OPVC CONTINUING PROJECT REPORT: 2015 **PROJECT YEAR:** 3 of 3

1. COVER PAGE

Project title: Fine-tuning P fertilizer rates for snap beans (2015)

PI: Ed Peachey
OSU Department of Horticulture
541-740-6712
Ed.Peachey@oregonstate.edu
4017 Ag & Life Sciences Bldg.
Corvallis, OR 97331

Co-PI: Aaron Heinrich
OSU Department of Horticulture
(541) 740-5750
Aaron.Heinrich@oregonstate.edu
4017 Ag & Life Sciences Bldg.
Corvallis, OR 97331

Cooperators: Scott Setniker, Gary Cook, Justin Chambers, Peter Kenagy, and Tim Winn

Total Project Request
Year 1: $12,733
Year 2: $14,109
Year 3: $12,014
Total: $38,856

2. EXECUTIVE SUMMARY

The overall objective of this three-year project was to provide farmers with updated fertilizer recommendations for snap beans. The goal was to maximize nutrient use efficiency without compromising bean yield and quality. This was accomplished by partnering with commercial bean growers to conduct on-farm research as well as conducting trials at OSU's Vegetable Research Farm.

To evaluate the response of snap bean to P fertilizer, paired field plots were set up at a total of 13 cooperator field locations (2014-15) from which total plant biomass and pod yield was compared for the grower P fertilizer rate vs. a zero P fertilizer control. Nine of the sites were planted to the cultivar 'OSU 5630', with the remaining varieties either small sieve or Italian varieties. **When Bray P1 soil test levels were ≥ 55 ppm, no yield response to additional P fertilizer was observed regardless of early or late planting date.** For the four sites with soil test P (STP) ≥30 but <55 ppm, all exhibited reduced growth and incomplete canopy closure by harvest compared to the grower P fertilizer treatment. But, despite the reduced growth, yield was increased by P fertilization at only 2 of the 4 sites. Replicated field trials conducted in 2015 at OSU's Vegetable Research Farm in a field with 32 ppm Bray P1 and 72 ppm K showed a yield response to P and K fertilizer that peaked at 40 lbs P2O5/acre and 100 lbs K2O/acre. Pooled data (2013-2015) indicate that significant savings in P fertilizer inputs could be attained by reducing P fertilizer rates to a minimal rate (15-30 lb P2O5 per acre) at sites with high soil test P (>55 ppm).

The results from the K fertilizer trial suggest that the recommendations given in the current OSU fertilizer guide for snap beans (FG 28) are adequate and no further research is needed. Based on data collected over 3 field seasons, we propose replacing the recommendations in FG 28 with the rates given in the table below. Because many growers are hesitant to leave out all P fertilizer, even when STP is ≥ 55 ppm, we suggest applying the quantity of P that is removed in the harvested pods (15 P2O5/acre) or what the whole plants takes up (30 P2O5/acre). Although 65% of the sites in this study were growing 'OSU 5630', nutrient uptake by small sieve and Italian varieties was similar in magnitude suggesting that the recommendations given are appropriate for all bush bean varieties grown in Oregon's Willamette Valley.

Soil test P	**Old**	**New**
(ppm)	**Band this amount of P_2O_5 (lb/a) at planting**	
0-15	120-150	**80-100**
15-55	90-120	**30-80**
over 55	60-90	**0-30**

OBJECTIVES

1. Evaluate and fine-tune P fertilizer rate recommendations for snap beans grown in Western Oregon.
2. Identify potential fertilizer savings by evaluating farmer nutrient management programs in relation to snap bean P fertilizer response and nutrient removal in the harvested product.
3. Generate a nutrient budget for N, P, and K for snap beans grown in Western Oregon.

3a. BACKGROUND

Oregon is the #2 snap bean producer in the US and grower's yields per acre are the highest of any other state (USDA NASS 2012). Despite the scale and importance of snap bean production, almost no research has been done on phosphorus (P) utilization over the past 30 yrs in the Willamette Valley (personal communication with John Hart, Emeritus professor, OSU Crop and Soils). As a result, P fertilization recommendations (OSU's Bush Beans: Western Oregon—West of Cascades Fertilizer Guide publication #FG 28) have not changed in decades despite changes in cultivars and increasing yields. Also, during this period, soil P levels have steadily increased due to P fertilization in excess of what is removed in the harvested product. If soil P levels are already at or above the critical value for optimum growth, any addition of P beyond crop needs represents a potential economic loss as well as an increased risk for negative environmental losses. The overall objective of this project is to provide farmers with fertilizer rate recommendations that will allow them to maximize nutrient use efficiency and yield while minimizing the potential for fertilizer losses.

Reviewing available literature (journal articles and other state's extension materials), current Oregon P fertilization recommendations (OSU's Bush Beans: Western Oregon—West of Cascades Fertilizer Guide publication #FG 28) are likely high. By comparing the pod yield from unfertilized P plots in grower fields to the adjacent field (standard practice), we can evaluate OSU's recommendations based on yield and soil test P values. Both early and late plantings must be evaluated because temperature affects P availability. Research from California showed a 40 percent reduction in available P with a 20°F decrease in soil temperature (Johnstone et al., 2005). In western Oregon, the minimum soil temperature at the 4-inch depth increases approximately 20°F between mid-April and early July.

