Flooded Soil Syndrome and P deficiencies on Four Iowa Soils

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Introduction

Several million acres of Midwest cropland were inundated during the floods of 1993. The length of inundation was from a few days to several months. In some areas growing crops were drowned out and other fields could never be planted. As the water receded and acres of barren ground were exposed, the reality of the disaster gave way to concerns for the 1994 crop and the development of Flooded Soil Syndrome. Flooded Soil Syndrome produces symptoms similar to Fallow Syndrome which was originally identified a number of years ago when crops planted to previously fallowed soil failed to produce expected yields. Experiences with fallow cropping systems suggest that growth problems were the result of P deficiencies. Corn is probably the most sensitive crop, however, less severe problems may also occur with soybeans and wheat (Fixen et al., 1984).

Classic P deficiency symptoms in plants generally include slow, stunted growth, purplish coloration of foliage, dark green coloration with dying leaf tips, delayed maturity, and poor grain development (Western Fertilizer Handbook, 1985). In fallow systems, starter fertilizer has corrected early growth problems and resulted in improved yields (Fixen et al., 1984). There may be difficulties identifying potential problem areas. In previously flooded or fallowed areas P deficiencies frequently develop on soils that have adequate levels of P according to commonly used soil extracts developed to estimate plant-available P. These soil tests solubilize and extract P from various fractions of the soil labile pool. In previously inundated soils more P is apparently extracted than is actually available to growing plants. This suggests that part of the problem may be the result of changes in P solubility of these soils.

Phosphorus availability to crops is also influenced by soil microorganisms. Enhanced P uptake by plants has been attributed to root colonization by vesicular-arbuscular mycorrhizal fungi (VAM) (Jefferies, 1987; Tinker, 1980). Research suggests that most annuals would be in midgrowth before they had much mycorrhizal development. Therefore, the impact of VAM on early P nutrition of a crop is unclear. However, reduced VAM colonization in fallowed soil may be responsible for the severe P deficiencies of the following crop that characterize Fallow Soil Syndrome (Lohry and Fixen, 1994).

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The objectives of this study were to determine the potential for development of P deficiency in corn planted in soil that was inundated with water during the 1993 growing season and estimate the incidence of VAM infection of corn roots collected from these same soils.

Methods

Soil was collected from 12 sites around Iowa (Table 1). The soils differed by parent material, cropping history, and 1993 water status. The experiment was conducted in the greenhouse. Twenty-cm diameter plastic pots were filled with the different soils and arranged in a randomized complete block with 4 replications. Selected soil properties are shown in Table 2.

The first crop was planted on 30 Nov 93. Four corn seeds (*Zea mays* L., Pioneer 3417) were planted in each pot. Approximately 2 weeks after germination the seedlings were thinned to two per pot. At the same time each pot was watered with a solution of NH_4NO_3 at a rate that would supply the equivalent of 112 kg N ha^{-1}. When plants reached the V2, V4, and V6 growth stage plant height was measured and plants were rated for purplish coloration of the foliage as indicators of the development of P deficiency symptoms. Plants were harvested for dry matter yield and root samples were collected at the V6 growth stage on 25 Jan 94. The harvested plant material was analyzed for total-P to determine plant uptake. Soil samples from the pots were taken for inorganic P analysis. The root samples were preserved and 10-cm root segments were placed under a microscope to count VAM colonization rates. After harvest the pots were replanted and another crop was grown. Plant height and purplish coloration of the leaves were recorded at the V2 and V4 growth stages. At V4 the plants were harvested for dry matter yield and to determine P-uptake. Selected root samples were collected for VAM colonization counts. Soil samples were analyzed for inorganic P. The pots were emptied and re-filled with more of the original soil and the entire experiment was repeated.

The soil samples were analyzed for inorganic P using several different techniques. Soil P was extracted using the standard Bray P-1, Olsen, and dilute salt (water soluble) methods and also a relatively new technique, iron hydroxide-impregnated filter paper strips (FIP). The Bray P-1 test extracts easily acid soluble P such as Ca-phosphates and some Al- and Fe-phosphates. The Olsen or $NaHCO_3$ extractent causes a decrease in the concentration of Ca in solution and results in an increase of P in solution. The weak salt extract is an attempt to approximate the soil solution P concentration. FIP simulates P adsorption by roots and primarily removes physically bound P from both calcareous and noncalcareous soils (Sharpley, 1991; Menon et al., 1988).

