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THE EFFECT OF VARIOUS CHELATES AND CHELATED CATIONS ON THE

AVAILABILITY OF PHOSPHORUS TO TOMATO PLANTS

by

Edgar Dale DeRemer

A thesis submitted in partial fulfillment
of the requirements for the degree

of

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in

Soil Chemistry

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INTRODUCTION

Shortly after the discovery of the usefulness of chelating compounds by agriculturists, whereby metallic cations are supplied in available form to plants, another use was proposed. This paper is dedicated to this resulting use, namely, that certain chelates appear to have value in keeping phosphate compounds from becoming "fixed" or "tied-up" in the soil.

Phosphorus, an important macro-nutrient, is found to be deficient in many of our mineral soils. It is often the first nutrient to become deficient when a soil is brought into cultivation. In some soils this is remedied by applications of phosphate fertilizer. However, many other soils have the ability to fix phosphorus, thus rendering residual and applied phosphorus unavailable for plant use.

There is one other known process which can complicate the method whereby the plant obtains phosphorus; that is the rendering of phosphorus unavailable within the plant's translocation system by precipitation with certain cations. This is a problem which has been recognized only within the last few years and which has not been extensively studied.

The objectives of this work were fourfold:

1. To study the effects of various chelates on the availability of phosphorus.

2. To study the effects of various common soil cations in the chelated form on the availability of phosphorus.

3. To determine whether the results obtained in connection with sand culture studies could be applied to a study using phosphorus deficient soils.

4. To study the mechanism by which plants absorb chelated cations.

LITERATURE REVIEW

"There is some evidence that certain chelating compounds may have value in maintaining fertilizer phosphorus in a more highly available state in the soil." This statement by Bear (1955) caused the author to become interested in this subject. This led to an initial study on the subject (DeRemer, 1957) where several unavailable forms of phosphorus were used, with chelate[1] applied, to determine if the chelate was able to render the phosphorus available to plants. The chelate apparently rendered phosphorus available, but the phosphorus appeared to be precipitated in the plant by excess iron, also supplied by the chelate.

Biddulph (1951) has shown that ferric phosphate was precipitated in plants by an excess of either iron or phosphate ions, or by a critical removal of water, which would increase the concentration of the reactants. This precipitation of ferric phosphate in the plant also apparently inhibits further uptake of iron and phosphorus.

Rediske and Biddulph (1953) found that the greatest mobility of iron within the plant occurred in nutrient cultures at low pH, low phosphorus, and low iron, indicating that with an excess of one ion precipitation occurs. DeKock (1955) and Olsen (1935) also found ferric phosphate as a precipitate in the plant.

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[1] An organic compound capable of supplying certain cations to the plant while keeping these cations from reacting to form insoluble compounds in the soil by surrounding them with a complex ring structure which causes the cation to lose its chemical identity.

Haertl (1957) showed that certain chelates were able to release iron and phosphorus to plants from insoluble ferric phosphate. His autoradiographs, however, showed phosphorus in greater concentrations in the veins of the leaf, indicating precipitation there. His work also indicated that certain chelates increased the solubility of iron, phosphorus, manganese and zinc found in fertilizers. He concluded that insoluble metallic salts can definitely be solubilized through the action of a chelating agent.

DeRemer (1957) found that acid Versenol, when placed in a water solution containing $FePO_4$, was able to chelate some of the iron, leaving part of the phosphate in a soluble form.

Lunt et al. (1958) found in a split medium experiment in which iron and phosphorus were not in direct contact that only 0.09 ppm. of phosphorus in a nutrient solution caused chlorosis in PI soybeans, which indicated an internal interaction of phosphorus with iron.

In the soil, phosphorus deficiency takes two forms, the first being the actual absence of the element from the soil. Phosphorus may not be present in the soil in sufficient quantities to sustain continued cropping. The second form of deficiency, which is actually a fixation, occurs when the phosphate anion unites with certain cations to form insoluble inorganic compounds. Common inorganic phosphate compounds found in the soil would include ferric, calcium, aluminum, and zinc phosphates. This action can also cause a reduction in the availability of phosphate, in the plant as well as the soil, by reaction with these soil cations.