To increase P utilization and reduce fertilizer use on soils with high levels of P involves understanding plant uptake, removal in the harvested product, and how much is cycled back into the soil with incorporated residues. For example, under high soil test P (STP) conditions, the P fertilizer application could either be eliminated or reduced so that P applied is equal to either total P uptake or what is removed in the harvested product. This would reduce fertilizer use and reduce or slow down the increase in STP values. Although high STP will not have a negative effect on the crop (i.e. is not phytotoxic), high levels increase the risk of a negative environmental losses.

Through this research we will be able to provide growers with better fertilizer rate recommendations. This will allow farmers to maximize yield while potentially saving money and reducing the risk of negative environmental consequences.

OBJECTIVES

1. Evaluate and fine-tune P fertilizer rate recommendations for snap beans grown in Western Oregon. Current P recommendations have not been revised in 30+ yrs despite production changes.
2. Identify potential fertilizer savings by evaluating farmer nutrient management programs in relation to snap bean P fertilizer response and nutrient removal in the harvested product.
3. Generate a nutrient budget for N, P, and K for snap beans grown in Western Oregon. By doing so, we can evaluate current fertilization practices and also provide recommendations for fertilizer rates to replace what is being removed in the harvested product yet maintain current soil test P and K levels.

3c. SIGNIFICANT FINDINGS

Phosphorus

- **In this study, no yield response to P fertilizer was observed when the soil test P (STP) level was ≥ 55 ppm Bray 1P.** This data set indicates that the current recommendations given in OSU's fertilizer guide *Bush beans: Western Oregon-west of Cascades (FG 28)* are excessive. When a field has an STP value ≥ 55 ppm Bray 1P, we recommend applying 15-30 lb P_2O_5/acre or even eliminating P fertilizer. **To be able to meet these low rates on high STP soils yet meet N fertilizer targets, shift away from low N, high P analysis fertilizers (i.e. 10-34-0) to higher N, lower P blends.**
- In a replicated field study at a site with 32 ppm Bray 1P to which 0, 40, 80, 120, and 160 lb P2O5/acre was applied, yield maxed out at 40 lb P2O5/acre.
- **Based on data from 3 field seasons and 14 sites, we propose the following changes to current P fertilizer recommendations:**

Soil test P (ppm)	**Old**	**New**
	Band this amount of P_2O_5 (lb/a) at planting	
0-15	120-150	**80-100**
15-55	90-120	**30-80**
over 55	60-90	**0-30**

- On average, total P_20_5 uptake in 18 grower fields over 2 field seasons using grower standard practices was 29 lb P205/A (range 19-41). The snap bean variety OSU 5630 was grown at 2/3rds of the test sites. P uptake for other varieties (small sieve and Italian) was similar in magnitude.
- **Of the total P uptake, approximately 45% was removed in the harvested product (pods) while 55% remained in the field.** The residue remaining in the field after harvest had a high N content (avg of 2.7%) and will break down rapidly; releasing N and P back into the soil.
- On average 1.5 lb P_2O_5/ton of pods was removed in the harvested product.
- The average grower fertilizer P_20_5 application was 75 lb/A (range 30-158) in 2013, 105 lb/A (range 50-158) in 2014, and 103 lb/A (range 38-180) in 2015. **If growers with STP ≥55 ppm applied only 30 lb P_2O_5/acre (what the crop takes up over a growing season), they could reduce P applications on average by 73 lb** P_2O_5**/acre (range 6-150). By reducing P yet maintain the same N rate, farmers could save an average of <u>$33/acre</u>** (range 3-67; this is based on the current prices of MAP and ammonium sulfate). This P fertilizer rate would be more P than is being removed in the harvested product and would slow down the increase in or maintain soil test P levels in the soil.

Potassium

- On average total K_2O uptake in grower fields using grower standard practices over 3 field seasons was 110 lb K_2O/A (range 62-172) . **Of the total K_2O uptake, an average of 35% was removed in the harvested product (pods) while 65% remained in the field to cycle back into soil.**
- In a replicated field study at a site with soil test K= 71 ppm to which 0, 50, 100, 150, and 200 lb K2O/A was applied, yield maxed out at 100 lb P2O5/A, **which is consistent with current K fertilizer recommendations and future research is not warranted at this time.**
- A rate of 200 lb K2O/A as KCl broadcast and incorporated on the same day as planting resulted in a decrease in emergence, plant growth, and yield. This was likely the result of a salt toxicity.

Nitrogen

- On average total N uptake in grower fields under grower standard practices over 3 growing seasons was 121 lb N/A (range 73-172). **Of the total N uptake, an average of 35% was removed in the harvested product (pods) while 65% remained in the field.**
- Due to a high N content of the foliage (avg of 2.7%) and warm fall soil temperatures, a significant fraction of the residue will rapidly mineralize (estimate of 15-30%) and be converted to nitrate. This nitrate will be subject to leaching with fall and winter rains unless a nitrate scavenging cover crop or fall crop is planted.

