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Inoculation and Fertilization of Field Pea

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Abstract

Many producers place nitrogen (N) and/or phosphorus (P) with pea seed at planting in the belief that seed yield or quality are enhanced by in-row fertilizer applications. An objective of this research is to determine if applications of N, P, or N + P fertilizers affect pea growth, seed yield, or seed quality. Different forms of *Rhizobium* inoculant also are being compared to determine if seed yield or quality are affected by the inoculant form used. A study began in 1999 at North Dakota State University Research Extension Centers located at Carrington, Dickinson, and Minot. Different N and P fertilizers were applied in-row or broadcasted in pea plots at each location. No advantage in pea plant stand, root nodule development, seed yield, or seed quality resulted from applications of fertilizer. No difference in seed yield and quality resulted when different inoculant forms were used. This study will be continued in 2000.

Introduction

Pea is a legume that is capable of meeting a portion of its N needs biologically, as long as roots have been colonized by *Rhizobium leguminosarum,* a N-fixing bacteria. Production guides suggest that somewhere between 30% to 80% of a pea crop's N needs can be met through biological fixation (Ali-Khan and Zimmer, 1989; Bowren et al., 1986; Murray et al., 1979). The rest of the N must be provided from the soil or from fertilizer applications.

Soil N levels generally are adequate for optimum pea yield and quality, as long as biological N-fixation occurs. Lack of a yield response to N fertilizer confirmed that biological fixation was adequate for maximizing pea yield in temperate environments (Crozat et al., 1994). Broadcasted N fertilizer reduced pea yield as rates were increased from 0 to 180 lb/acre in soils already containing large amounts (> 135 lb/acre) of N (Gubbels, 1992).

Nitrogen fertilizer applications generally inhibit biological N-fixation by *R. leguminosarum*. Nitrogen-fixing nodules never formed on inoculated pea roots when 100 lb N/acre was broadcasted shortly after planting (Sosulski and Buchan, 1978). Reducing the N rate did inhibit nodule formation initially, but nodules developed later. The inhibitory effect of N fertilizer on nodule formation results from the fertilizer’s contribution to the soil N pool. Bowren et al. (1986) concluded that nodule formation became inhibited as soil N levels approached 35 lb/acre, and were progressively inhibited as levels exceeded this amount. This suggests that N fertilizer applications will reduce biological N-fixation by *R. leguminosarum*, except where the amount of N applied as fertilizer plus that contained in the soil is less than 35 lb/acre.

Small N fertilizer applications have stimulated nodule formation on pea roots in some low N environments (Oghoghorie and Pate, 1971), as with other pulse crops (Kauskik et al., 1995). Bowren et al. (1986) suggested that applications of 10 to 20 lb N/acre enhanced pea seedling growth prior to nodule development in low N soils. Slinkard and Drew (1988) concurred with this recommendation, but warned that the N fertilizer should not be applied in-row. Musbach (1934) concluded that in-row applications of N fertilizer caused germination injury to peas, particularly in dry or coarse-textured soils. Seed yield and quality were reduced when fertilizer containing 13 lb N/acre was applied in-row compared with broadcasted.

In-row applications of fertilizers containing N caused germination injury to peas in central North Dakota (Franzen, 1998). No advantage in yield resulted from applying fertilizer with the seed compared with an unfertilized treatment. These data concur with results from experiments located in other regions of the state (Carr et al., 1998), and raise the question of why this practice is used in North Dakota. In some instances, in-row placement of N even reduced pea yield (Carr et al., 1998), suggesting that in-row fertilizer additions can be detrimental and should be discouraged.

Applications of fertilizers containing nutrients besides N have been shown to cause germination injury to peas when applied in-row. Musbach (1934) found that pea stands were reduced when ordinary superphosphate (0-20-0) was applied in-row, but concluded that the germination injury was warranted because of the increased vigor of the surviving plants. Seed yield was reduced when triple superphosphate (0-46-0) was applied at 40 and 60 lb P/acre in-row compared with banding fertilizer beside seed, but not at a 20 lb/acre rate (Gubbels, 1992). Stand reductions were associated with in-row applications of P at all three rates.

Peas were more sensitive to in-row placement of P than either lentil or fababean (Henry et al., 1995). Pea yield was less when P was applied in-row compared to a side-banded treatment at three different locations over a three year period. Plant stand reduction probably explained the suppressive effect of in-row applications of P fertilizer on pea yield. It was concluded that side-banding is preferred for peas compared with in-row placement of P fertilizer.