PRELIMINARY EXPERIMENT

Methods

The first experiment was designed primarily to test plant response
to the greenhouse environment and to determine if previous results
(DeRemer, 1957) could be duplicated in this more northerly environment.

In order to study the effects of chelate on the availability of
phosphorus, two unavailable forms of phosphorus were used with chelates
added. This was done to determine if the chelates were able to render
this insoluble phosphate available to plants.

Marglobe tomatoes were grown in a sand culture using acid washed
white Monterey sand. The containers were two gallon glazed crocks
which had drain holes in the bottom. The nutrient solution was a modi-
fication of Hoagland's #1 full strength solution (1950). This modifi-
cation contained no phosphorus or iron (table 1).

The phosphorus, in the forms $AlPO_4$ and $Ca_3(PO_4)_2$, was added at the
rate of 150 pounds P_2O_5 per acre and was mixed with the sand prior to
planting.

The chelates used were Versenol[1] and Chel 138[2]. Versenol was
chosen because it would supply a comparison to previous work (DeRemer,
1957). Chel 138 was chosen because it had shown great ability to
alleviate iron chlorosis in highly calcareous soils and was a "stronger"

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[1]Versenol is the trade name for the sodium salt of hydroxyethyl-
ethylenediaminetetraacetic acid. This material was obtained from
Bersworth Chemical Company, Farmingham, Massachusetts.

[2]Chel 138, composition classified, was supplied by the Giegy
Chemical Corporation, New York.

Table 1. Composition of the nutrient solution

Stock solution number	Compound in stock solution	Ml. stock solution per liter of nutrient solution	Ion concentration in ppm. in the nutrient solution
			ppm.
1	M. KNO_3	6	NO_3 : 868
2	M. $Ca(NO_3)_2$	4	K : 234
3	M. $MgSO_4$	2	Ca : 160
4	.0466 M. H_3BO_3	0.5	B : 2.5
			Mg : 48.6
			S : 192

Minor element stock solution[a]		
Compound	Gm. compound per liter of stock solution	Ion concentration in ppm. in the nutrient solution
		ppm.
$MnCl_2 \cdot 4H_2O$	1.81	Mn : 0.5
$ZnSO_4 \cdot 7H_2O$	0.22	Zn : 0.05
$CuSO_4 \cdot 5\ H_2O$	0.08	Cu : 0.02
$H_2MoO_4 \cdot H_2O$	0.02	Mo : 0.01

[a]A supplementary stock solution which will supply manganese, zinc, copper, and molybdenum. One ml. of this solution is added to one liter of the nutrient solution.

chelate than Versenol. Both chelates were used in two forms, as the iron chelate and as the acid form, and were initially added at the rate of 1 ppm. iron or equivalent. The experimental design was a 2 x 4 factorial with three replications.

The seeds were planted January 14 and seedlings transplanted February 1. Chelate treatments were applied three days later, giving the plants time to recover from transplanting before treatment was initiated. The plants were harvested March 23, 1958, and then dried and weighed. The results were analyzed statistically. pH was checked periodically and found to range between 7.2 to 7.5 for all treatments.

Results

Seven weeks after treatment application, the tomato plants were harvested, dried in a forced air drier at 75° F., and weighed. The plant weights, with their corresponding treatments, appear in table 2.

Table 2. Tomato plant top weight in preliminary experiment

Treatment		Replications			
Phosphate	Chelate[a]	1	2	3	Mean
		grams per pot			
A. AlPO$_4$	Fe V-ol	4.32	3.53	6.71	4.85
B. "	Fe 138	3.10	11.55	8.18	5.71
C. "	H V-ol	2.80	4.89	10.51	6.07
D. "	H 138	11.24	8.56	9.85	9.88
E. Ca$_3$(PO$_4$)$_2$	Fe V-ol	4.35	5.56	11.00	6.97
F. "	Fe 138	8.01	7.42	10.24	8.56
G. "	H V-ol	3.91	5.86	9.99	6.59
H. "	H 138	10.29	6.71	9.53	8.84
L. S. D. (.05)					1.30

[a]V-ol = Versenol; 138 = Chel 138.