3d. METHODS

Paired on-farm P plots

To evaluate crop response to P fertilizer at current soil P test levels on-farm, growers (6 commercial farms) excluded P applications at planting from a small area of their field (seeder width by approximately 30-40' in length), and N and K were applied to these plots to replace the fertilizer that was excluded from these plots. To match grower N rates, ammonium sulfate was broadcast in the plot. If K was banded at seeding, KCl or K-K-Mag was banded approximately 3" from the seedline and 2" deep using a hand-push fertilizer applicator. Information for the 6 sites is given in Tables 1 and 2. At harvest, three 6 ft. sections of row were harvested in the 'No-P' plots as well as outside the plot (grower standard practice or 'Grower' plot) and pods were stripped by hand. Stand, pod yield, and foliage weight were recorded. The beans were mechanically graded and then dried at 60C. The foliage was shredded using a 5 hp shredder (MTD model 242-645-000), from which a subsample was collected and dried in an oven at 60C. The dried foliage and pods were then ground to a fine powder and sent to Brookside Laboratories, Inc for nutrient analysis.

Table 1. Site information for paired on-farm P plots.

						Grower fert application		
Site	Location	Seeding date	Variety	Previous crop	Avg row spacing	N	P2O5	K2O
					in		lb/acre	
1	Independence	8-May	OSU 5630	NA	30	100	100	100
2	Dever-conner	13-May	OSU 5630	corn	20	50	79	102
3	Dever-conner	14-May	Rimember	corn	28	53	111	60
4	N. Corvallis	26-May	OSU 5630	annual rye	23	68	180	0
5	Lebanon	6-Jun	Sahara	wheat	30	82	110	70
6	N. Albany	25-Jun	Piertton	Vetch/cereal CC	26	50	38	0
					2015 avg	**67**	**103**	**55**
					2014 avg	**84**	**105**	**88**
					2013 avg	**51**	**76**	**NA**

Table 2. Soil characteristics for the paired P plots and replicated P and K research farm trials.

Site	Soil series	Texture	Est CEC meq/100g	pH	Bray I P	K[1]
					ppm (mg/kg)	
1	Dayton	silt loam	15	6.2	51	89
2	Chehalis	silty clay loam	29	6.3	99	183
3	Cloquato	silt loam	23	5.8	88	288
4	Chehalis	silty clay loam	24	5.9	81	190
5	McBee	silty clay loam	37	5.2	32	181
6	Chapman	loam	19	6.0	53	219
Research farm	Chehalis sicl	Silty clay loam	21	6.5	32	71

1- Mehlich III

Research farm P and K replicated trials

Fertilizer P and K fertilizer response trials were conducted at OSU Vegetable Research farm located in Corvallis. Soil characteristics for the field site are given in Table 2. Each trial was replicated 4x in a randomized complete block design. The variety planted was 'OSU 5630'. Each plot was 10 ft by 25 ft. All operations occurred on May 5 (preplant fertilizer, incorporation, planting, and P and N banding). Dual Magnum was applied at 1.5 pints/A on May 6.

For the P trial, 120 lbs K2O/A as KCl was broadcast and incorporated using a rotary hoe to a depth of 6 inches. Immediately following incorporation the crop was seeded at a target rate of 10 plants/ft (~174,000 seeds/acre) on 30" rows. After seeding, triple super phosphate (TSP; 0-45-0) treatments were banded at the following rates using a hand pushed fertilizer spreader (4" over by 2" deep from the seed): 0, 40, 80, 120, and 160 lb P2O5/A. Ammonium sulfate (AS) was banded with the TSP at a rate of 40 lbs N/A.

For the K trial, KCl was hand applied evenly to each plot at the following rates: 0, 50, 100, 150, and 200 lbs K2O/A. The fertilizer was incorporated with a rotary hoe that was lifted up at the end of each plot to minimize soil and fertilizer movement between plots. After the crop was seeded (see above for spacing and density), P (TSP) and N (AS) were banded at a rate 100 lbs P2O5/A and 40 lbs N/A, respectively.

At 62 days after planting (July 16), an 8 ft section of row from each plot was harvested and the pods were stripped by hand. Stand, pod yield, and foliage weight were recorded. The beans were mechanically graded and then dried at 60C. The foliage was shredded using a 5 hp shredder (MTD model 242-645-000), from which a subsample was collected and dried in an oven at 60C. The dried foliage and pods were then ground to a fine powder and sent to Brookside Laboratories, Inc for nutrient analysis.

3e. RESULTS & DISCUSSION

Paired on-farm P plots

Marketable pod yield and P uptake is given Fig.1 & 2. Of the sites that had STP <55 ppm, only 1 site (6- N. Albany) showed a reduction of yield when P fertilizer was excluded. Plants at site 5- Lebanon in the 'No P' plots were smaller with incomplete canopy closure, but no decrease in yield was observed, though the pod grade was shifted so that more beans were in a smaller sieve size for the 'No P' plot. Although site 5 had the lowest STP (32 ppm), it was a late planting when soils were warm, possibly increasing the supply of P to the plant. A similar result was noted at ones site in 2014 where the plants were smaller in the 'No P' plot, but yield was the same. This suggests that at moderate soil test P levels (30-55 ppm) the plant partitions energy and resources into foliage growth rather than pod production.

