# THE RESIDUAL EFFECTS OF ZINC FERTILIZATION [1]

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## ABSTRACT

The residual value of zinc fertilizer applied to Portneuf silt loam near Kimberly, Idaho was determined by three methods, a) DTPA-extractable Zn, b) plant growth and Zn uptake by beans (Phaseolus vulgaris) grown in a field experiment, and c) plant growth and Zn uptake by beans grown in a pot experiment on soil taken from field plots previously fertilized with Zn.

The plant growth and Zn uptake data from the field and pot experiments indicate that application of 10 lb Zn/A is adequate for at least three bean crops. DTPA-extractable Zn on samples taken in 1983 indicate adequate available Zn for a fourth crop. The soil tests are still above 1 ppm and they decrease slowly with time. Thus, the single 10 lb Zn/A will likely suffice for several more crops. The experiment is being continued.

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## INTRODUCTION

Relatively few reports exist in the literature dealing with field studies of residual zinc. Boawn et al. (1960) first reported pronounced residual effects of Zn applied to a neutral soil in central Washington. They showed that Zn rates ranging up to 16 lb Zn/A increased the 0.1 N HCl-extractable Zn from the soil and increased the Zn uptake by crops for as long as 6 years. Brown et al. (1964) related the residual response of crops to field applications of different Zn rates, time since applications were made, and the dithizone-extractable Zn. Visual effects on plant growth were evident 3 or 4 years after the Zn was applied. Boawn (1974, 1976) reported results from two experiments conducted on calcareous and non-calcareous soils in Washington. Seven crops of corn (Zea mays L.) were grown on these experiments. He concluded that a new elevated equilibrium level of 0.1 N HCl- or DTPA-extractable Zn persisted through the seven crops when as little as 5 lb Zn/A was applied. The enhanced availability of Zn as measured by soil tests was also evident from the Zn uptake by each of the crops.

Residual Zn effects have been reported as long as 4 years after field application from California (Zink, 1966), Michigan (Vinande et al., 1968), and Virginia (Schnappinger et al., 1972).

The work reported here was conducted to supply answers to frequently asked questions concerning the need for frequent application of Zn to beans (Phaseolus vulgaris) grown in southern Idaho.

## METHODS AND MATERIALS

A field experiment was conducted on Portneuf silt loam near Kimberly, Idaho wherein the plots were large enough to continue them for several years to determine the residual value of Zn fertilizer. The

plots (20x45 ft) were cropped to beans each of 3 years. Starting in 1980, 10 lb Zn/A was applied to selected plots; in 1981 an additional 10 lb Zn/A was applied to some of the previously treated plots as well as to previously unfertilized plots. Similar treatments were applied a third time in 1982. Thus, in the third year the total applied zinc amounted to 0, 10, 20, and 30 lb Zn/A. In addition the single 10 lb Zn/A applied in each of the 3 years allowed evaluating the residual effects of these single applications. The zinc was applied by spraying zinc sulfate solution on the soil surface before plowing. The treatments were evaluated on the basis of soil tests for available Zn, plant growth in the field, and by pot tests using soil from the field-treated plots.

Soil samples consisting of 15 cores per plot to a depth of 12 in. were taken from each plot in the spring of each year. They were dried at 30 C, sieved (2 mm) to remove debris, and analyzed for DTPA-extractable Zn (Lindsay and Norvell, 1978).

The beans were planted about June 1 each year. They were furrow irrigated according to the needs established by tensiometers placed in the rows at 12- and 18-in depths. Plants were sampled (15 whole plants) at various times, washed in distilled water, dried at about 55 C, weighed, and ground to pass a 40-mesh screen in a Wiley mill equipped with stainless steel blades and screen. Bean yields were measured by harvesting two 30-ft rows from each plot when the crop was mature.

An additional evaluation of residual zinc was made by growing Sanilac beans in a growth chamber on soil (0 to 12 in) from some of the variously treated field plots. Besides the soil as it came from the field, treatments also included fresh applications of 10 ppm Zn as zinc

sulfate. Each pot contained 4.5 kg of soil. De-ionized water was added as needed to bring the soil moisture to 25 percent by weight. Supplemental N, P, K, and S were added to all pots to ensure adequate amounts of these nutrients. The beans were allowed to grow for approximately 4 weeks. The above-ground portions were harvested and processed in the same way as the field samples. All plant samples were digested in a mixture of nitric and perchloric acids (3+1). The resulting solution was diluted and analyzed for Zn and several other mineral constituents.

## RESULTS AND DISCUSSION

### Soil Tests

The DTPA-extractable Zn (Table 1) indicates marked responses to applied Zn and that the increased soil tests persisted into succeeding years. The soil test values measured in 1983 indicate only slight differences among the 10 lb Zn/A applications made in 1980, 1981, and 1982. All of the levels were increased well above the 0.6 ppm Zn considered adequate for good crop growth. In addition values resulting from accumulative 20 or 30 lb Zn/A show step-wise increases.

