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TO

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Nitrogen, Phosphorus and Potassium Management for Recrop Small Grain in Western North Dakota

By

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I. Project Orientation

Small grain is normally grown after summer-fallow in western ND. Recrop grain production, albeit more risky, can be successful but more intensive management is needed than with a grain-fallow rotation. Fertilization, weed control, and stubble management are much more critical. Recrop wheat experiments were established at nine locations to study fertilizer management under recrop conditions. Four experimental designs were used, and not all designs were used at every site. The "N Management" series of experiments was established at five locations and the purpose was to compare various N sources, N placements, and times of application. The "P Management" series of experiments was established at four locations and the purpose was to compare P sources and placement methods. The "N Rate" series of experiments was established at eight locations and the purpose was to measure crop response to N for soil test and tissue test calibration. The "Chloride" series of experiments was established at all locations and the purpose was to measure the effect of chloride-containing fertilizers (KCl or $CaCl_2$) on crop yield and root-rot severity (*H. sativum*).

A summary of the locations is shown in Table 1.

Table 1. Site and experiment orientation.

Site (nearest town)	Experiments	Result
Bowbells	N Management, N rate, Cl	Harvested
Dickinson	P Management, Cl (HRSW, durum, barley)	Weeds, poor stand
Fortuna	N Management, N rate, Cl	Harvested
Hettinger	N Management, N rate, Cl	Severe crusting
Minot	P Management, N rate, Cl (HRSW, durum, barley)	Harvested
Rawson	P Management, N rate, Cl	Harvested
Stanley	N Management, N rate, Cl	Harvested
Williston E	N Management, N rate, Cl	Harvested
Williston W	P Management, N rate, Cl	Hail

Not all experiments were successfully carried to completion. Weeds, crusting and hail forced the abandonment of three sites.

Soil test data for the havested sites is summarized in Table 2. All sites were fairly low in available N, except Bowbells, which had over 100 lb/A of NO_3-N in the 2-3 foot layer. The Rawson site tested low in P, the rest were medium.

The specific treatments, results, and discussion for each experiment series are discussed separately. Because of the large amount of data generated, the discussion will be limited to "high points" found in the data. A complete documentation of data can be found in the Appendix. At the time of this writing, thorough statistical analysis is not complete.

Table 2. Soil test data from harvested field experiments.

Site	NO_3-N 0-2'	Olsen P	Avail. K	pH	EC
	lb/A				mmho/cm
Bowbells	43*	17	550	7.9	.2
Fortuna	9	10	455	7.6	.4
Minot	38	15	430	6.7	.2
Rawson	14	6	440	7.9	.3
Stanley	15	16	390	7.8	.3
Williston E	34	17	415	7.3	.2

*Substantial NO_3-N in 2-3' at this site.

II. Nitrogen rate experiments.

The major fertilization problem in recrop wheat production is inadequate nitrogen. Serious and widespread N deficiencies occurred in SW ND in 1982. An abundance of spring moisture prompted considerable recrop plantings, especially in the more dairy/livestock orientated areas of SC and SW ND. Recrop fields showing N deficiency at joint to boot stage were commonly observed. Possibly 50% of the recrop fields in this area were affected by N deficiency.

The specific treatments used in these experiments were 0, 20, 40, 60, 80 and 100 lb N per acre as ammonium nitrate, incorporated. A randomized-complete block design was used and either three or four replications were employed. Thirty lb/A of P_2O_5 were added to all treatments.

The effect of N on grain yield is summarized in Table 3. No effect was observed at Bowbells, which would be expected due to the high amounts of subsoil N (over 100 lb in the 2-3' layer). Yield increases were observed at all other sites. A "most profitable" rate was chosen by observation of the data. An addition of 20 lb N/A which did not produce a 2 bu/A increase was not considered "profitable". "Most profitable" rates varied from 0 to 80 lb N/A. The purpose of selecting a "most profitable" rate was to select the observations for soil test calibration. A <u>very</u> simple model is used. Assuming that when a farmer sends in a soil sample for a recommendation that he wishes to be at the "point of maximum profit", then by using a similar approach we can calculate the amount of soil + fertilizer N is needed to produce the stated yield goal.

Table 3. Effect of N on wheat yields.

Site	N rate, lb/A					
	0	20	40	60	80	100
	bu/A					
Bowbells	17*	18	17	17	15	17
Fortuna	24	25	31	35*	34	37
Minot	18	25	31	34*	31	29
Rawson	27	33*	33	35	36	37
Stanley	18	23	24	27	31*	28
Williston E	16	18*	19	19	18	17

*Selected by observation of the data to be the "most profitable rate".