Based on the data from 2014 and 2015, we are confident in releasing the following changes to P fertilizer recommendations:

Soil test P	**Old**	**New**
(ppm)	**Band this amount of P_2O_5 (lb/a) at planting**	
0-15	120-150	**80-100**
15-55	90-120	**30-80**
over 55	60-90	**0-30**

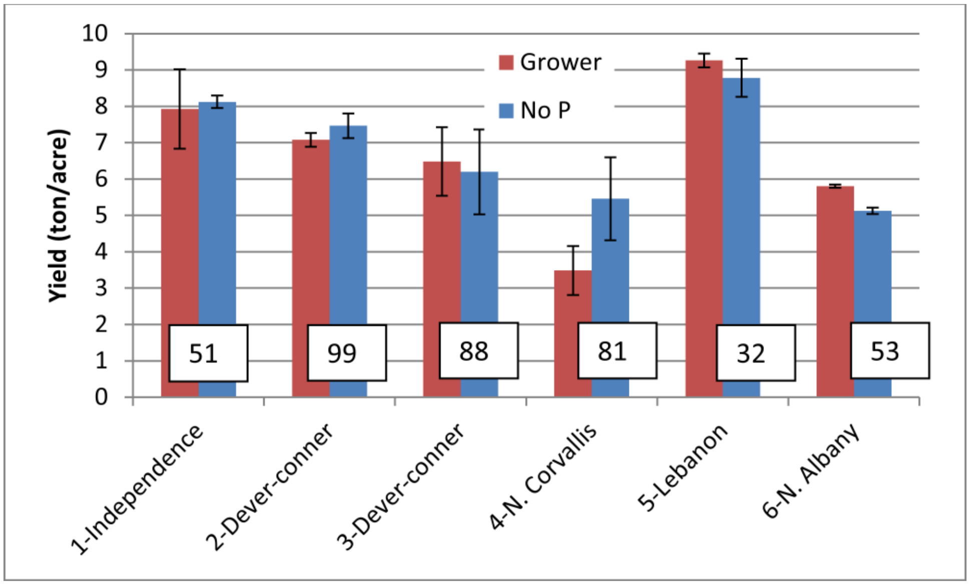

Figure 1. Marketable pod yield (#1 and #2's) from a plot in each grower field receiving no P fertilizer (No P) compared to the surrounding field that received the grower standard P rate (Grower). Error bars represent the SE of 3 subsamples (not true replicates). Values in boxes represent the pre-plant soil test Bray 1 P level in ppm.

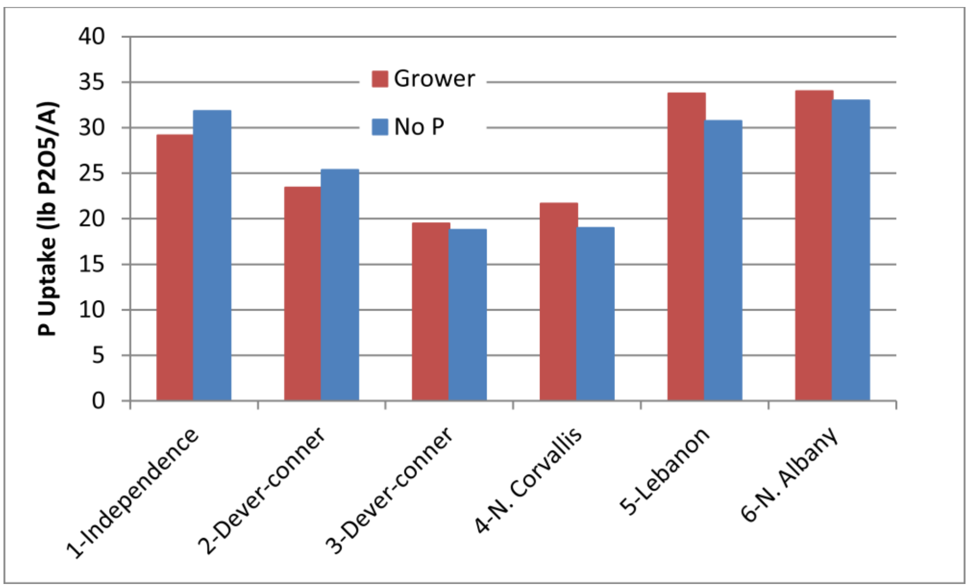

Figure 2. P2O5 uptake in aboveground biomass from a plot in each grower field receiving no P fertilizer (No P) compared to the surrounding field that received the grower standard P rate (Grower).

Nutrient uptake is given in tables 3-5. Results are similar to previous years. A significant portion of N, P, and K (65%, 56%, and 65%, respectively) is cycled back into the soil in the residues left in the field after harvest. To prevent the build-up of P to high levels, this cycling of P back into soil should be considered and future P fertilizer rates reduced. In the case of N, the tissue concentration is relatively high (avg 2.7%) and will release the N back to the soil quickly. If an overwintering crop is not planted, much of this N will leach in the form of nitrate to groundwater.

Table 3. P uptake in foliage and pods, and P removed from the field in the harvested product.