These results were analyzed statistically to determine effects of treatment, type of chelate, type of phosphorus, and type of chelated

cation. Table 3 is the table of analysis of variance.

Table 3. Analysis of variance in preliminary experiment

Source	df.	Sum of sqs.	Mean sq.	F.	Sig.
Total	23	189.186			
Treatments	7	56.215	8.031	1.427	(.40)
Phosphorus	1	2.425	2.425	0.431	(n.s.)
Chelate	1	40.626	40.626	7.221	(.02)
Cation	1	4.309	4.309	0.766	(n.s.)
Replications	2	54.212	27.016	4.818	(.03)
Error	14	78.759	5.626		

Coefficient of variation--31.28 percent

The statistics show that there were not sufficient replications to detect a definite difference between treatments. The variation in this experiment conducted in February-March is nearly double that of the sand culture experiment done in June-July.

However, the experiment did reveal certain trends. First, the Chel 138 increased plant growth much more than did Versenol. Second, in the $AlPO_4$ treatment the acid form of both chelates increased plant growth more than the chelated iron.

Except for phosphorus deficiency, there were no apparent deficiencies or toxicities shown by the plants. Therefore, it was decided to continue to use the same nutrient solution and culture methods on the next, more extensive experiment.

Discussion

This preliminary experiment served very well the purpose for which it was designed. The trend of the experiment closely duplicated results from previous experiments done in California. However, this experiment showed that winter experiments in the greenhouse in this more northerly

location were not to be preferred without adequate provisions for light
and temperature. Plant growth was so slow that phosphorus was appar-
ently supplied fast enough to provide the plant with sufficient phos-
phorus even from the less soluble salts.

It was also noticed that Chel 138 increased plant growth much more
than Versenol did. In the field, it has been observed that Chel 138 is
a much more effective chelate than Versenol. Also, in the $AlPO_4$ treat-
ment, the acid chelates produced better growth than did the iron
chelates. The reason for this is brough out in the discussion regarding
the sand culture experiment.

SAND CULTURE EXPERIMENT

Methods

Upon completion of the preliminary experiment, it was believed that differences could be measured between treatments with a sand culture experiment, using four replications and four plants per pot. Therefore, a more extensive experiment was planned. This second experiment made use of the same nutrient solution and two unavailable forms of phosphorus--$FePO_4 \cdot 2H_2O$ and $AlPO_4$, both of which we might expect to find in the soil. $FePO_4$ was chosen instead of the $Ca_3(PO_4)_2$ which was used in the preliminary experiment. Because of its much lower solubility, the $FePO_4$ would tend to supply less soluble phosphorus to the plants. The phosphates were added to the sand at the same rate as in the previous experiment. Two chelates were again used: Versenol, as chelated to iron, zinc, manganese, and as the acid form; and Chel 330[1] as chelated to iron, zinc and as the acid form. Chel 330 was chosen for this experiment instead of Chel 138 due to the facts that it is commercially available and is available as the chelate of the above listed cations. The reasons for the choice of these cations, as chelated, is enlarged upon in the discussion. These chelates were also added at the initial rate of one ppm. iron or equivalent. For clarity, the sixteen treatments are listed below:

    1. $FePO_4$--no chelate (check)
    2.   "   --Fe Versenol
    3.   "   --Zn Versenol

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[1]Chel 330 acid is diethylenetriaminepentaacetic acid, sold under the trade name of Sequesterene 330. Material used was obtained from the Giegy Chemical Corporation, New York.

4. FePO$_4$ --Mn Versenol
5.   " --Acid Versenol
6.   " --Fe Chel 330
7.   " --Zn Chel 330
8.   " --Acid Chel 330
9. AlPO$_4$ --no chelate
10.   " --Fe Versenol
11.   " --Zn Versenol
12.   " --Mn Versenol
13   " --Acid Versenol
14   " --Fe Chel 330
15.   " --Zn Chel 330
16.   " --Acid Chel 330

Marglobe tomatoes were again cultivated using the same methods as with the preliminary experiment. However, one gallon glazed crocks were used rather than the two gallon size. The plants were grown for a period of eight weeks, from April 26th to June 24th, then harvested, dried, and weighed.

