Final Report – 2021 (for Wyoming Bean Commission)

Effect of Nitrogen Rates on Yield of Dry Bean with and without Fertilizer K – Powell REC

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Introduction

After conducting several field studies in Lingle with varying N rates and conducting two studies in Powell (2019 and 2020), we have pretty good evidence that it rarely pays to apply more than 60 pounds N per acre regardless of initial soil N concentration. Since dry bean is an N_2-fixing legume, it stands to reason that fertilizer N applications are going to vary in effectiveness. Across the US Dry Bean Belt, and across the world, dry bean producers and researchers routinely question the need for fertilizer N and what rates are truly needed.

Many factors determine how much N a dry bean crop might need to optimize yield. Of course, existing soil factors such as available NO_3-N, soil organic matter concentration, and the yield goal are among those factors. In addition to these three factors, the concentrations of other soil nutrients such as P and K could indirectly affect how much fertilizer N would be optimal. In 2019, we compared a zero-N fertilizer rate to 50 units across two different fertilizer P rates (zero and 140 units of P_2O_5). In 2020, we again tested those two same N rates against three P rates (zero, 67, 135 units of P_2O_5). In both years, no effect was observed from any of those N and P rates. These two tests included ten different dry bean genotypes so the lack of response did not appear to be genotype specific.

Given those results from 2019 and 2020, we decided that soil P levels were not involved in the lack of response to N. However, we have recently begun to question the availability of soil K and whether K might be limiting and thus, affect dry bean's response to N. Suspecting that K is limiting is not a new concept. A typical soil test will provide information on concentrations of available K (and other cations such as Ca, Mg, Na) but oftentimes, the soil test also includes what is called the base saturation test. Because Ca, Mg, and K are cations that compete with one another, the base saturation test provides information on whether the ratios between Ca, Mg, and K are in balance or out of balance (i.e., too much Ca/Mg prevents root sites from accessing enough K). Our calcareous soils typically have a very low base saturation value for K which means that despite being plentiful in the soil, available K might be too low to compete with Ca and/or Mg to meet the needs of high-yielding dry bean crops expected by Wyoming producers.

Objectives

The primary objective of this test was to compare soil-applied N rates combined with different soil-applied K rates in the Bighorn Basin on dry bean. Recent evidence with alfalfa suggests that K may be limiting on our Wyoming soils and combining N and K rates will give us some important data on whether K is deficient on dry bean and/or whether the lack of N effects are really caused by low soil K.

Methods

In order to conduct this test, we identified a one-acre field at PREC with a relatively low soil-N concentration. Within that field, we established 18 strips (11-feet wide) and applied 0, 40, or 80 pounds N per acre and/or 0, 100, and/or 200 pounds K_2O per acre. This created nine unique treatments with each treatment/strip replicated twice. The results of the pre-season soil sample are provided in Table 1.

Concentrations of N and P found in the incoming irrigation water that were collected mid-to-late-season are also provided in Table 1. No other fertilizers were applied to the plot test area although one recommendation called for P, S, and Zn (which was not applied).

Plots were sown on 2 June 2021. Plots were six-rows wide with a 22-inch row spacing, and 15-foot length. Seeding rate was approximately 100K per acre. Seven cultivars and three of our own experimental lines (LPID-series) were tested within each of the 18 strips (please see Results section for the cultivar entries). The study consisted of 180 plots. Flowering dates were recorded twice weekly throughout July. For maturity, buckskin pod date was recorded for each plot by also scouting twice weekly.

Normalized difference vegetation index (NDVI) was recorded on 23 June and 2/4 August. Ten leaf blades (third uppermost trifoliolate) were collected on 27 July for leaf mineral analysis (N, P, K, Ca, S, Mg, Fe, Zn, B, Cu, Mn). Leaf chlorophyll was recorded on 5 August 2021 on a third uppermost trifoliolate leaf blade (three leaflets per plot). Devices used for NDVI, leaf blade analysis, and leaf chlorophyll are shown in Figure 2.

Harvest began on 10 September for the early-maturing cultivars and was ultimately completed by 21 September with plots being harvest as they matured. A Zurn research plot combine was used to collect grain from the two-center rows of each plot. Seed was cleaned free of trash and dirt prior to collecting yield weights. Ultimately, yield and seed size (a.k.a., number of seed per pound) were recorded. Additionally, soil samples were collected from each strip immediately after harvest.

Table 1. Pre-season soil analysis in 2021 for the NK genotype study.