		Foliage		Pods		Total		P removed with pods	
		Grower	No P	Grower	No P	Grower	No P	Grower	No P
Site	Location	--------------------------------		lb P2O5/acre		--------------------------------		% of total	
1	Independence	14	14	15	17	29	32	52	55
2	DeverConner	12	14	12	12	23	25	51	46
3	Dever-Conner	10	8	10	10	19	19	50	55
4	N. Corvallis	16	12	5	7	22	19	24	38
5	Lebanon	17	16	17	14	34	31	49	47
6	N. Albany	24	22	10	11	34	33	29	33
	2015 avg	15	14	11	12	27	26	43	46
	2014 avg (n=7)	14	13	13	12	27	24	48	49
	2013 avg (n=5)	19	NA	13	NA	32	NA	41	NA
	3 yr avg (n=18)	**16**	**14**	**12**	**12**	**29**	**25**	**44**	**47**

Table 4. K uptake from Grower plots

Site	Location	Foliage	Pods	Total	Residue K2O returned to soil
		--------	lb K2O/acre	---------	% of total
1	Independence	38	36	74	51
2	Dever-Conner	61	37	98	63
3	Dever-Conner	72	39	111	65
4	N. Corvallis	60	15	75	79
5	Lebanon	72	51	123	59
6	N. Albany	84	61	144	58
	2015 avg	65	40	104	63
	2014 avg	65	37	102	62
	2013 avg	87	38	124	70
	3 yr avg	**72**	**38**	**110**	**65**

Table 5. N uptake from Grower plots

Site	Location	Foliage	Pods	Total	Residue N returned to soil
		-------------	lb/acre	-------------	% of total
1	Independence	64	59	123	52
2	Dever-Conner	55	39	94	59
3	Dever-Conner	43	32	76	57
4	N. Corvallis	56	17	73	77
5	Lebanon	101	46	147	69
6	N. Albany	99	63	162	61
	2015 avg	70	42	112	63
	2014 avg	68	43	111	61
	2013 avg	98	42	140	70
	3 yr avg	**79**	**42**	**121**	**65**

Cost analysis for reducing P fertilizer rates when soil test P is ≥55 ppm

When soil test P is high (≥55 ppm) there is the potential to reduce P fertilizer rates without sacrificing yield or product quality. Table 6 estimates the fertilizer savings if the farmers in our study were to eliminate or reduce their fertilizer rates. Because most farmers are reluctant to completely eliminate P fertilizer, we suggest that they apply 15 or 30 lb P2O5/A, which is what is removed in the harvested pods or taken up by the whole plant (pods and foliage), respectively. Even when 30 lb P2O5/A is applied, the average cost savings were $33/A.

Table 6. Cost savings when P fertilizer rates are reduced for high soil test P soils (≥55 ppm). The cost savings assumes that the only the P rates are changed (i.e., same N rate) and are based on a price of MAP (11-52-0) and Ammonium Sulfate (21-0-0) of $654/ton and $358/ton, respectively.

				P2O5 (lb/A)		
				0	15	30
Site	Year	Bray 1 P	P2O5 applied (lb/acre)		$/acre	
5	2014	73	36	16	9	3
1	2013	181	43	19	13	6
3	2013	121	44	20	13	6
2	2013	158	47	21	14	8
3	2014	55	60	27	20	13
2	2015	99	79	36	29	22
3	2015	88	111	50	43	36
5	2013	159	131	59	52	45
7	2014	387	135	61	54	47
6	2013	189	158	71	64	57
1	2014	64	158	71	64	57

6	2014	69	159	71	65	58
4	2015	81	180	81	74	67
		Avg	**103**	**46**	**40**	**33**
		Min	**36**	**16**	**9**	**3**
		Max	**180**	**81**	**74**	**67**

Research farm P replicated trials

P fertilizer response on gross pod yield is given in Fig. 3. Maximum yield was obtained at 40 lb P2O5/A. Additional fertilizer above 40 lbs did not result in a yield response, though foliage growth responded to rates >40 lbs (Table 7). Differences in P uptake for pods were not significantly different, but it was for the foliage (Table 7).

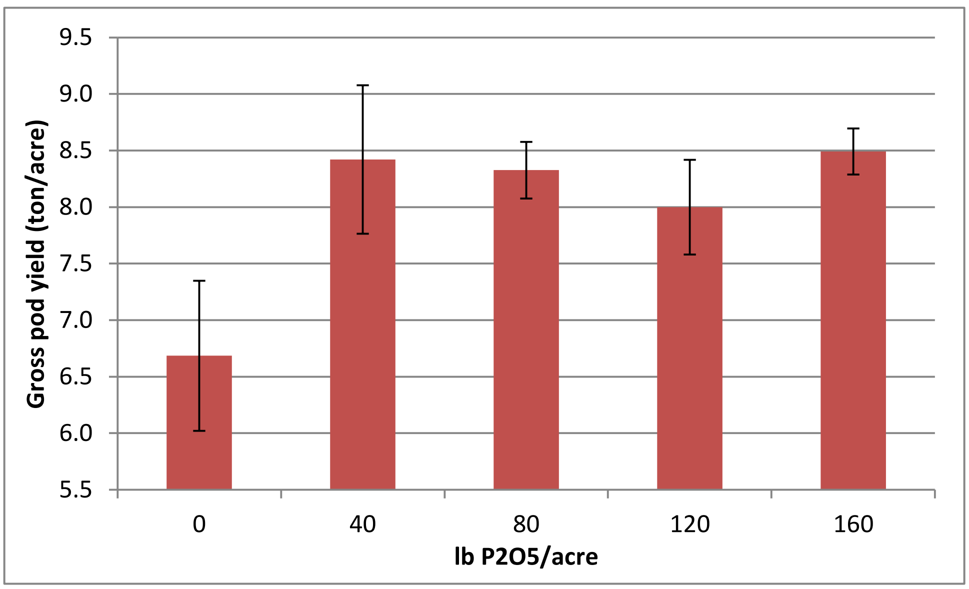

Figure 3. Gross pod yield from replicated P trial at OSU's Vegetable Research Farm in a field with soil test P= 32 ppm Bray P1. Error bars represent the SEM (n=4).