Results of this analysis are presented in Table 4. Data from 1981 sites are also included. The critical determination is the lb N/bu wheat. This ratio varies from experiment to experiment, but the empirical average of 2.5 lb N/bu is exactly the factor presently used in NDSU recommendations. This is an important finding as little data from western ND was used in the original establishment of present NDSU recommendations. This base of data greatly strengthens our assurance in making N recommendations in western ND.

Table 4. Soil test calibration, 1981-1982.

Site	Yield	Soil + fertilizer N needed*	lb N/bu
	bu/A	lb/A	lb N/bu
1982			
Bowbells	17	43	2.5
Fortuna	35	69	2.0
Minot	34	98	2.9
Rawson	35	48	1.4
Stanley	31	95	3.1
Williston E	18	54	3.0
1981			
Stanley	43	104	2.4
Fortuna	18	51	2.8
New Town	26	93	3.5
Dickinson	13	55	4.2
Williston	33	75	2.2
Minot	37	23	0.6
Minot	35	42	1.2
Williston	32	75	2.4
Battleview	35	106	3.0
Average and 95% confidence interval			2.5± 0.5

*NO_3-N in 0-2 ft plus fertilizer N needed for most profitable yield.

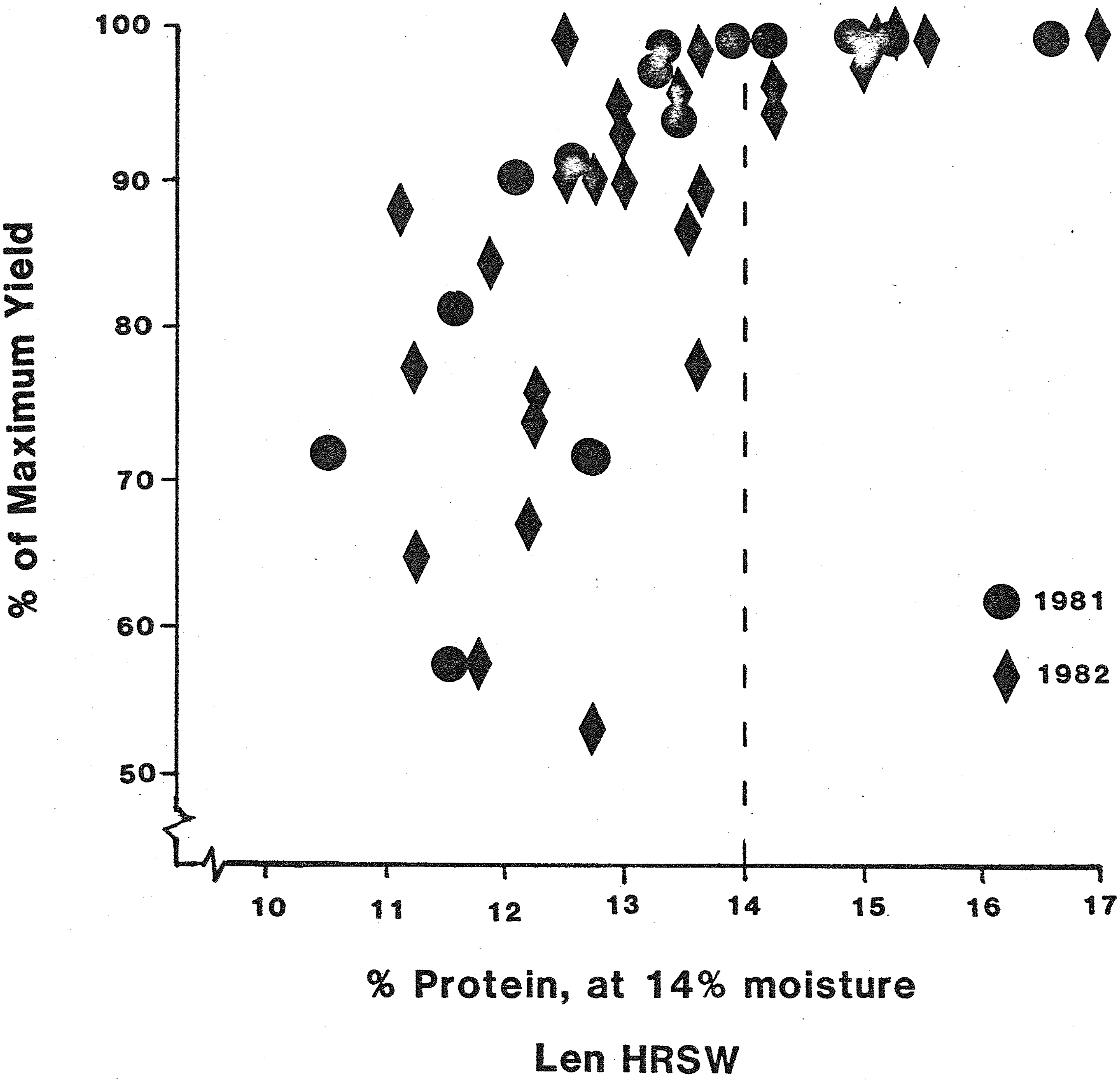
The effect of N rate on grain protein content is presented in Table 5. As expected, N increased grain protein contents. The important issue is how protein response and yield response are related.

