4	99.8	87.6	84.6	0.22 ± 1.16
signif. $B_3 > A_3$		***	***	—	—	—	—
Standard A_1		6.65	5.24	13.21	9.27	10.69	0.58
Deviation B_1		4.99	7.06	5.60	4.69	5.71	0.63
s values A_2		8.36	7.58	10.30	8.02	7.78	1.00
B_2		7.54	7.60	5.31	5.55	6.49	0.57
A_3		5.79	5.53	5.72	5.28	4.89	0.44
B_3		4.94	5.35	7.35	4.56	5.25	0.35

Nine trials with "Absolvent" seedlings grown in calcium-deficient solutions, and "Diplomat" seedlings grown in calcium-deficient and complete nutrient solutions, for 7 to 8 days with or without the addition of 0.1% 507, revealed the general 507 effect well. Diagram 2 shows the association between the leaf 1: root 1 ratios induced by the control and the corresponding ratios induced by the 507. When the leaf 1: root 1 ratio for the control is 1, then the ratio expected for the 507 is 1, and there is no 507 effect. The corrective effect of the 507, in inducing a more vertical type, constantly increased as the control groups became more horizontal. Thus, the effect of the 507 can be measured as the ratio: $\frac{\text{leaf 1: root 1 507}}{\text{leaf 1: root 1 control}}$; as the ratio decreases, the 507 effect increases.

TABLE 4

W. wheat "Absolvent" grown in complete and calcium-deficient Hoagland solutions, with and without addition of 0.1% preparation 507. Lengths and standard error terms are given in mm.

Treatment	*Solution*	*leaf 1*	*leaf 2*	*root 1*	*root 2*
Control A	Complete	132.0 ± 1.39	97.0 ± 1.21	35.2 ± 5.06	37.2 ± 4.82
+ 507 B	Complete	139.6	100.6	37.8	39.7
Control C	Ca-deficient	126.3	86.7	51.6	51.7
+ 507 D	Ca-deficient	130.6	91.6	67.9	71.7
Difference and significance level		A>C** B>A** B>D***	D>C* B>A* A>C*** B>D***	D>C* C>A* D>B***	C>A* D>C** D>B**

Consequent to the diagram it would follow that if a nutrient solution should produce short leaves and long roots (i.e., a leaf 1: root 1 ratio less than 1), the 507 would shorten the roots and bring the ratio back to 1. It was indeed observed that when plants were grown in distilled water, a very low ratio was induced and that 507 application increased the ratio by decreasing the root length.

Increasing the application rate of 507 to 1% further accentuated the vertical growth type, under conditions where the nutrient solution gave an extremely horizontal character to the growth of

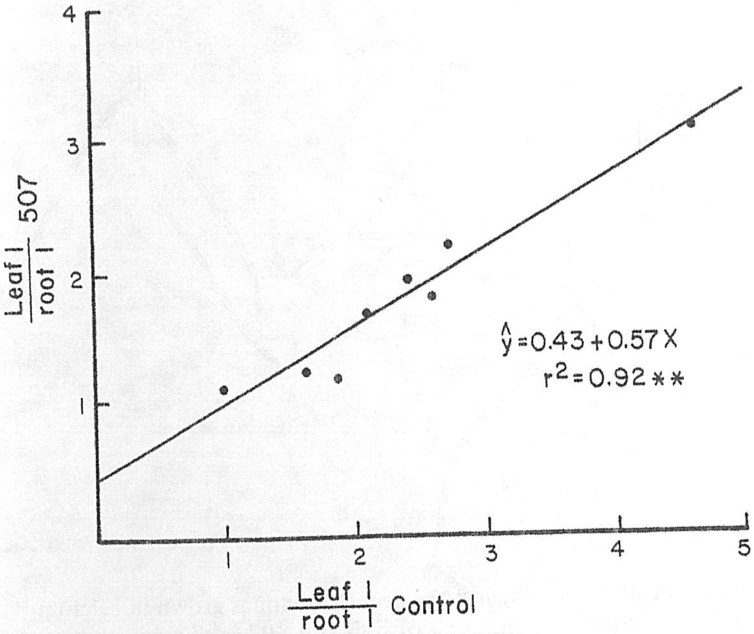

Diagram 2. Association between the leaf 1/root 1 ratios induced by the control solutions and the corresponding 507 treatments.

the control. In this case seminal roots 4 and 5 grew considerably longer than the control.