Soil Trait	**Concentration or Value**
Nitrate-N	7 ppm
Ammonium-N	3.3 ppm
Phosphorus (P)	12 ppm
Potassium (K)	206 ppm
Magnesium (Mg)	4.7 ppm
Sulfate-S	22 ppm
Zinc (Zn)	0.9 ppm
Iron (Fe)	8.3 ppm
Manganese (Mn)	4.6 ppm
Copper (Cu)	0.7 ppm
Boron (B)	0.62 ppm
pH	8.0
Organic Matter	2.04%
CEC (meq/100g)	20.5
Incoming Water NO_3-N	0.59 ppm
Incoming Water NH_4-N	<0.1 ppm
Incoming PO_4-P	0.01 ppm

Figure 2. RapidScan CS-45 used for NDVI (left), example of a ground leaf sample (center), and the SPAD-502 leaf chlorophyll device (right).

Results

Vegetative indexes (NDVI) on 23 June and leaf chlorophyll were unaffected by N or K fertility (Table 2). The same was true for the 2/4 August sampling (Table 3). However, cultivars did differ significantly for NDVI (Table 4). The cultivar 'Max' had higher NDVI in early July than the other eight cultivars. In general, there were no N-K fertility-by-cultivar interactions for NDVI. However, a significant K rate-by-genotype interaction was observed for leaf chlorophyll (Table 5). Soil-applied N did have a tendency to increase leaf blade N concentration (Figs. 3 & 4). However, soil-applied K did not appear to increase leaf blade K concentration (Figs. 5 & 6).

Flowering and maturity dates did not differ among the N-K fertilizer treatments (Tables 6 & 7). Likewise, upright stature did not differ among the N-K fertility treatments (Table 8). For yield, no differences were observed among the nine different N-K fertility treatments (Table 9). Seed size and the number of seed per pound were also similar across the N-K fertility treatments (Tables 10 and 11).

In contrast to the yield similarity among the N and K treatments, cultivars/genotypes differed significantly for most yield-related traits. Yield, yield components, and maturity for each is provided in Table 12. An experimental line, PT9-5-6, which we've grown frequently here in Powell, ranked first but PT9-5-6 was only significantly greater than Max and Croissant. Poncho, Othello, and Max were clearly the earliest to mature.

Post-harvest soil N and K concentrations were not different among the N-K fertility treatments (Tables 13, 14, 15, & 16). Other soil traits were unaffected by the N-K fertility treatments. We did observe higher Olsen-P concentrations in the top one-foot of soil as compared to the subsurface profile (Table 17). The K base saturation was notably low at 2.3% or lower within the surface and subsurface sample.

Table 2. Effect of the nine soil N-K treatments on NDVI on 23 June 2021 at Powell. Data are averaged across the ten genotypes.

N Rate		**K Rate**	
	0	100	200
0	0.28	0.24	0.26
40	0.25	0.27	0.26
80	0.26	0.25	0.27

P-values for the three sources of variation were: N Rate, 0.944; K Rate, 0.438; N Rate-by-K Rate, 0.028. The significant N-by-K interaction (P=0.028) appeared to be associated with a slightly decreasing NDVI at zero K as N rate increased combined with a slightly increasing NDVI at 100 K as N increased. We've concluded that this interaction is likely a statistical anomaly and not of biological importance.

Table 3. Effect of N rate and K rate on NDVI on 2/4 August at Powell. Data are averaged across the ten genotypes.

N Rate		**K Rate**	
	0	100	200
0	0.85	0.85	0.86
40	0.85	0.85	0.86
80	0.86	0.85	0.86

P-values for the three sources of variation were: N Rate, 0.284; K Rate, 0.198; N Rate-by-K Rate, 0.605.

Table 4. Effect of seven cultivars and three experimental lines on NDVI 23 June 2021 and NDVI on 2-4 August 2021. Data are averaged across the nine N-K fertilizer treatments. No fertility treatment-by-genotype interactions were found. P-values for genotype was P<0.001 for both sampling dates.