After the plants were weighed, they were **wet ashed**, using a modification of the method of Piper (1950), using sulfuric, nitric and perchloric acids. Samples were then analyzed for iron, using a modification of Jackson's method (1958), using ortho-phenanthroline. Phosphorus was determined by the method set forth in the U.S.D.A. Handbook #60 (1954).

Results

In table 4 are listed plant top weights for each treatment and replication and their means. Analysis of variance and coefficient of variation were calculated to determine if differences were real and to compare differences in this experiment with those of the previous one.

Table 5 shows a significant difference in yields between the two forms of phosphorus. Thus it appears that the plants were able to use more phosphorus from aluminum phosphate than from the ferric phosphate as evidenced by the better growth. There was also a significant difference in yield between Chel 330 and Versenol.

Table 4. Tomato plant top weights--sand culture experiment

| Treatment | | Replications | | | | |
Phosphate	Chelate[a]	1	2	3	4	Mean
			grams per pot			
1. FePO$_4$	none	9.35	10.04	13.12	9.53	10.51 ←
2. "	Fe V-ol	5.32	10.31	9.83	7.13	8.15
3. "	Zn V-ol	6.11	7.90	11.27	9.85	8.78
4. "	Mn V-ol	7.58	8.41	12.02	9.93	9.49
5. "	H V-ol	7.31	8.41	12.02	7.37	8.78
6. "	Fe 330	6.95	12.25	13.52	12.85	11.39 ←
7. "	Zn 330	11.84	13.32	11.25	16.56	13.24
8. "	H 330	13.82	12.30	15.26	11.38	13.19 ←
9. AlPO$_4$	none	11.52	13.60	11.00	9.61	11.43 ×
10. "	Fe V-ol	10.93	10.46	11.40	8.47	10.32
11. "	Zn V-ol	10.03	13.42	13.07	9.83	11.59
12. "	Mn V-ol	13.82	13.82	9.95	12.80	12.60
13. "	H V-ol	12.59	12.11	13.29	16.39	13.60
14. "	Fe 330	9.19	18.34	11.63	12.99	13.04
15. "	Zn 330	9.72	12.58	14.38	14.36	12.76
16. "	H 330	14.57	13.62	16.80	12.88	14.47
L. S. D. (.05)						0.45

[a]V-ol = Versenol; 330 = Chel 330.

Table 5. Analysis of variance--sand culture experiment

Source	df.	Mean sq.	F.
Total	63		
Treatments	15	15.049	3.075**
Phosphorus	1	65.929	13.470**
Chelate	7	17.709	3.618**
Phosphorus x chelate	7	7.168	1.468
Error	48	4.894	

Coefficient of variation--19.28 percent

**Significant at 0.01 percent level.

To compare the effect of the various chelated cations on the availability of phosphorus from the two sources, the treatment means are combined and the results presented in table 6.

Table 6. Averages of the means of the two phosphate treatments

Treatment	Mean average	Treatment	Mean average
check	10.97	check	10.97
Fe V-ol	9.23	Fe 330	12.21
Zn V-ol	9.68	Zn 330	13.00
Mn V-ol	11.04		
H V-ol	11.19	H 330	13.83
L. S. D. (.05)	0.88	L. S. D. (.05)	1.38

Both Fe Versenol and Zn Versenol decreased yields, while all forms of Chel 330 increased yields. The yields due to Mn Versenol and acid Versenol were very near those of the check and both yielded better than did the iron and zinc Versenol.

The chelated cations were ranked in the order of effect on yield. It was found that H > Zn > Fe for Chel 330. Manganese was chelated only to Versenol and the above order was found for Versenol chelates with Mn Versenol following H Versenol. Thus the order would be H > Mn > Zn > Fe.

The coefficient of variation for this experiment was greatly decreased over that of the preliminary experiment. Table 7 shows results of ash analysis of plant tops for iron and phosphorus. Values given are average of values for the three replications (pots) of each treatment.