Table 7. Harvest yields, tissue P, and P uptake from a replicated field trial conducted at OSU's Vegetable Research Farm. Values in the same column with the same letter do not differ (LSD p=0.05).

Trt	Gross pod yield		Foliage biomass (fresh)		Pod DM		Foliage DM		#1 grade (sieves 1-4)	Pod tissue P		Foliage tissue P	Pod uptake	Foliage uptake	
lb P2O5/A	ton/A		ton/A		lb/A		lb/A		% of total	%		%	lb P2O5/acre		
0	6.7	b	7.6	c	1,013	b	2,455	c	60	0.45	a	0.23	10.6	13.1	b
40	8.4	a	8.6	b	1,300	a	2,894	b	61	0.43	ab	0.21	12.9	14.0	ab
80	8.3	a	9.4	ab	1,309	a	3,088	ab	62	0.41	b	0.21	12.2	15.0	ab
120	8.0	ab	9.5	ab	1,250	ab	3,227	ab	66	0.41	b	0.22	11.7	16.3	a
160	8.5	a	9.9	a	1,334	a	3,286	a	60	0.42	ab	0.22	12.8	16.5	a
ANOVA p=	0.091		0.002		0.100		0.004		0.271	0.156		0.377	0.282	0.122	
LSD	1.4		0.9		256		386		NS	0.04		NS	NS	3.0	

Research farm K replicated trials

In this trial we observed a yield response to application of KCl fertilizer that peaked at 100 lb/acre K2O (Fig. 4). **These results are consistent with current OSU recommendations for snap beans and further K research is not warranted at this time.**

At 200 lb K2O/acre rate we observed a yield depression and this treatment only achieved 91% of the max yield. Even though the fertilizer was broadcast and incorporated, the yield depression was likely the result of a salt toxicity. Emergence was negatively affected by the high rate KCl addition, reducing the stand by 8-16% (Fig. 5). Cl in tissues and Cl uptake increased with increasing KCl rates (Tables 8-12). Other than Cl and K, there were few statistical differences in plant nutrient concentrations among treatments (Tables 8&9). Relationships between nutrients concentrations are given in Tables 13 & 14.

Although these data are interesting, few growers apply pre-plant KCl applications >150 lb K2O/acre (broadcast and incorporated). Also, the beans were planted on the same day that the KCl was broadcast and incorporated, which may have resulted in high levels of K and Cl near the seed. Given additional time the KCl may have dispersed, resulting in a lower concentration near the seed.