Cultivar/Genotype	**NDVI - June**	**NDVI - August**
Croissant	0.26	0.87
LPID-3	0.26	0.85
LPID-7	0.25	0.86
LPID-9	0.27	0.86
Max	0.30	0.84
Monterrey	0.27	0.87
Othello	0.24	0.85
Poncho	0.28	0.85
PT9-5-6	0.25	0.86
PT11-13-1	0.24	0.84
LSD (0.05)	0.01	0.01

Table 5. Effect of Cultivar/genotype and K Rate on leaf chlorophyll. The P-value for the K-Rate-by-genotype interaction was 0.009. The interaction appeared to be associated with the differential responses of LPID-7, Max, and Monterrey (green) to K Rate whereas the other seven genotypes showed relatively steady chlorophyll across K rates. Each value represents the average across six plots.

Cultivar/Genotype		**K Rate**	
	0	**100**	**200**
Croissant	51	51	49
LPID-3	46	48	47
LPID-7	50	45	46
LPID-9	47	46	49
Max	52	48	49
Monterrey	47	51	46
Othello	50	49	50
Poncho	49	49	51
PT9-5-6	48	49	48
PT11-13-1	49	46	47
LSD (0.05)	-- 3 --		

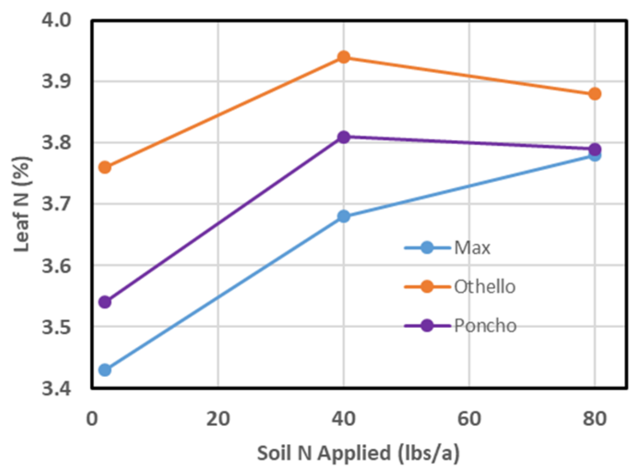

Figure 3. Leaf N concentration as affected by soil applied N rate for three early-maturing cultivars.

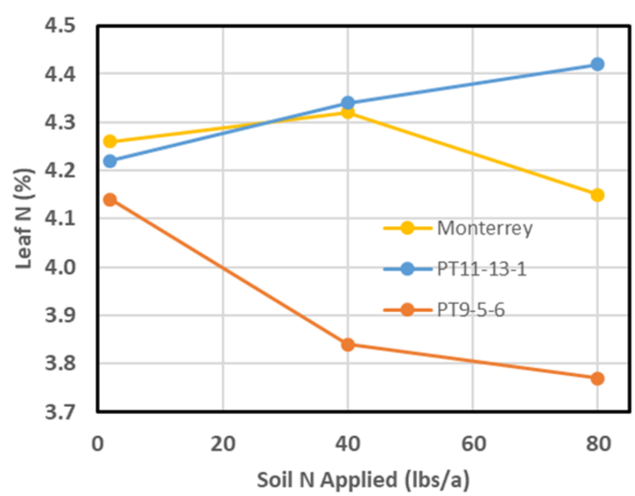

Figure 4. Leaf N concentration as affected by soil applied N rate for three late-maturing genotypes.

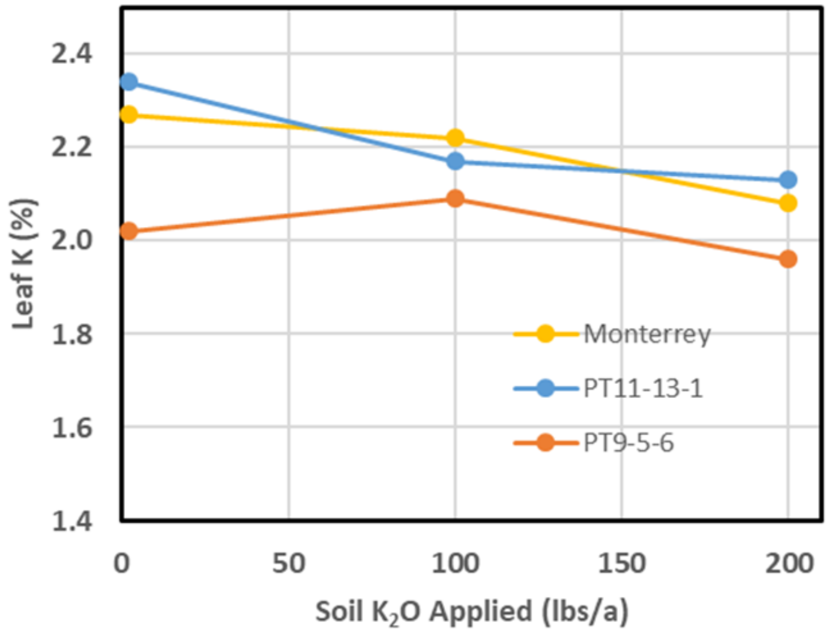

Figure 5. Leaf K concentration as affected by soil applied K rate for three late-maturing genotypes.