When the 1982 soil tests are plotted against the amount of Zn applied over the 3 years, the data form a straight line that indicates the DTPA-extractable Zn increases about 1.0 ppm from applying 7 lb Zn/A. Boawn (1971) showed that the DTPA soil test increased 1.0 ppm for each 7 lb Zn/A applied and that both the 0.1 N HCl and DTPA soil tests on Warden fine sandy loam in central Washington responded linearly to application of as much as 800 lb Zn/A. Comparison of the two methods indicates that the ratio of DTPA-Zn to 0.1 N HCl-Zn was approximately 0.625.

Values for the 1983 sampling appear to be generally lower than those obtained in 1982, although by current calibration they are still adequate. This general decrease may result from reversion of the Zn to un-extractable forms or it may be a seasonal fluctuation. The latter seems reasonable, since the 1983 values for the single 10 lb Zn/A applied in each of the 3 years all are essentially the same. The 1982 application showed the same decrease after 1 year as did the 1980 application after 3 years. If reversion of Zn to un-extractable forms were occurring, the Zn applied in 1980 should have reverted the most.

These results are similar to those presented by Boawn (1974, 1976) for calcareous and non-calcareous soils in Washington. The DTPA-extractable Zn in his studies decreased faster than those obtained in this study, but elevated soil test values persisted throughout 7 years from a single application of 10 lb Zn/A on both soils, however, they were considered adequate for only the first 3 years. He concluded that the extractable Zn levels appeared to approach a new equilibrium value for each level of Zn applied. Application of 20 lb Zn/A was adequate for 7 years on both soils studied and may provide an adequate level of Zn for many years, since the final values measured were still well above the adequate level.

Zn Uptake Field Experiment

In each of the three years the beans not fertilized with Zn showed strong to severe zinc deficiency symptoms. Those fertilized with Zn grew normally. The results of plant analysis on whole plant samples taken on July 16, 1982 are shown in Table 2.

The dry weights of all Zn fertilized plants were nearly the same. Zn concentration, however, increased with increasing soil test as a

result of increasing Zn fertilization. As a consequence Zn uptake increased as Zn fertilization increased. It is significant to note that Zn uptake on July 16 was essentially the same for the three single 10 lb Zn/A applied in each of 3 years.

Boawn (1974) measured Zn uptake by corn where Zn was applied 1, 2, 3, or 4 years previously. All values were the same as for a current season application for corn grown on the noncalcareous Shano soil (0.185 to 0.197 lb Zn/A) and showed only a slight decrease in the fourth year for that grown on the calcareous Hezel soil (0.261 to 0.355 lb Zn/A). These levels of uptake are much larger than those measured for beans in the experiment reported here which averaged generally less than 0.1 lb Zn/A. This difference in Zn removal by the two crops may be a factor in the more rapid decrease in soils test Zn given by Boawn. Especially since all above ground portions of the corn were removed, whereas the bean straw was returned to the plots during bean harvest. Thus, about three or more times more Zn was removed from the soil in the corn experiments as was removed from the bean experiment.

Growth Chamber Experiment

A third indication of the residual value of Zn fertilization is shown in Table 3. The plant growth data indicate a marked response to residual Zn regardless of which of the 3 years it was applied. Where 10 lb Zn/A had been applied, plant growth was more than 2.5 times that from the unfertilized treatment. For the 30 lb Zn/A accumulative treatment plant growth was increased almost 4 times that from the unfertilized soil. The Zn concentration of the plants increased only slightly until maximum growth was obtained and then increased markedly with increasing Zn availability, thus both plant size and Zn

concentration increased Zn uptake. Again, the three single 10 lb Zn/A applications made in 3 different years showed equal Zn uptake. Additional uptake occurred from the 30 lb Zn/A accumulative treatment and where the fresh Zn applications were made at the beginning of the pot experiment. The increased Zn availability resulting from the fresh applications and the high rate applied in the field probably results from the small pots (4.5 kg soil) and the rapid growth rate the plants experienced under the favorable conditions in the growth chamber. Such increases were not evident in the field experiment.

SUMMARY

The data presented here clearly indicate a residual value of Zn fertilizer applied to Portneuf silt loam. The effect was measured three ways: (a) increased soil test levels, (b) analysis of plants grown in a field experiment through three crops of beans, and (c) growth and Zn uptake of beans grown in a growth chamber experiment using soil obtained from field plots previously fertilized with Zn.

The results indicate that after three crops of beans the DTPA-extractable Zn is a reliable indicator of Zn adequacy. The values initially about 0.5 ppm Zn were increased to near 1.7 ppm as a result of applying 10 lb Zn/A and were still near 1.5 ppm after three crops. Values above 0.6 ppm are considered adequate for good crop growth.