3. *Combining preparations 505 (oak bark) and 507.* Five different series were run with "Absolvent" seedlings grown in calcium-deficient Hoagland solutions with and without aqueous extracts of preparation 505. This preparation induced the very horizontal type of growth associated with calcium and raised macronutrient levels. The roots sometimes took on a somewhat woody character relative to the control, having organish-brown color splotches and an enhanced stiffness. In these series, plants were also treated with combinations of 505 plus 507. In order not to load this report with too many figures, the results are summarized in Diagram 3. The drawings shown are born out by mostly significant differences in length of roots and leaves.

Generally, as the 507 effect became more intense, the horizontal effect from the combination of 505 plus 507 became more intense, i.e., the 507 effect was counteracted and growth was led back into a more horizontal development.

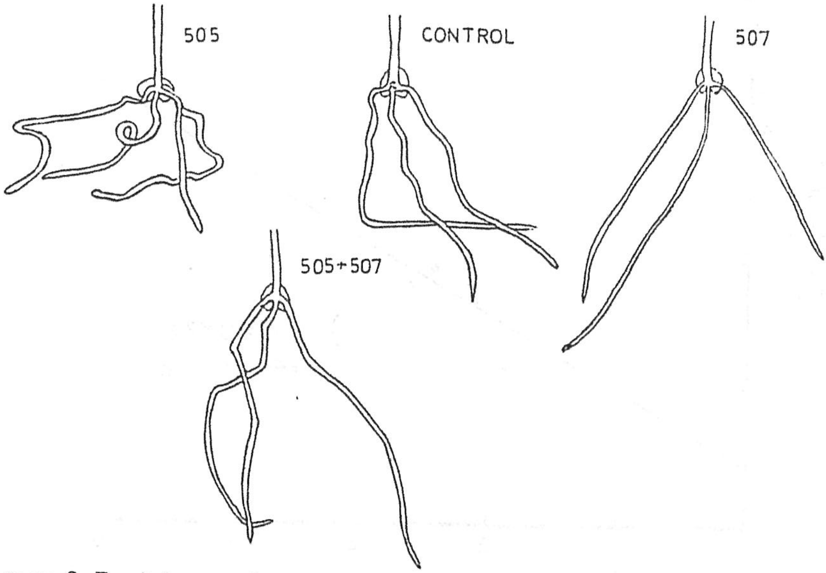

Diagram 3. Root forms of w. wheat "Absolvent" seedlings grown in calcium-deficient Hoagland solutions. Additions of 505 and 507, alone and in combination.

Previously, the 507 effect relative to the control was represented as the ratio of ratios: $\frac{\text{leaf 1: root 1 507}}{\text{leaf 1: root 1 control}}$; thus, as the 507 effect increased, the ratio decreased. Similarly the 505 + 507 effect relative to the 507 can be represented by the ratio of ratios: $\frac{\text{leaf 1: root 1 505 + 507}}{\text{leaf 1: root 1 507}}$; as the horizontal effect of the 505 in the combination increases, the ratio increases. Regression with x equal to the 507 effect and y equal to the 505 + 507 effect revealed a negative relationship between the two effects represented by the equation $\hat{y} = 3.29 - 2.91x$, with $r^2 = 0.865$.*

A rather dynamic interplay between the two preparations appears to exist. Inspection of the data and the linear relationship showed that when the intensity of the 507 effect was low because the control showed a more vertical type of growth anyway (control leaf 1/root 1 ≤ ca. 1.55), then the 505 + 507 combination would stimulate root growth in a vertical fashion. Thus, the oak bark appears to antagonize the valerian effect in two ways: by inhibiting it if it is intense or by stimulating it if it is naturally low.