In the case of Versenol, with the iron chelate, iron concentration in the plant was low, but in the manganese, zinc, and acid treatments plant iron was quite high. In the Chel 330 Fe treatments there was more iron in the plant than in either the zinc or acid Chel 330 treatments.

Phosphorus concentration remained quite uniform for all treatments except Zn Versenol where more phosphorus was present.

For the $FePO_4$ treatment, all chelates lowered the P:Fe ratio, with Fe and Zn Versenol decreasing the ratio the least and Mn Versenol

decreasing it the most. In the $AlPO_4$ treatments, Fe and Zn Versenol again decreased the P:Fe ratios the least.

Table 7. Iron and phosphorus concentrations in the tops of tomato plants grown in sand culture (average of three replications)

Treatment		Iron	Phosphorus	Phosphorus: iron ratio
Phosphate	Chelate[a]			
		ppm.	ppm.	
1. $FePO_4$	none	611	1372	2.246
2. "	Fe V-ol	480	1021	2.130
3. "	Zn V-ol	937	1803	1.924
4. "	Mn V-ol	868	1309	1.508
5. "	H V-ol	764	1175	1.538
6. "	Fe 330	793	1218	1.536
7. "	Zn 330	691	1167	1.688
8. "	H 330	685	1105	1.614
9. $AlPO_4$	none	663	1192	1.798
10. "	Fe V-ol	562	1086	1.934
11. "	Zn V-ol	572	1152	2.014
12. "	Mn V-ol	576	951	1.652
13. "	H V-ol	776	1345	1.734
14. "	Fe 330	753	1117	1.484
15. "	Zn 330	611	1122	1.836
16. "	H 330	650	1181	1.818

[a]V-ol = Versenol; 330 = Chel 330.

Discussion

From preliminary experiments several trends were noticed. It appeared that the iron chelates tended to slow up plant growth and increase the severity of phosphorus deficiencies. However, as evidenced by chemical analysis and better growth, the chelate was able to render somewhat more phosphorus available to the plant. It is possible that the chelate supplied the plant excess iron, which could have rendered the phosphorus unavailable again.

Therefore, the next logical step was to find a cation that did not form insoluble phosphate salts and apply it in the chelated form. If

the above mechanism was the actual cause of the poor growth, then this new cation in the chelated form would allow the chelate to free the phosphate for plant use and yet not supply the plant with an excess of a cation which would again render the phosphorus unavailable within the plant.

This new compound, therefore, should produce superior growth results compared to the iron chelate. It was noted that while iron and zinc ions do tend to form insoluble phosphates, manganese and hydrogen ions do not. Therefore, with the theory that manganese and hydrogen ions would produce a yield contrast to iron and zinc, these four cations were chosen to be chelated.

To make a comparison the yields from the sand culture experiment using the four cations (chelated to Versenol) are tabulated in table 6. As can be seen from the table, iron and zinc caused the lower yields.

A further comparison, between iron and hydrogen, can be made on the sand culture experiment, with 16 replications, and on the soil experiment, with 32 replications.

Table 8. Two comparisons of the effect of iron chelate and chelate on tomato plant yields

Sand Culture Experiment mean yields of 16 replications in grams per pot		Phosphorus Deficient Soil Experiment mean yield of 32 replications in grams per pot	
Iron	10.72	Iron	2.71
Hydrogen	12.51	Hydrogen	3.04
L.S.D. (.05)	0.70	L.S.D. (.05)	0.29

This evidence supports the supposition that certain cations are able to render phosphorus unavailable in the plant. It also offers a good explanation of why certain chelates tend to depress yields.

Generally, the variation of iron and phosphorus concentration in the plant was not great. However, several trends were noticed. In the Versenol iron with $FePO_4$ treatment, the iron and phosphorus concentrations in the plant tops were quite low. This is possibly due to the phosphorus and iron becoming insoluble in the plant roots, which were not analyzed. This would be enhanced by the effect of the excess iron supplied by chelate, both from the original iron chelate source and from the action of the chelate on the ferric phosphate. As shown by Biddulph (1951), an excess of either iron or phosphate ion in the plant is believed to cause the precipitation of $FePO_4$ in the plant roots. Also, the ferric phosphate which has precipitated in the plant roots tends to inhibit further uptake of both iron and phosphorus.