Table 5. Effect of N on grain protein contents, adjusted to 14% moisture basis.

Site	N rate, lb/A					
	0	20	40	60	80	100
	%					
Bowbells	15.0	15.2	15.4	15.2	15.7	16.1
Fortuna	11.3	12.2	11.8	12.9	12.7	12.4
Minot	12.7	12.3	13.0	13.6	14.2	13.8
Rawson	11.3	12.4	12.9	13.4	14.2	15.1
Stanley	11.7	12.2	13.6	13.6	14.2	14.6
Williston E	13.5	14.2	15.6	17.0	17.1	18.3

Figure 1 presents the relative yield, expressed as a percentage of the maximum observed yield at each site, versus the percent protein. Data from 1981 is included. To avoid confusion, data from yield decreases from N (at very high N rates) are not included.

It can be easily seen in this figure that a clearly definable "break" between N deficiency and N sufficiency can be observed. Even without statistical procedures a "critical level" of around 14% protein can be observed. Such a "critical level" could have important extension use. Since protein is commonly determined in the marketing process, a farmer can make a qualitative post-harvest evaluation of his N fertilization program by comparing his field protein figure with established "critical levels". While such a determination has no value to the crop just harvested, it can be used to promote better N management in the future. One problem with such an approach is that spring wheat varieties can vary in their inherent protein contents. The data so far generated is only for 'Len' wheat, but it is conjectured that estimates


100
90
80
70
60
50
% of Maximum Yield
10
11
12
13
14
15
16
17
1981
1982
% Protein, at 14% moisture
Len HRSW

of protein "critical levels" for other varieties can now be made that a "critical level" for a benchmark variety has been determined.

Other determinations (tissue N, dry matter production, grain N uptake, dry matter N uptake) have been made and are documented in the Appendix.

In summary, we feel that a great stride has been made in the past two years in predicting and then evaluating the N fertilizer needs for recrop wheat in western ND.

III. Phosphorus management trials.

Phosphorus placement has received much attention in recent years, as growers strive for maximum fertilizer efficiency. Research has been underway for several years in ND to compare deep P placement with the more traditional methods of broadcast or drill application.

These experiments compared two N sources (UAN deep and AA deep) with five types of P management (APP deep, PA deep, CSP surface, CSP drill, and no P). A no-fertilizer check was also included.

The gist of the results can be summarized in Table 6. Nitrogen fertilizer alone increased yields substantially at both sites. Phosphorus fertilization had no effect on yields at the Minot site, which had a medium test. The grain P uptake for that site showed no significant differences between no P and plus P.

Table 6. Summary of P management trials, with respect to P placement.

Treatment Average*	Minot Yield	Minot GPUP**	Rawson Yield	Rawson GPUP**
	bu/A	lb P/A	bu/A	lb P/A
No fertilizer	27	6.6	24	5.3
60 lb N/A, No P	40	8.8	32	6.3
60 lb N, P sfc	39	9.0	34	7.4
60 lb N, P deep	41	8.8	34	6.8
60 lb N, P drill	41	9.1	33	6.7

*Averaged across fertilizer source.

**GPUP = grain P uptake.

The Rawson site, with a low P test, was somewhat disappointing in its lack of yield response to P. Yields were increased by N, but the difference due to addition of P (1-2 bu/A) probably was not significant. Grain P uptake (GPUP) was increased by N fertilization. Phosphorus fertilization seemed to increase GPUP but the differences are probably not significant.

Again, extensive measurements have been made at these sites, but a study of these measurements has not indicated a superiority of N source, P source, or P placement. Without a yield increase it is difficult to draw any conclusions with respect to P source or placement method.