4. *Preparation 503 (camomile) and 507.* Two samples of preparation 503 were available: a two-year-old, well-decomposed sample (0) and a new sample (N), used shortly after the fermentation in the ground was completed. Although 0-503 had no significant effects on "Absolvent" seedling roots, N-503 increased root 1 length 33% over a complete Hoagland solution control in one trial. In three trials with complete, 50% and 100% calcium-deficient solutions, the combinations of N-503 and 507 led to an increase of root length over the 507 (Table 5).

TABLE 5

Effects of preparation 507 and N-503 + 507 on the length of leaves and roots of wheat "Absolvent" grown in 50% Ca-deficient Hoagland solutions. Lengths and standard errors are given in mm.

Treatment		*leaf 1*	*leaf 2*	*root 1*	*root 2*
Control	A	139.1 ± 1.50	105.6 ± 2.60	51.1 ± 1.65	52.3 ± 2.80
+ 0.1% 507	B	141.1	106.2	72.5	79.0
+ 0.1% 507 + N503	C	145.4	116.6	97.5	93.3
Difference and significance level		C>A*	C>A** C>B*	B>A*** C>A*** C>B***	B>A*** C>A*** C>B***

Also, the effect of calcium-containing solutions inhibiting the expression of the vertical effect of 507 on "Absolvent" seedlings was lifted by the combination of N-503 and 507, but not by the combination of 0-503 and 507.

Although there appears to be an enhanced 507 effect with the N-503 + 507 combination, further tests are required with 503 preparations to better characterize the effect. The above results appear to indicate differences in quality between different 503 samples.

5. *Preparation 500 (horn manure).* Some tests were carried out with preparation 500, which is a cow manure that has undergone a fermentation process. As is shown in Table 7, the wheat variety "Probus" responded to increasing applications of 500 with corre-

sponding elongation of roots. As manure is known to contain appreciable auxin levels, this result is not unexpected, although it is not necessarily caused by auxins. When seedlings of the variety "Absolvent" were used in tests, significant effects similar to those shown in Table 7 were achieved only when calcium-deficient nutrient solutions were utilized. The increases in length following the addition of 100 ppm of preparation, in percent of the control groups, were as shown in Table 6.

TABLE 6

	in complete Hoagland solution	*in calcium-deficient Hoagland solution*
leaf 1	—	+ 2.3*
leaf 2	+ 4.6%	+ 11.9%***
root 1	+ 2.3%	+ 35.3%***
root 2	+ 7.7%	+ 20.1%**

6. *Liquid manure.* Five series of growth experiments were carried out with liquid manure. Treatments included applications of 0.01-1% liquid manure; manures with and without preparations 502-507; with and without trace elements; and in complete and nitrogen-deficient nutrient solutions.

Liquid manures induced a strongly horizontal type of root growth. The root growth between plants was very non-uniform, the roots tended to bend and curve, and root hairs were long and clustered. The roots also tended to be shorter than those of their control groups. The addition of trace elements could partially correct these effects. Diagram 4 shows the root development induced by liquid manure with and without preparations. Although an increased vertical effect due to the preparations was common in the experiments comparing liquid manures, preparations did not always result in significant differences in root lengths.

7. *Compost.* Under one-sided, high-macronutrient-level conditions, compost additions balanced out the horizontal growth tendency (see Table 8). These results are reminiscent of the trace element effects shown in Diagram 1. Compost-grown plants have, however, a more vigorous leaf growth and a more greatly enhanced sideroot development than do the plants which have received trace elements.

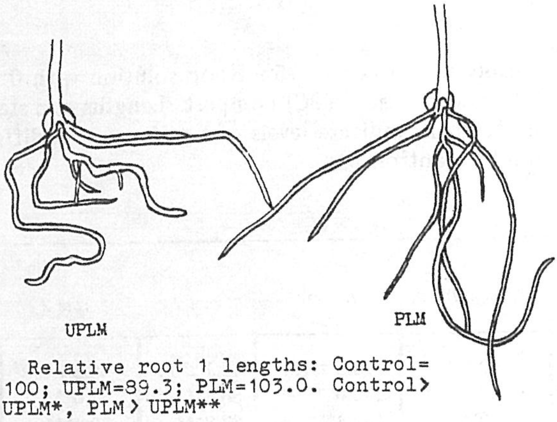

Diagram 4. Root forms of w. wheat "Absolvent" seedlings grown in 75% Knop solutions plus trace elements and ferric citrate. 0.1% additions of un-prepared (UPLM) and prepared (PLM) liquid manure.