Results

A significantly greater number of plants growing in previously inundated soil showed the development of P deficiency symptoms at about the V4 growth stage during the first crop both times the experiment was conducted. The greenhouse results were confirmed during the early part of the 1994 growing season as P deficiencies were apparent in areas of fields that had been inundated with water during 1993. Field P deficiency symptoms were most apparent at about the V4 growth stage and dissapeared later in the season. Development of symptoms also seemed to be dependent on the hybrid planted.

In the greenhouse, average plant height was greater for plants growing in normal soils (Table 3). Plants growing in previously inundated soil had the greatest incidence of purplish coloration of foliage. About 31% of pots containing normal soil had plants showing the classic purplish coloration of P deficiency compared to about 56% of pots containing previously inundated soil. At the V6 growth stage P deficiency symptoms were no longer noticable. It is immposible to predict from the greenhouse experiment the effects of early development of P deficiency on crop yield. However, because the symptoms seem to dissapear later in the season the effect on yield could be minimal.

Early during the second crop (V2) purplish foliage developed in corn growing in nearly all soils. Plant height measured at the same time showed that corn in normal loess soils (soils 9 and 11) was taller than the same previously inundated soils (soils 10 and 12). There were no differences between the other soils. At the V4 growth stage none of the foliage had purplish coloration and while plant height varied depending on soil type there were no differences between normal and corresponding inundated soils. These results suggest that after one season the effects of Flooded Soil Syndrome are absent or much less pronounced.

Initial concentrations of soil P (Table 2) showed that all soils except the inundated Webster (soil 4) were in the range of values generally considered high enough that a crop response to fertilizer P would be unlikely. In most cases the previously inundated soil had higher soil P concentrations than the normal soils. There was no correlation between soil test levels and dry matter yield or P-uptake during the first trial of the experiment. During the second trial of the experiment some correlation between soil extractable P and dry matter yield, P-uptake and VAM colonization were noted (Table 4).

Problems with root sampling and VAM counting techniques at the beginning of the experiment made differences in colonization difficult to detect. However, after the first crop there were differences in the colonization rates of the different Webster soils. The inundated Webster soils tended to have slightly lower colonization rates than the same normal soil. VAM infection rates were determined for the Webster soils from root samples collected after the second crop. There were no detectable differences.

During the second trial of the experiment 10-cm root segments were rated according to the percentage of root area infected with VAM. Root samples collected at harvest on 21 Mar 94 showed that previously inundated soils tended to have lower VAM infection rates (Table 5). There was no correlation between P deficiency symptoms (purplish foliage and plant height) and VAM infection rates. Based on these results it is not clear what effect VAM colonization has on development of Flooded Soil Syndrome.

Summary

Corn planted to previously inundated soil showed greater development of P deficiency symptoms than corn growing in normal soils. Extractable soil P was higher in soils that developed deficiency symptoms indicating that the soil tests used were not useful in predicting occurance of the problem. Some P deficiency symptoms developed in the second crop but the rate was similar for all soils suggesting that the mechanisms responsible for Flooded Soil Syndrome are short lived and after one season relatively normal growing conditions may be expected. VAM infection rates were difficult to determine. There was no correlation between VAM infection rates and P-uptake and dry matter yield for corn grown in any of the soils used in the experiment. Apparently VAM infection rates were not a determining factor in the occurance of P deficiency symptoms associated with Flooded Soil Syndrome in this experiment.

Table 1. Background information on the soils used in the greenhouse experiment.

Soil	Soil Series	1993 Water Status	1992 Crop	1993 Crop
1	Webster	Normal	Corn	Soybeans
2	Webster	Inundated	Corn	Soybeans
3	Webster	Normal	Soybeans	Corn
4	Webster	Inundated	Soybeans	Corn
5	Lawson	Inundated	Corn	not planted
6	Lawson	Inundated	Soybeans	not planted
7	Lawson	Inundated	Grass	Grass
8	Chequest	Inundated	Soybeans	Corn
9	Kalona	Normal	Corn	Soybeans
10	Kalona	Inundated	Corn	Soybeans
11	Kalona	Normal	Corn	Corn
12	Kalona	Inundated	Corn	Corn

Webster cl - fine-loamy, mixed, mesic, Typic Haplaquolls
Lawson si cl - fine-silty, mixed, mesic, Cumulic Hapludolls
Chequest si cl - fine, montmorillonitic, mesic, Typic Haplaquolls
Kalona si cl - fine, montmorillonitic, mesic, Typic Haplaquolls

Table 2. Selected initial soil properties.