These experiments, especially the Rawson site, raise an important question - are our current soil test recommendations (based on the Olson test) too liberal? This is not the first time that a "low" site has failed to respond in ND. Could it be that perhaps organic P plays a significant role in the P nutrition of wheat in our high organic matter soils? Usually the Olson extracts of ND soils are amber, some quite amber, from organic matter extracted from the soil. Doubtless this extracted organic matter contains P, probably more P than is present in inorganic form. Should this organic P be determined as well? We are in the process of re-evaluating the available data in ND concerning the Olson test and P response in wheat.

IV. Nitrogen management experiments.

Currently no adjustment is made in NDSU recommendations concerning the grower's choice of N source, or his decision to use fall or spring application. The philosophy that a "pound of N is a pound of N" is used. It is recognized, however, that conditions exist in a recropping situation where all N sources, placements, or timing may not perform similarly. Ammonia volatilization, erosion loss, microbial immobilization, leaching, and denitrification are processes that may alter the relative efficiency of the various N management schemes available to the grower.

These experiments were designed to test the relative efficiency, as measured by plant response, of several N management schemes. Sources and placements were anhydrous ammonia (AA) deep, liquid urea-ammonium nitrate (UAN) deep, UAN surface, urea surface, and ammonium nitrate (AN) surface. The N rate was 60 lb/A and each of the above source/placement combinations was applied in the fall and spring. At least a week transpired in the spring between surface application and subsequent tillage or seeding. This was done to give a "worst case" testing of the surface applied urea-based fertilizers.

The average effect of N source and placement, averaged across time of application, is shown in Table 7. Data from Bowbells is omitted, due to the lack of N response at that site. Significant overall response to N was noted at the other three sites. Deep placements of N gave the highest yield at the Fortuna site, with urea giving the lowest yield. Anhydrous ammonia gave the highest yields at the Stanley location, followed by the UAN and AN treatments, with urea also giving the lowest yield at this site. This is an initial indication that significant ammonia volatilization occurred with the urea source at these two sites. This is hardly surprising, since the urea was applied on the surface under very heavy trash (untilled wheat stubble from the previous crop) conditions at these two sites. This conforms with present theories of urea loss. Such urea losses were not observed at the Williston E location. At this location, the yields seem to be favored by deep placement rather than source. Average yield response to N was less at this site, however. Also, a light rain occurred the night after the spring fertilization treatments, which sould minimize urea losses at this site.

Table 7. Average effect of N source and placement on wheat yields.

	Site+			
Treatment*	Fortuna	Stanley	Williston E	Average
	bu/A			
No N	17	22	17	19
AA deep	33	30	21	28
UAN sfc	29	28	19	25
UAN deep	33	28	22	28
Urea sfc	25	25	20	23
AN sfc	31	28	19	26

*Averaged across fall or spring application, N rate was 60 lb/A.
+Bowbells omitted from table, no effect of N on yield.

The average yields from these sites show the highest yield from AA and UAN deep, followed by AN and UAN surface, and followed by urea surface. Although some of these yield differences are not great, the data suggest some benefit from deeper placement, and ammonia losses from surface-applied urea.

These conclusions are mostly substantiated by the grain N uptake data (Table 8). The average uptakes rank in approximately the same order as grain yields, with deep placements giving the highest uptake and urea the lowest. This is partially due to the fact that grain yield is one factor in calculating grain N uptake.

Table 8. Average effect of N source and placement on grain N uptake.

Treatment*	Site+			
	Fortuna	Stanley	Williston E	Average
	lb N/A			
No N	23	31	23	26
AA	42	30	35	36
UAN sfc	36	28	32	32
UAN deep	45	27	38	37
Urea sfc	32	25	34	31
AN sfc	40	28	33	34

*Averaged across fall or spring application, N rate was 60 lb/A.
+Bowbells not included in table, no effect of N on yield.

Forage N uptake (milk stage) is presented in Table 9. This is a measurement with much higher experimental variability than grain yield or grain N uptake, as we used a non-destructive tiller count and random tiller weight method to estimate dry matter production. This data does not substantiate the urea losses observed in the grain yield data, but the averages do suggest a placement effect, in favor of deep placement. This effect, if real, could be explained in part by microbial N immobilization which could occur with surface N applications in heavy stubble. Again, these conclusions are tentative until the statistical significance can be studied in depth.

Table 9. Average effect of N source and placement on total N uptake in wheat forage.

Treatment*	Site+			
	Fortuna	Stanley	Williston E	Average
	lb/A			
No N	17	30	33	27
AA	38	58	56	51
UAN sfc	25	49	56	43
UAN deep	40	49	66	52
Urea sfc	31	43	57	44
AN sfc	36	42	59	46

*Averaged across fall or spring application, N rate was 60 lb/A.
+Bowbells not included in table, no effect of N on yield.