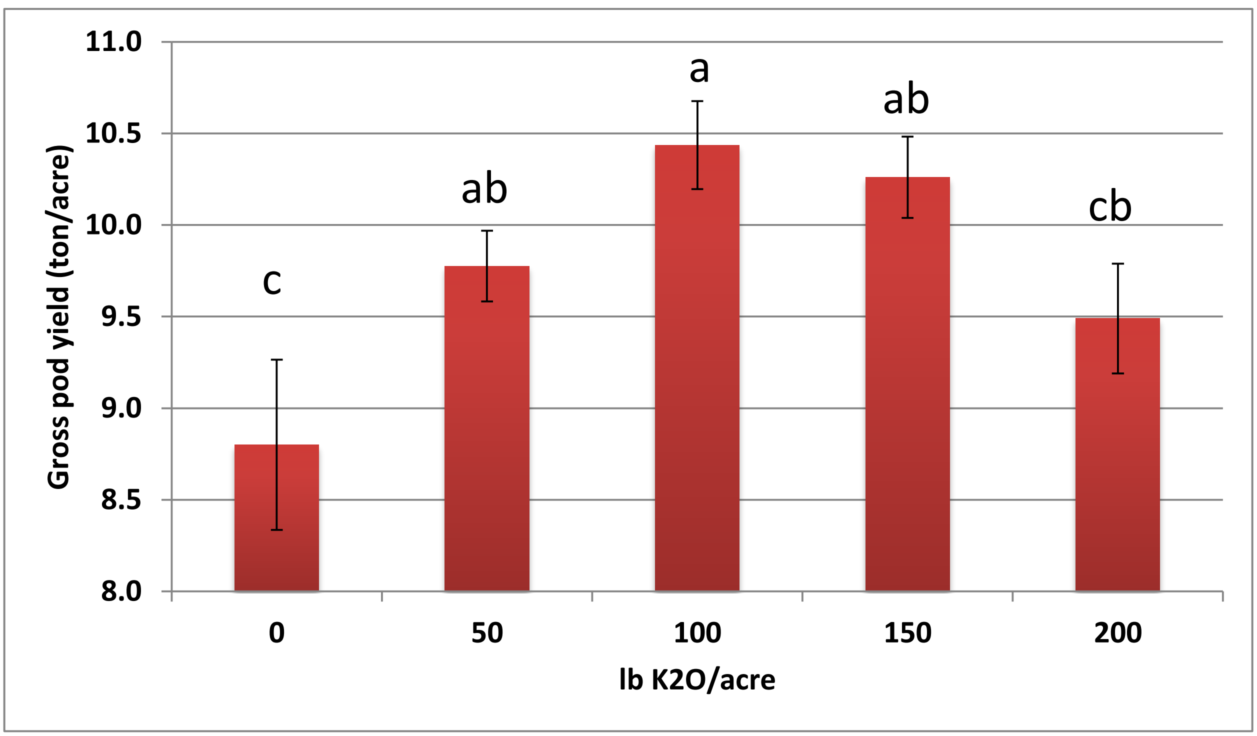

Figure 4. Gross pod yield from replicated K trial at OSU's Vegetable Research Farm in a field with soil test K= 71 ppm. Fertilizer (KCl) was broadcast and incorporated preplant. Error bars represent the SEM (n=4). Values with the same letter do not differ (LSD; p=0.05).

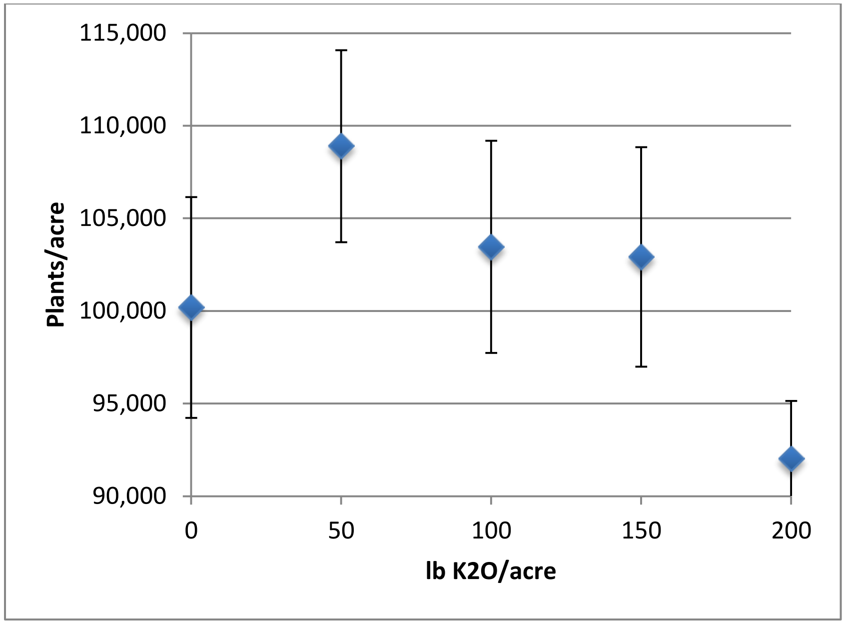

Figure 5. Emergence as effected by rate of KCl. Error bars represent the SEM (n=4).

Table 8. Tissue nutrient concentration in foliage (n=4)

Treatment lb K2O/acre	N %	P %	K %	S %	Cl ppm	Mn ppm	Ca %	Mg %	B ppm	Fe ppm	Zn ppm
0	2.83	0.24	0.87	0.15	4,956	54	3.1	1.01	26.5	291.5	23.5
50	2.76	0.25	0.99	0.16	6,173	51	2.9	0.94	25.4	398.0	25.7
100	2.75	0.25	1.17	0.17	6,423	47	2.6	0.82	24.9	325.3	23.9
150	2.62	0.23	1.13	0.16	7,401	49	2.7	0.82	23.2	309.3	23.0
200	2.63	0.24	1.21	0.16	7,808	43	2.7	0.81	23.3	358.8	21.8
Significance (ANOVA) p=	NS	NS	**0.100**	NS	**0.012**	NS	NS	**0.009**	**0.050**	NS	NS
LSD (0.05)			**0.28**		**1,518**			**0.12**	**2.4**		

Table 9. Tissue nutrient concentration in pods (n=4)

Treatment lb K2O/acre	N %	P %	K %	S %	Cl ppm	Mn ppm	Ca %	Mg %	B ppm	Fe ppm	Zn ppm
0	3.78	0.44	1.77	0.20	1988	20.8	0.71	0.35	17.5	86.9	38.9
50	3.73	0.46	1.97	0.21	2370	20.2	0.69	0.35	18.0	101.2	39.8
100	3.75	0.46	2.15	0.21	2504	23.1	0.73	0.35	17.9	93.5	40.5
150	3.66	0.44	2.01	0.20	2550	20.6	0.70	0.34	17.0	91.1	38.9
200	3.57	0.45	2.26	0.21	2840	20.1	0.69	0.35	18.3	96.5	41.6
Significance (ANOVA) p=	NS	NS	**0.003**	NS	**0.001**	NS	NS	NS	NS	NS	NS
LSD (0.05)			**0.21**		**297**						