Evidence from these experiments indicates the probability that the chelate has some direct solubilizing effect on the insoluble phosphate compounds. It is believed that the complexing agent is able to chelate some iron (or other cation) from the insoluble phosphate, thus enabling the phosphate to be acquired by the plant. However, for the chelate to able to c omplex the iron from the phosphate, it must be in the free form (complexing agent). Just how this comes about is not completely understood, but possibly the plant is able to remove a cation from the chelate, leaving the complexing agent in the soil or nutrient solution.

Thus a cycle is formed, with the chelate molecule acting as a carrier. The chelate is introduced and the plant removes a cation from the chelate molecule. This leaves the complexing agent free to chelate another cation. If there is ferric phosphate present, the complexing agent can chelate some of the iron, leaving the phosphate in a soluble

form. This mechanism might be very desirable as it supplies both of these nutrients to the plant. One disadvantage of this mechanism is that the iron and phosphorus may again unite within the plant to form an insoluble phosphate.

In the $FePO_4$ treatment (table 4) all chelates lowered the P:Fe ratio, with iron and zinc chelates decreasing the ratio the least and manganese and hydrogen chelates decreasing it the most. Decreasing the ratio occurs either by supplying the plant with more iron or less phosphorus. Yet in the treatment where the P:Fe ratio was decreased the most, the highest yields were obtained. As lowering the P:Fe ratio would likely be caused by a decrease in phosphorus concentration, a discrepancy seems to have appeared. This may be explained by a somewhat confusing twofold effect. The manganese and hydrogen chelates probably did not supply iron in excess amounts, which would cause $FePO_4$ precipitation in the roots. However, the hydrogen and manganese chelates probably supplied iron in small quantities, readily taken up and utilized by the plant, which further allowed the plant to utilize the phosphorus it received. The result of this would be better plant growth, even though the plant had less total iron and phosphorus than the plants it out-yielded.

PHOSPHORUS DEFICIENT SOIL EXPERIMENT

Methods

Two soils were selected from the Uinta Basin area of Utah for
their obvious phosphorus deficiencies. The soil which, for convieni-
ence, we will call soil "A", is a Tabiona sandy clay loam taken from
the land of Mr. Earl H. Van Tassel, Tabiona, Utah. The land was in a
five-year-old stand of alfalfa which was yielding poorly. It is a
soil of moderate permeability, located on a 4 percent slope and having
slight water erosion. pH ranges near 7.7 to 7.9 with total soluble
salts of about 0.04 percent. Available P_2O_5 ranges from 10 to 23
pounds per acre, decreasing with depth. Texture is sandy clay loam
at the surface which becomes finer with depth.

Soil "B", taken from the land of Mr. Hugh Colton, Vernal, Utah,
is a Naples clay loam. The land had been in native meadow for the
last ninety years but was plowed in 1957 and planted to barley and
wheat in September 1957. The stand was uneven, with evidence of high
salt concentrations at the surface. The texture of the surface soil
is clay loam, becoming coarser with depth. Evidence points out the
possibility that the soil is poorly drained. Slope is not noticeable.
pH ranges from 7.8 to 8.3, with soluble salts testing 0.18 percent in
the sample used for experimentation. Available P_2O_5 tested 34 pounds
per acre.

In order to determine if the sand culture experiment results
could be closely duplicated in the soil and to see if chelates are
instrumental in keeping fertilizer phosphorus available in the soil,

two phosphorus deficient soils were obtained. The first soil, obtained near Tabiona, Utah, is a Tabiona sandy clay loam testing 23 pounds per acre P_2O_5. The other soil is a Naples clay loam testing 34 pounds per acre P_2O_5. Both of these soils were selected for their obvious phosphorus deficiency (both soils had about 1/100 the P_2O_5 that might be found in an average soil). The soils were potted in one gallon glazed crocks. Tomatoes were transplanted into the soil August 20th.