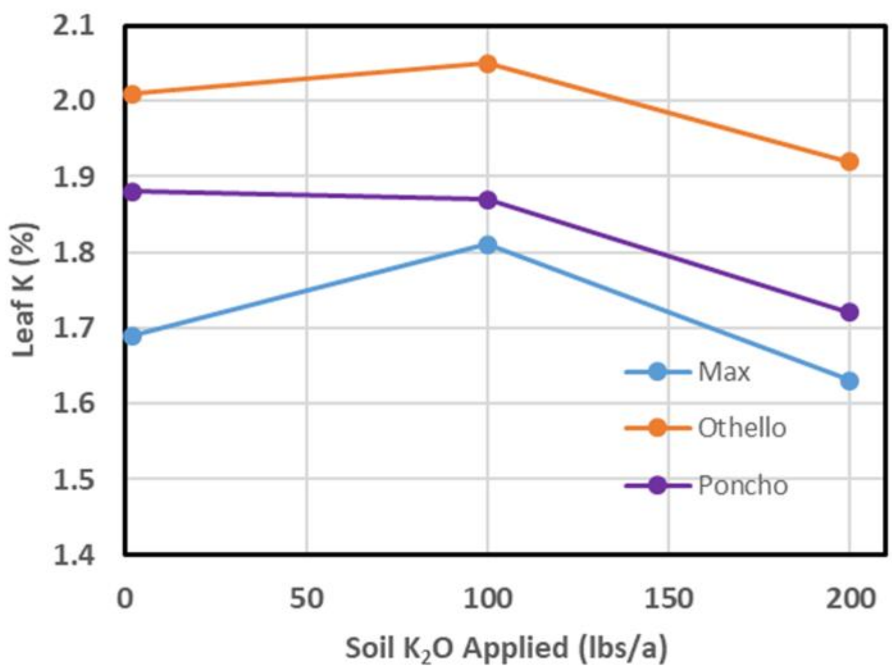

Figure 6. Leaf K concentration as affected by soil applied K rate for three late-maturing genotypes.

Table 6. Effect of N rate and K rate on flowering date (days after planting). Values are averaged across 10 genotypes. Each data point represents 20 plots.

N Rate		K Rate	
	0	100	200
0	45	45	46
40	46	46	45
80	45	45	46

Table 7. Effect of N rate and K rate on maturity date (days after planting). Values are averaged across 10 genotypes. Each data point represents 20 plots.

N Rate		K Rate	
	0	100	200
0	88	87	89
40	89	89	90
80	89	88	89

Table 8. Effect of N rate and K rate on upright stature. A value of 0 indicates that the canopy was fully prostrate and a value of 10 indicates the canopy was fully upright. Values are averaged across 10 genotypes. Each data point represents 20 plots.

N Rate		K Rate	
	0	100	200
0	6.7	6.5	6.2
40	6.4	6.7	6.6
80	6.6	6.8	7.0

Table 9. Effect of three N rates combined with three K rates on dry bean yield (lbs/a) at Powell in 2021. Data are averaged across the 10 entries with each data point representing 20 plots. P-values were:
N Rate, 0.589; K Rate, 0.121; N Rate-by-K Rate, 0.654.

N Rate		K Rate	
	0	100	200
0	4059	3646	3996
40	3765	3684	3981
80	3947	3829	3965

Table 10. Effect of three N rates combined with three K rates on dry seed size (mg) at Powell in 2021. Data are averaged across the 10 entries. Each value represents 20 plots.

N Rate		**K Rate**	
	0	100	200
0	391	381	390
40	385	387	393
80	395	388	388

Table 11. Effect of three N rates combined with three K rates on dry seed per pound at Powell in 2021. Data are averaged across the 10 entries. Each value represents 20 plots.

N Rate		**K Rate**	
	0	100	200
0	1169	1196	1169
40	1186	1182	1160
80	1159	1182	1177

Table 12. Effect of cultivar/genotype on yield, seed size, seed per pound, and maturity at Powell in 2021. Values are averaged across the nine N-K fertility combinations.