Applications of P-containing fertilizers with pea seed reduced plant stand in experiments in North Dakota. Pea stand was reduced by 15% from the in-row application of 5 lb/acre P as MAP compared with an unfertilized treatment in central North Dakota (Franzen, 1998). Plant stand was reduced by 34% from the in-row placement of 6 lb/acre of P as triple superphosphate in southwestern North Dakota (Carr et al., 1998). Seed yield and quality were not enhanced by in-row P additions at any location.

Peas require adequate amounts of P (Bowren et al., 1986; Slinkard and Drew, 1988), and yield and seed quality can be enhanced by P fertilizer in soils testing low in P (Pulung, 1994). Response to P fertilizer is variable even in low P soils, however, which may result from the confounding effect that different *R. leguminosarum* strains have on fertilizer response. An inoculant X fertilizer interaction occurred when single strain and multi-strain inoculants were compared (Sosulski and Buchan, 1978). Seed CP concentration was greater when a single *R. leguminosarum* strain was used to inoculate peas compared with a commercial multi-strain inoculant, and N fertilizer was applied. Differences in seed CP concentration were not detected between inoculant treatments when fertilizer was not applied.

Previous research suggests that complex factors govern the response of peas to N and P fertilizer applications. This is particularly true in regards to in-row fertilizer placement. Most research indicates that germination injury will result when N and P fertilizers are applied in-row, although exceptions exist. In some instances, seed yield and quality can be reduced. Environmental factors confound a consistent response to in-row placement of fertilizer, as do pea inoculant X fertilizer interactions. Development of consistent fertilizer recommendations for pea growers in North Dakota from previous experiments has been impossible because the experiments differed in experimental design and analyses. A multi-location experiment is needed to determine if in-row placement of N and P fertilizer enhances seed yield or quality under North Dakota growing conditions.

The procedures of this study are to determine if:

- yield or quality of peas are enhance by in-row and broadcasted placement of N, P, and N + P fertilizers in low soil N and P environments;
- seed yield and quality response results from inoculating peas with different formulations of commercially available R. leguminosarum; and
- an inoculant formulation x fertilizer interaction exists for seed yield and quality.

Procedures to attain objectives

Objective 1

An experiment began at Carrington, Dickinson, and North Central (Minot) Research Extension Centers in 1999. The experiment was located in a field that was low in N (< 30 lb/acre) and P (< 8 ppm Olsen P) at each location, and where lentil and pea had not been grown for at least five years. Seventeen treatments were included (Table 1). Fertilizers contained in the treatments were distributed from the Dickinson Research Extension Center (DREC) to other locations, as was pea inoculant. A single supplier provided the pea inoculant in 1999, and the same *R. leguminosarum* strains were provided in dry peat, liquid, and granular forms. The inoculant was stored in a dark, refrigerated environment until just prior to seeding, when the inoculant was placed with peas.

Fertilizer was applied in all plots receiving "broadcasted" fertilizer treatments using a small-plot planter. The peas were planted in a separate operation. Fertilizer was placed with peas during seeding in the same band in a single-pass in plots receiving "with seed" fertilizer treatments. The green-cotyledon pea cultivar Majoret was seeded at 325,000 pure live seed/acre at each location.

Plots were arranged in a randomized complete block design with blocks replicated four times. Individual plot dimensions varied between sites but were a minimum of 4.5 ft by 20 ft. Plots were comprised of 7 to 9 rows, depending on the location.

Stand counts were made at approximately 14 and 30 days after planting (DAP) by counting the number of plants in a 10.76 ft^2 (1 m^2) area from the center four rows of each plot. Ten plants were randomly selected and excavated at 30 DAP so that roots could be observed for evidence of N-fixation activity. The presence of abundant pinkish-red nodules were considered as evidence that N-fixation was occurring. The absence of nodules, or the presence of cream-colored nodules, were considered as evidence that *R. leguminosarum* were not fixing N effectively.

The experiment was managed at each location following acceptable agronomic procedure for optimum pea yield and quality. Upon reaching physiological maturity, a small-plot combine was used to harvest peas. Seed yield and test weight were determined for the entire plot; seed weight will be determined from a 250 seed sub-sample.

Sub-samples of peas from plots receiving each treatment were randomly selected from three blocks and analyzed for CP concentration by standard procedures. Separate sub-samples were collected following the same procedure and evaluated for food grade quality at the Federal Grain Inspection Service facility located in Grand Forks.