In general, the main effect of application time was non-significant for all measured variables. No trends could be observed in favor of a single timing.

V. Chloride fertilization of small grains.

Chloride-containing fertilizers have been shown to reduce root disease severity in Oregon. Significant but erratic responses to "potash" fertilizers have been documented in ND and MT for many years, especially with barley. These experiments were designed to test the theory that perhaps the "potash" responses on small grain that have been documented in ND and MT could actually be chloride responses, where chloride had a beneficial effect in reducing root disease severity.

Treatments were the "check" (60 lb N and 30 lb/A P_2O_5), the "KCl" treatment (60 lb N, 30 lb P_2O_5, and 100 lb/A K_2O as KCl), and the "$CaCl_2$" treatment (60 lb N, 30 lb P_2O_5, and 94 lb/A Cl as $CaCl_2$). Root disease severity was estimated using standard methods.

Data from other sites are included, courtesy of Dr. Bill Dahnke and Dr. Bob Stack.

The effect of chloride fertilization on root rot severity is shown in Table 10. Overall disease severity was not large at any particular site, with the exception of Ypsilanti where disease reached moderate levels. None of the differences in disease severity were great, but an interesting trend appears. Root disease severity for the chloride treatments was numerically equal or less than the check at 11 of 12 sites. The unusual site was Minot HRSW. At all other sites, the data tends to suggest a beneficial effect of chloride on root rot severity. Again, the overall intensities were not large and the differences were not large. There seems to be an average 10% reduction in disease from chloride fertilization.

Table 10. Effect of chloride-containing fertilizers on common root rot severity. North Dakota, 1982.

Nearest Town	Crop	Treatment[+] Check	KCl	$CaCl_2$
		— Disease severity[++] —		
Ypsilanti	HRSW	3.1	2.4	2.7
Spiritwood	HRSW	2.0	1.9	1.9
Spiritwood	Barley	2.5	2.2	2.4
Spiritwood	HRSW	2.3	1.9	2.2
Spiritwood	Barley	1.7	1.6	1.5
Braddock	HRSW	1.9	1.7	1.5
Stanley	HRSW	2.1	1.7	1.8
Fortuna	HRSW	1.6	1.6	1.5
Rawson	HRSW	2.4	2.2	2.1
Minot	HRSW	2.1	2.3	2.2
Minot	Durum	2.1	2.1	2.0
Minot	Barley	2.3	2.1	2.1
Average over-all		2.2	2.0	2.0

[+] Check = 60-30-0, KCl = 60-30-100-94 Cl, $CaCl_2$ = 60-30-0-100 Cl.
[++] 1 = none 2 = slight 3 = moderate 4 = severe.

Additional research is needed to confirm these findings. Root disease ratings are a measurement with a large inherent experimental variability. Experiments with more precision are planned in 1983, since these 1982 experiments suggest a possible reduction in root disease from chloride fertilization.

Effect of chloride fertilizers on grain yield is presented in Table 11. In general, no effect on yield was observed for HRSW, even though some encouraging reductions in root disease severity occurred at some sites. The yield data for barley seems much more encouraging. This agrees with work in MT and ND which has shown scattered barley yield increases to "K" on high K soils. This also agrees with the general consensus of pathologists, that barley yields are more easily reduced by root rot than HRSW.

Table 11. Effect of chloride-containing fertilizers on grain yield. North Dakota, 1982.

Nearest Town	Crop	Treatment		
		Check	KCl	$CaCl_2$
		bu/A		
Ypsilanti	HRSW	41	40	40
Spiritwood	HRSW	54	53	53
Spiritwood	Barley	47	51	48
Spiritwood	HRSW	37	37	36
Spiritwood	Barley	62	65	65
Braddock	HRSW	42	40	46
Stanley	HRSW	26	28	27
Fortuna	HRSW	29	31	29
Rawson	HRSW	38	36	37
Minot	HRSW	33	34	35
Minot	Barley	83	87	84
Minot	Durum	45	41	44
Williston	HRSW	20	20	18
Bowbells	HRSW	16	16	14
Average HRSW		34	34	34
Average Barley		64	68	66

Not enough data (one site) exists to make conclusions concerning durum wheat. In general, root pathologists rate durum as being intermediate in susceptibility to common root rot.

VI. Use of this data.

The PPI and FAR may use the data in parts I-IV of this report for their programs. The authors request that the data in part V not be released at this time for two reasons: 1) The data presented is tentative in nature and another year's confirmation is desired before the results are made public. 2) Some of the data presented was not generated by the authors and permission to release such data would have to come from the other researchers as well.