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Table 1. The DTPA-Extractable Zn as affected by time of application and sampling date, resulting from field application of Zn fertilizer

| Zn Applied | | | DTPA-Extractable Zn | | | |
|---|---|---|---|---|---|---|
| 1980 | 1981 | 1982 | 1980 | 1981 | 1982 | 1983 |
| lbs/A | | | ppm | | | |
| 0 | 0 | 0 | 0.4 ±0.42 | 0.4 ±0.05 | 0.5 ±0.10 | 0.4 ±0.05 |
| 10 | 0 | 0 | 1.6 ±0.26 | 1.8 ±0.28 | 1.7 ±0.11 | 1.4 ±0.21 |
| 0 | 10 | 0 | 0.5 ±0.05 | 1.8 ±0.17 | 1.9 ±0.53 | 1.2 ±0.21 |
| 0 | 0 | 10 | 0.4 ±0.05 | 0.4 ±0.10 | 1.7 ±0.54 | 1.5 ±0.14 |
| 10 | 10 | 0 | 1.6 ±0.26 | 3.4 ±0.32 | 2.9 ±0.53 | 2.3 ±0.63 |
| 0 | 10 | 10 | 0.5 ±0.05 | 2.1 ±1.23 | 3.5 ±0.61 | 2.4 ±0.21 |
| 10 | 0 | 10 | 1.4 ±0.28 | 1.9 ±0.36 | 2.8 ±0.25 | 2.1 ±0.38 |
| 10 | 10 | 10 | 1.4 ±0.28 | 3.2 ±0.31 | 4.6 ±0.94 | 3.0 ±0.12 |
| Date Sampled | | | 5/80 | 5/81 | 5/82 | 3/83 |

Table 2. The plant yield, Zn concentration and Zn uptake of Viva beans grown in the field, sampled July 16, 1982, variously fertilized with Zn.

| Zn Applied | | | DTPA-Extr | Dry | Zn | Zn |
|---|---|---|---|---|---|---|
| 1980 | 1981 | 1982 | Zn - 1982 | Weight | Conc. | Uptake |
| | lbs/A | | ppm | lbs/A | ppm | lbs/A |
| 0 | 0 | 0 | 0.45 | 950 | 17.7 | 0.0167 |
| 10 | 0 | 0 | 1.70 | 1350 | 24.2 | 0.0326 |
| 0 | 10 | 0 | 1.90 | 1120 | 24.0 | 0.0268 |
| 0 | 0 | 10 | 1.70 | 1230 | 26.5 | 0.0325 |
| 10 | 10 | 0 | 2.90 | 1310 | 29.0 | 0.0379 |
| 0 | 10 | 10 | 3.55 | 1290 | 29.0 | 0.0375 |
| 10 | 0 | 10 | 2.82 | 1280 | 31.0 | 0.0395 |
| 10 | 10 | 10 | 4.57 | 1260 | 33.0 | 0.0416 |
| LSD 0.05 | | | | 190 | 5.0 | 0.009 |
| 0.01 | | | | 260 | 6.8 | 0.012 |

Table 3. The yield, Zn concentration and Zn uptake of beans grown in pots on soil from field plots fertilized with Zn at different times

| Zn Applied To | | | | DTPA-Extr. Zn | Dry Wt. | Zn Conc. | Zn Uptake |
|---|---|---|---|---|---|---|---|
| Field | | | Pots | | | | |
| 1980 | 1981 | 1982 | 1983 | | | | |
| | lbs/A | | ppm | ppm | g/pot | ppm | µg/pot |
| 0 | 0 | 0 | 0 | 0.6 | 1.74 | 10.0 | 17 |
| 0 | 0 | 0 | 10 | | 7.12 | 17.0 | 121 |
| 10 | 0 | 0 | 0 | 1.5 | 4.77 | 12.5 | 58 |
| 10 | 0 | 0 | 10 | | 7.36 | 19.0 | 140 |
| 0 | 10 | 0 | 0 | 1.7 | 4.61 | 11.6 | 53 |
| 0 | 10 | 0 | 10 | | 8.25 | 19.0 | 156 |
| 0 | 0 | 10 | 0 | 1.7 | 4.92 | 12.0 | 59 |
| 0 | 0 | 10 | 10 | | 7.60 | 20.6 | 156 |
| 10 | 10 | 10 | 0 | 4.6 | 6.87 | 17.0 | 117 |
| 10 | 10 | 10 | 10 | | 7.90 | 21.6 | 170 |
| LSD 0.05 | | | | | 2.38 | 5.0 | 62 |
| 0.01 | | | | | 3.26 | 6.8 | 82 |