Data within the experiment were analyzed using the GLM procedure available from SAS for each variable tested. Nonorthogonal contrasts will be used to compare means of the unfertilized with fertilized treatments, fertilizer placement methods, and fertilizer rates, where *F*-tests indicate that significant differences exist between treatments (P # 0.05). Linear and polynomial regression analyses will be performed using the REG procedure from SAS. Plant count and seed yield, weight, CP concentration, and test weight will be the dependent variable and fertilizer rate will be the independent variable for in-row MAP treatments applied with peas inoculated with a dry peat formulation.

The experiment will be analyzed across locations and years if the *F*-test for homogeneity among sites indicates that variances between environments are homogeneous for each variable tested. The experiment will be analyzed within locations and years if the variances are heterogeneous, or if locations, years, or a location X year interaction are significant for any variable tested.

Objectives 2 and 3

The procedure used to meet *Objectives 2* and *3* were identical to that used to meet *Objective 1*, except for the analyses of the data. Non-orthogonal contrasts will be used to compare means of treatments, but different treatments will be compared than those under *Objective 1*. Contrasts will include means of unfertilized, non-inoculated treatments with unfertilized, inoculated treatments, and means of fertilized treatments with different inoculant formulations.

Results and Discussion

Preliminary statistical analyses indicate that in-row applications of only 4 lb N and/or 20 lb P_2O_5 never increased and sometimes reduced pea plant stand in 1999, depending on the fertilizer used. An in-row application of 40 lb MAP (4 lb N + 20 lb P_2O_5)/acre reduced pea plant numbers at both Carrington and Dickinson, while an application of 48 lb TSP (20 lb P_2O_5)/acre reduced plant numbers at Minot. Plant stand was not affected when fertilizers were broadcasted. These data concur with results of previous research at Dickinson and fail to support current recommendations that MAP can be applied safely with pea seed at 40 lb MAP/acre.

Pea plant roots were evaluated for the presence or absence of nodules at Carrington and Dickinson. Fewer nodules developed when 80 lb N/acre was broadcasted prior to planting at both locations, compared with unfertilized plots. Smaller nodules developed when 80 lb N/acre was applied at Dickinson, but not at Carrington. Applications of 4 lb N and/or 20 lb P_2O_5 did not affect nodule numbers or size, whether broadcasted or in-row.

Fertilizer applications did not increase pea yield, test weight, or seed weight at any location. Crude protein concentration or food grade were not affected at Dickinson, where comparisons were made between fertilized and unfertilized peas. These preliminary data fail to indicate any advantage of applying fertilizer to properly inoculated peas for yield and quality.

Different forms of *Rhizobium* inoculant (granular, liquid, and peat-based) were compared for pea plant growth, yield, and quality in this same study. No differences in pea yield and quality occurred between *Rhizobium* inoculant forms at any location.

This study will be repeated at Carrington, Dickinson, and Minot in 2000.

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Table 1. Treatments of an experiment located at Carrington, Dickinson, and North Central Research/Extension Centers during 1999 and 2000.

---------------------------------- Treatment ------------------------------------	-- lb N/P_2O_5 applied per acre --
0 inoculant + 0 fertilizer	0/0
Dry peat inoculant + 0 fertilizer	0/0
Dry peat inoculant + 20 lbs/acre 11-52-0 [with seed]	2/10
Dry peat inoculant + 40 lbs/acre 11-52-0 [with seed]	4/21
Dry peat inoculant + 48 lbs/acre 0-45-0 [with seed]	0/21
Dry peat inoculant + 48 lb/acre 0-45-0 [broadcasted]	0/21
Dry peat inoculant + 13 lbs/acre 34-0-0 [with seed]	4/0
Dry peat inoculant + 40 lbs/acre 11-52-0 [broadcasted]	4/21
Liquid inoculant + 0 fertilizer	0/0
Liquid inoculant + 40 lbs/acre 11-52-0 [with seed]	4/21
Liquid inoculant + 40 lbs/acre 11-52-0 [broadcasted]	4/21
Liquid inoculant + 48 lbs/acre 0-45-0 [broadcasted]	0/21
Granular + 0 fertilizer	0/0
Granular + 40 lbs/acre 11-52-0 [with seed]	4/21

Granular + 40 lbs/acre 11-52-0 [broadcasted]	4/21
Granular + 48 lbs/acre 0-45-0 [broadcasted]	0/21
0 inoculant + 235 lbs/acre 34-0-0 [broadcasted]	80/0