On the other hand, when "Absolvent" seedlings were grown in complete Hoagland solutions to which trace elements had been added, then the prepared compost effected a more horizontal type of growth. Plants grown in nitrogen-deficient solutions showed the opposite influences of un-prepared and prepared composts (see Table 9).

These data seem to indicate that compost can either induce more of the horizontal or more of the vertical type of root growth, and that the direction of the influence depends on the nutrient milieu and is affected by the preparations. Compost seems to act as a

TABLE 7

W. wheat "Probus" grown in Knop solution with different levels of preparation 500. Lengths and standard errors are given in mm. Asterisks indicate levels of significance of differences between treatments and the control.

Treatment	*leaf 1*	*root 1*	*root 2*	*root 3*
Control	101.8 ± 1.80	78.8 ± 1.71	72.5 ± 1.31	64.2 ± 1.75
1.17 ppm 500	96.5	78.1	68.9	58.4*
11.7 ppm 500	98.0	85.0*	76.1	66.7
117 ppm 500	97.8	100.7***	87.6***	80.2***

TABLE 8

W. wheat "Absolvent" grown in 75% Knop solution with 0.1% levels of unprepared (UPC) and prepared (PC) compost. Lengths and standard errors are given in mm. Asterisks indicate levels of significance of differences between treatments and the control.

Treatment	*leaf 1*	*leaf 2*	*root 1*	*root 2*	*mg dry matter per plant*
Control	143.9 ± 1.3	115.2 ± 1.8	42.1 ± 3.5	36.5 ± 2.8	35.0
UPC	154.2***	135.0***	58.3**	67.0***	33.9
PC	149.9**	139.4***	67.8***	70.3***	36.0

mediative, balancing agent. More experiments are necessary to gain a more complete understanding of these complex relationships.

Discussion

As only three of the six compost preparations were included in these growth tests, further work will have to be carried out with the other preparations (yarrow, stinging nettle, and dandelion) to complete the picture.

In Rudolf Steiner's agriculture lectures, these preparations are recommended for application to manures and composts. Treatment of manures with the preparations is intended to stimulate certain processes in the crop plants which receive the manures. The eventual effects of the oak bark and valerian preparations are associated with the effects of two elements on plants: oak bark with calcium and valerian with phosphorus. Oak bark is used because in it calcium is used which "remains within the realm of life;" valerian is used because it will stimulate in manure "the right way to what we call the 'phosphoric' substance." As calcium and phosphorus are essential for all plant life, it can be assumed that processes corresponding to them are present in every plant. However, according to Steiner, the plants used for the preparations use elements in an exemplary way and the preparations are meant to stimulate the right relationship of the crop plant to these elements.

The horizontal type of root growth is induced by calcium and high levels of other salts in the nutrient solutions. It is also in-

TABLE 9

W. wheat "Absolvent" grown in 75% complete or nitrogen-deficient Hoagland solutions with trace elements and iron and 0.1% levels of unprepared (UPC) and prepared (PC) composts. Lengths and standard errors are given in mm. Sideroots are graded on a point system according to development.