Soil	pH	Extractable P				OM
		Bray P-1	$CaCl_2$	Olsen	FIP	
		---------------------- mg P kg^{-1}			------------------------	(%)
1	7.5	32.9	0.61	20.7	34.4	6.9
2	7.3	41.7	0.53	30.3	40.8	7.0
3	7.9	33.0	0.64	19.6	30.5	7.2
4	7.8	0.8	0.67	32.4	44.7	6.4
5	7.5	28.2	0.13	34.4	33.0	2.7
6	7.2	21.7	0.0	34.2	28.3	2.7
7	7.0	46.6	0.08	30.0	34.1	2.2
8	6.3	71.4	0.29	94.0	85.3	3.3
9	6.3	80.2	0.44	58.6	68.5	4.3
10	6.3	92.4	0.35	105.9	104.5	5.6
11	7.0	77.7	0.81	58.3	60.0	6.6
12	7.0	104.1	0.40	91.6	78.5	5.7

Table 3. Average values and mean squares for P deficiency symptoms from the first crop of the first trial. Planting date: 30 Nov 1993.

Growth Stage	V2		V4		V6	
	Color	Ave. Ht.	Color	Ave. Ht.	Color	Ave. Ht.
Soil		(cm)		(cm)		(cm)
1	0.00	36.6	0.75	85.8	0.25	109.3
2	0.50	36.9	0.50	83.8	0.50	106.5
3	0.00	36.9	0.00	86.0	0.25	108.1
4	0.75	36.9	1.00	75.1	0.50	108.9
5	0.00	34.1	0.00	83.8	0.25	108.1
6	0.25	37.6	0.25	88.4	0.50	109.5
7	0.25	34.4	0.00	80.8	0.00	111.7
8	1.00	36.4	1.00	79.1	1.00	113.9
9	0.25	34.9	0.50	83.1	0.50	109.6
10	1.00	32.6	1.00	73.6	1.00	113.3
11	0.00	32.7	0.00	84.9	0.50	108.5
12	0.75	33.6	0.75	79.5	0.50	114.1
			Mean Squares			
Soil	0.61**[†]	13.2	0.7*	81.1**	0.34	25.2*
Contrast by Soil						
1 vs. 2	0.5	0.19	0.125	8.0	0.12	15.3
3 vs. 4	1.12**	0.00	2.0**	239.3**	0.12	1.3
9 vs. 10	1.12**	10.70	0.5	182.9**	0.5	18.5
11 vs. 12	1.56**	1.40	0.25	54.4	0.06	63.3*
Nrml vs. Inun.	2.67**	0.01	0.67*	211.5**	0.26	32.7

[†] *, ** significant at the 0.05 and 0.01 probability levels, respectively.

Table 4. Pearson Correlation Coefficients for plant material harvested on 3 Mar 94 and extractable P in soil samples collected before planting.

	P Uptake	Dry Matter	VAM
Bray P-1	ns	ns	ns
Olsen	-.40**[†]	ns	ns
$CaCl_2$	ns	-.36**	-.53**
FIP	-.45**	ns	-.28*
VAM	.28*	ns	

[†] *, ** significant at the 0.05 and 0.01 probability levels, respectively.

Table 5. VAM infection rates at 3 harvest dates. First harvest results are reported as an average of the number of 10-cm root segments (n=10) that were infected. The last two harvest dates are reported as a rating of the percentage of root area infected by VAM on a scale of 1 to 5 where 1 represents a 0 to 5% infection rate and 5 represents a 75 to 100% infection rate of 10 10-cm root segments.

Harvest Date	25 Jan 94	21 Mar 94	4 Apr 94
Soil			
1	8	1.66	1.18
2	7.25	1.77	1.63
3	9.25	1.05	1.08
4	6.25	0.93	1.24
5	8.75	2.85	2.59
6	8.75	3.10	2.11
7	8.75	4.55	1.77
8	8.5	0.61	1.89
9	8.25	2.24	1.87
10	8.75	1.41	2.04
11	8.75	1.61	1.49
12	7.75	2.85	2.06
		Mean Squares	
Soil	2.77	3.7**[†]	0.79**

[†] ** significant at the 0.01 probability level.

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