In this experiment two chelates were added to the soils, along with 100 pounds per acre P_2O_5 from a calcium metaphosphate fertilizer testing 0-46-0. The chelates were Versenol and Chel 330, each chelated to iron and as the acid form, making four chelate treatments. The experiment was set up as a randomized block with two soils, four replications and ten treatments. The treatments are listed below:

1. check (no treatment)
2. 100 lbs. P_2O_5 per acre
3. P_2O_5 and Chel 330 Fe
4. P_2O_5 and Versenol Fe
5. P_2O_5 and Chel 330 H
6. P_2O_5 and Versenol H
7. Chel 330 Fe
8. Versenol Fe
9. Chel 330 H
10. Versenol H

The treatments, both P_2O_5 and chelate, were applied August 25, 1958. Plants were given water whenever it was apparent that the top of the soil was dry. Plants were harvested, dried and weighed on October 2nd.

Results

On October 2nd, five and a half weeks after treatments were applied, plants were harvested. As the plants were starting to flower at this early date, possibly due to the adverse conditions imposed by the treatments, the plants were harvested before the originally

intended seven weeks were up.

As in previous experiments, the plants were dried in a forced air dryer at 75° F., then weighed. The plant weights, along with their corresponding treatments, appear in table 9.

Table 9. Tomato plant top dry weights—phosphorus soil experiment

Treatment[a]		Soil[b]	Replications				
Phosphorus	Chelate		1	2	3	4	Mean
			grams per pot				
1. (-)	(-)	A	4.41	4.29	4.20	4.70	4.40
2. (+)	(-)	A	5.10	4.81	5.24	5.31	5.12
3. (+)	330 Fe	A	3.52	5.04	5.17	5.87	4.90
4. (+)	V-ol Fe	A	3.96	3.98	4.81	5.82	4.64
5. (+)	330 H	A	4.53	3.78	5.43	4.42	4.54
6. (+)	V-ol H	A	3.96	4.96	5.66	8.52	5.77
7. (-)	330 Fe	A	3.98	4.57	6.41	4.36	4.84
8. (-)	V-ol Fe	A	4.57	3.72	3.92	4.63	4.21
9. (-)	330 H	A	4.41	4.76	5.07	4.41	4.66
10. (-)	V-ol H	A	6.78	5.36	4.81	4.54	5.37
11. (-)	(-)	B	0.00	0.97	0.00	1.12	0.52
12. (+)	(-)	B	2.38	0.93	0.80	1.33	1.36
13. (+)	330 Fe	B	0.23	0.99	0.17	2.52	0.98
14. (+)	V-ol Fe	B	0.38	0.52	0.11	1.71	0.68
15. (+)	330 H	B	0.42	0.40	1.14	2.79	1.19
16. (+)	V-ol H	B	0.21	1.15	2.35	1.56	1.32
17. (-)	330 Fe	B	0.44	0.85	0.20	0.92	0.60
18. (-)	V-ol Fe	B	0.59	0.72	0.46	1.55	0.83
19. (-)	330 H	B	0.19	0.00	0.93	1.57	0.92
20. (-)	V-ol H	B	0.74	0.16	0.32	1.09	0.58

[a](-) signifies no treatment; (+) signifies 100 pounds per acre P$_2$O$_5$ applied; 330 denotes Chel 330; V-ol denotes Versenol.

[b]Soil A = Tabiona sandy clay loam; Soil B = Naples clay loam.

In order to determine if and where differences were significant, these results were analyzed statistically. Table 10 shows the results of the statistical analysis.

This experiment made apparent the following facts:

1. That soil A yielded about five times better than soil B.

2. That added phosphorus increased yields in both soils. (The plants

which were treated lost the purplish color from the underside of
their leaves[1] in one to four days after treatment.)

3. That the chelates definitely affected yields but that the effect on
   yield, either positive or negative, was characteristic of each
   individual chelate.