Cultivar/Genotype	**Yield**	**Seed Size**	**Seed per Pound**	**Maturity**
	lbs/a	mg	no.	dap
PT9-5-6	4051	361	1258	95
Monterrey	4006	373	1218	95
LPID-7	3965	360	1267	89
Poncho	3937	396	1149	78
LPID-3	3921	453	1008	93
Othello	3910	375	1214	78
LPID-9	3868	418	1088	99
PT11-13-1	3806	374	1214	93
Max	3641	412	1106	77
Croissant	3605	368	1234	91
LSD (0.05)	313	15	45	2

Table 13. Effect of soil-applied N and K rates on soil NO_3-N in the top 1-foot of soil just after harvest. Values are the average of two plots.

N Rate		K Rate	
	0	100	200
0	4	7	7
40	9	6	5
80	5	8	6

Table 14. Effect of soil-applied N and K rates on soil NO_3-N in the soil profile (12 to 24-inch) just after harvest. Values are the average of two plots.

N Rate		K Rate	
	0	100	200
0	1	1	1
40	1	1	1
80	1	1	1

Table 15. Effect of soil-applied N and K rates on soil K in the top 1-foot of soil just after harvest. Values are the average of two plots.

N Rate		K Rate	
	0	100	200
0	201	209	204
40	195	193	205
80	204	197	214

Table 16. Effect of soil-applied N and K rates on soil K in the soil profile (12 to 24-inch) just after harvest. Values are the average of two plots.

N Rate		K Rate	
	0	100	200
0	166	242	197
40	165	197	215
80	212	231	216

Table 17. Post-harvest soil traits in the top one-foot and the 12-to-24 inch depth of the profile.

Soil Trait	Surface (0 to 12-inch)	Subsurface (12 to 24-inch)
Ammonium-N	2.83 ppm	1.39 ppm
Olsen-P	16.0 ppm	5.8 ppm
Potassium (K)	202	204
Magnesium (Mg)	530	596
Calcium (Ca)	3582	4097
pH	7.9	8.04
CEC	22.8	26.0
Percent Base Sat K	2.3	2.0
Percent Base Sat Mg	19.3	19.0
Percent Base Sat Ca	78.4	79.0

Discussion and Summary

Current recommendations for N fertilizer to dry bean are often adjusted to account for pre-season soil N and soil organic matter as well as yield goal. However, some dry bean producers still apply 60 to 100 pounds of N at planting to ensure that the dry bean crop will not run out of N. Our limited observations (including those in this report) indicate that there was no gain nor penalty from applying 80 units of N or less. If N is relatively cheap, adding N fertilizer seems to be much like insurance. However, if N is expensive, producers need to be able to predict more accurately whether applying N will be cost effective.

This 2021 research did not support the idea that adding K may improve yield of the N-fertilized plots. One explanation for this observation could be that the 100 and/or 200 units of K_2O that we added made little difference. This explanation is supported by the post-season soil test data that showed K base saturation to be 2.3% and was not improved by the K fertilizer. Soil scientists often suggest that we strive for a soil K base saturation between 4% and 8% to minimize the possibility of K-deficiency.

Our measures of NDVI and leaf chlorophyll did not show differences among N and K fertilizer treatments. However, there were trends for fertilizer N to increase leaf blade N concentrations and for fertilizer K to increase leaf blade K concentrations. We have seen N fertilizer do this before in many of our previous studies, that is, we add N and seed increases in many traits except not for yield. In contrast to the lack of differences for the soil N and K treatments, our research documented differences in canopy traits and yield among cultivars.

Results of this research will complement previous research by fine-tuning the yield vs. N response curves that could ultimately give producers confidence that less N applied could increase profit. Adding the K-factor to this study did indicate whether or not there was a synergy between N and K.

If these observations of dry bean not responding to N fertilizer can be demonstrated on producer fields and growers become confident that they can reduce their N rates, then there is potential for the added benefit of the bean industry being acknowledged for having less impact on the environment. Our work with N fertilizer on dry bean these past six years was highlighted in UW's College of Agriculture Reflections Magazine so we are letting the public know that dry bean producers are supporting two goals at once, reducing grower fertilizer costs and reducing environmental impact. If reduced N rates are ultimately adopted by Wyoming dry bean producers, we believe we are less than three years away from this industry being nationally recognized for reducing its environmental impact.