Treatment	*Solution*		*leaf 1*	*leaf 2*	*root 1*	*root 2*	*sideroots*
Control	Complete	A	154.7 ± 4.1	180.4 ± 3.2	53.8 ± 5.2	60.7 ± 3.0	2.3 ± 0.4
UPC	Complete	B	159.4	141.6	81.1	90.1	3.6
PC	Complete	C	158.7	186.8	58.8	85.6	5.0
Control	N-deficient	D	150.3	127.4	55.5	50.6	1.9
UPC	N-deficient	E	167.1	192.2	57.1	86.7	4.8
PC	N-deficient	F	154.3	155.9	82.7	91.6	6.2

	leaf 2	*root 1*	*root 2*	*sideroots*
Differences with levels of significance	A>D***, C>B***, A>B*** C>F***, E>B***, E>D*** E>F***, F>D***	B>A**, B>C** B>E**, F>E** F>C**	A>D*, B>A***, C>A*** E>D***, F>D***	B>A*, C>B*, F>E* C>A***, E>D***, F>D***

duced by the oak bark preparation 505. According to E. Pfeiffer (1941), the preparation 505 contains about 10 percent calcium with 0.1 percent solubility. At the 100 ppm levels of 505 used in the nutrient solution experiments, one could assume 0.01 ppm of levels of calcium provided by the oak bark. Despite this, the preparation has been shown to exhibit a strong calcium-like effect. Likewise, according to Pfeiffer's analysis, the preparation 507 would supply only minute quantities of phosphorus to a nutrient solution which contains phosphorus anyway. Although the oak bark preparation was found by Pfeiffer to contain relatively high levels of numerous trace elements, the valerian preparation was found to contain only trace amounts of one element (manganese). These results suggest that the preparation effects on plants, demonstrated above, are not due simply to the minerals in the preparations added.

The two main tendencies of root growth reported on here are a straight-forward example of two formative processes which can be found in many variations in the plant kingdom. Primarily it is a characteristic of each plant species as to whether its roots grow downwards in an elongated fashion, or in all directions, in a horizontal, oblique, and downwards manner. Though in these experiments a wide range of tendencies appeared in the seminal roots of one species, it seems that the vertical root type better represents what is specific for the species wheat then does the horizontal type, and that the valerian encourages the species-specific growth type with its "phosphoric" effect. Thus, the valerian appeared to work to balance the leaf 1 to root 1 length ratio of 1.

Effects similar to those caused by valerian can be caused by adding trace elements to macronutrient-containing solutions. These effects of trace elements fall in line with some concepts suggested recently by Koepf (1980). The mineral elements — alkalis, alkaline earths, and trace elements — have different roles in biological processes. These substances have roles in producing organic substances (C, H, O, N, S compounds), or in organization, and in fashioning form. The trace elements have their role largely in the processes of organization and fashioning form.

The polarity between calcium and other salts on the one hand, and "phosphoric" substances on the other, has been explained by R. Steiner in another context. In his series of lectures called *Spiritual Science and Medicine* (1937), he says "all the forces inherent in phosphorus, e.g., are polar opposites to those in carbonate of calcium," and "Here you have, in external nature, two states which are polar to one another; that which acts in a saline manner and that which acts in a phosphoric manner." In the above-described experiments, this polarity appeared to manifest itself clearly in root growth as the polarity between calcium and trace elements, or oak bark and valerian. It is a major tenet of the bio-dynamic philosophy that in the polarity of what are called cosmic and terrestrial forces, lime and nitrogen are carriers of the terrestrial forces, and trace elements, silica, sulfur and phosphorus are carriers of the so-called cosmic forces.

Some preliminary experiments were made with manures. The type of root growth produced by calcium and higher levels of salts is also produced by liquid manure. Here it is possible that readily available nitrogen has played a major role. However, the effect of composts in experiments seemed to vary according to whether the nutrient solution would by itself produce the one or the other type of growth. Compost appeared to have a potentially mediative, balancing effect on plant response to nutrients, and seemed to mediate between the two polar growth types. Here more work is necessary to clarify the relationships. Without more data, it also remains an open question as to how the findings with preparation 500 relate to the other results with manures; e.g. whether preparation 500 might have a liquid-manure-like effect, perhaps related to its release of nitrogen, or whether it will have an effect like a well-made compost. More work is necessary to gain a complete picture.

This work has been possible through financial help from Michael J. Scully, Buffalo, Illinois, USA, and the Rudolf Steiner Foundation for Scientific Research, Stuttgart and Nürnberg. Germany.

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