Table 10. Analysis of variance--phosphorus deficient soil experiment

Source	df.	Ssqs.	Msq.	F.	Sig.[a]
Total	79	367.170			
Replications	3	10.119	3.373	5.64	(.001)
Soils	1	311.576	311.576	521.29	(.001)
Phosphorus	1	2.542	2.542	4.25	(.025)
Chelates	4	3.754	0.939	1.57	(.125)
Soil x phosphorus	1	314.183	314.183	525.65	(.001)
Soil x chelates	4	318.256	79.564	133.12	(.001)
Phosphorus x chelates	4	8.239	2.060	3.45	(.01)
Soil x phosphorus x chelate	4	23.958	5.989	10.02	(.001)
Error	57	34.070	0.5977		

Coefficient of variation--26.93 percent

[a]Significance not measured beyond (.001).

Discussion

The greatest variation in this experiment was between the two
soils. As both were low in phosphorus, the great difference probably
was mostly due to the high salt concentration in Soil B and the result-
ing poor structure and crusting.

Added phosphorus cleared up phosphorus deficiency symptoms
quickly in most cases but did not stimulate fast growth. The poor
growth of all plants can probably be attributed to two factors, namely,
cool fall weather and low nitrogen content of the soils.

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[1]The main visible phosphorus deficiency symptom in tomatoes.

The effect of chelate on yield was similar in most cases to results obtained from previous sand culture experiments. Looking at the treatment means, it is noticed that chelates generally suppressed yields. However, upon looking at the third and fourth replications, it is noticed that chelated fertilizer treatments were superior to the regular fertilizer treatments. This brings up the possibility of a third factor being involved, possibly a combination of temperature and moisture. There was a temperature differential in the greenhouse which could not be avoided. Replications 3 and 4 were in a warmer location than replications 1 and 2. Just what the effect of the temperature-moisture-chelate interaction is, is not known.

SUMMARY

In order to determine if chelates affected the solubility of phosphorus, Marglobe tomatoes were grown by the sand culture method with phosphorus supplied in insoluble forms and various chelates added. Apparently the chelates rendered phosphorus available to the plants. Theories were proposed to explain the negative as well as positive growth responses and phosphorus deficiencies. A theory was proposed to explain the mechanism by which chelates rendered insoluble phosphates available for plant use.

Then, two phosphorus deficient soils were chosen to study the effect of chelates on phosphorus fertilizer availability. Chelates and phosphorus fertilizer were applied to the soils. The chelate had a definite effect on yield, but the effect was determined by the type of cation chelated and possible temperature-moisture relationships.

Generally, chelates were able to render insoluble phosphate available to plants in small amounts. However in most cases, the mechanism is not efficient enough to allow economical use of chelates to increase phosphorus availability.

LITERATURE CITED

1. Bear, F. E. 1955 Iron chelates in agriculture. Agricultural Chemicals. 7:34.

2. Biddulph, O. 1951 The translocation of minerals in plants. Mineral nutrition of plants, E. Truog, editor. University of Wisconsin Press.

3. DeKock, P. C. 1955 The phosphorus-iron relationship in genetical chlorosis. Plant Physiology, 30:293.

4. DeRemer, E. D. 1957 The relationship between an iron chelate and the availability of phosphorus in the soil. Unpublished thesis. California State Polytechnic College, San Luis Obispo, California.

5. Haertl, E. J. 1957 The use of chelate compounds in fertilizer formulations. Fertilizer Solutions, winter issue.

6. Hoagland, D. R. and Arnon, D. I. 1950 The water culture method for growing plants without soil. California Experiment Station Bulletin, Circular #347.

7. Jackson, M. L. 1958 Soil chemical analysis. Prentice-Hall, New Jersey. pp. 389.

8. Lunt, O. R., et al. 1958 Inconsistencies of the bicarbonate ion as a direct cause of chlorosis. Paper given at the regional meeting, Western Society of Soil Science.

9. Olsen, C. 1935 Iron absorption and chlorosis in green plants. Compt. Rend. Trav. Lab. Carlsberg Ser. Chim. 21:15-52.

10. Piper, C. S. 1950 Soil and plant analysis. Interscience Publishing Co. New York. pp. 272.

11. Rediske, J. H. and Biddulph, O. 1953 The absorption and translocation of iron. Plant Physiology, 28:576.

12. United States Salinity Laboratory Staff. 1954 Diagnosis and improvement of alkali soils. U.S.D.A. Handbook #60. pp. 34.