Table 10. Nutrient uptake by foliage (n=4)

Treatment	N	P	K	S	Cl	Mn	Ca	Mg	B	Fe	Zn
lb K2O/acre	------------------- lb/acre --------------------					g/acre	lb/acre		---------- g/acre --------		
0	92.3	7.8	28.5	4.9	16.2	80.4	101	33	39	438	80
50	98.3	9.0	35.5	5.6	22.2	81.2	103	33	41	634	81
100	98.0	9.0	42.0	5.9	23.1	75.6	94	29	40	539	76
150	92.3	8.0	39.7	5.5	26.1	78.8	94	29	37	493	79
200	94.6	8.6	43.6	5.8	28.1	69.6	99	29	38	589	70
Significance (ANOVA p=)	NS	NS	**0.103**	NS	**0.012**	NS	NS	NS	NS	NS	NS
LSD (0.05)			**11.9**		**6.2**						

Table 11. Nutrient uptake by pods (n=4)

Treatment	N	P	K	S	Cl	Mn	Ca	Mg	B	Fe	Zn
lb K2O/acre	------------------- lb/acre --------------------					g/acre	lb/acre		---------- g/acre --------		
0	54.6	6.4	25.7	2.9	2.9	13.7	10.3	5.1	11	57	26
50	57.9	7.1	30.6	3.2	3.7	14.3	10.8	5.4	13	71	28
100	60.2	7.4	34.5	3.3	4.0	16.8	11.7	5.6	13	68	30
150	61.0	7.3	33.4	3.4	4.3	15.6	11.7	5.7	13	69	29
200	52.4	6.7	33.2	3.1	4.2	13.5	10.2	5.1	12	64	28
Significance (ANOVA p=)	NS	NS	**0.010**	NS	**0.032**	**0.011**	NS	NS	NS	NS	NS
LSD (0.05)			**4.7**		**0.9**	**1.9**					

Table 12. Nutrient uptake in aboveground biomass (foliage+pods; n=4)

Treatment	N	P	K	S	Cl	Mn	Ca	Mg	B	Fe	Zn
lb K2O/acre	------------------- lb/acre --------------------					g/acre	lb/acre		---------- g/acre --------		
0	146.9	14.2	54.2	7.8	19.0	94.1	111	38	51	494	106
50	156.2	16.1	66.2	8.8	25.9	95.4	114	39	54	706	109
100	158.2	16.3	76.5	9.3	27.1	92.4	106	35	53	607	105
150	153.2	15.3	73.1	8.9	30.3	94.4	105	35	50	562	108
200	147.0	15.3	76.8	8.9	32.3	83.1	109	34	50	653	97
Significance (ANOVA p=)	NS	NS	**0.027**	**0.092**	**0.013**	NS	NS	NS	NS	NS	**0.100**
LSD (0.05)			**14.6**	**1.0**	**7.0**						**7.4**

Table 13. Tissue nutrient relationships in pods. The values given below are Pearson correlation coefficients (r; n=20) and statistical significance. Yellow highlighted values indicate an r value ≥0.7 and a probability that r does not equal 0 (highlighted if p<0.05).

	N	P	Mg	K	Ca	S	B	Fe	Mn	Cu	Zn	Al	Cl
N	1.000	0.576	0.647	0.087	0.410	0.685	0.345	0.641	0.584	0.463	0.514	0.445	-0.390
		0.008	0.002	0.715	0.073	0.001	0.136	0.002	0.007	0.040	0.020	0.049	0.089
P		1.000	0.715	0.485	0.512	0.850	0.782	0.676	0.393	0.827	0.551	0.343	0.210
			0.000	0.030	0.021	<.0001	<.0001	0.001	0.087	<.0001	0.012	0.139	0.375
Mg			1.000	0.233	0.779	0.819	0.548	0.665	0.682	0.590	0.581	0.449	-0.133
				0.323	<.0001	<.0001	0.012	0.001	0.001	0.006	0.007	0.047	0.575
K				1.000	0.247	0.504	0.648	0.322	0.294	0.262	0.359	-0.351	0.600
					0.293	0.023	0.002	0.167	0.208	0.264	0.120	0.130	0.005
Ca					1.000	0.461	0.479	0.370	0.585	0.327	0.331	0.188	-0.008
						0.041	0.033	0.108	0.007	0.159	0.155	0.427	0.973
S						1.000	0.679	0.809	0.617	0.731	0.700	0.375	0.093
							0.001	<.0001	0.004	0.000	0.001	0.103	0.696
B							1.000	0.524	0.332	0.529	0.302	0.117	0.230
								0.018	0.153	0.017	0.196	0.625	0.330
Fe								1.000	0.331	0.623	0.643	0.412	0.110
									0.154	0.003	0.002	0.071	0.644
Mn									1.000	0.315	0.486	0.085	-0.258
										0.176	0.030	0.721	0.273
Cu										1.000	0.539	0.434	0.226
											0.014	0.056	0.339
Zn											1.000	0.310	0.138
												0.183	0.561
Al												1.000	-0.301
													0.197
Cl													1.000

Table 14. Tissue nutrient relationships in foliage. The values given below are Pearson correlation coefficients (r; n=20) and statistical significance. Yellow highlighted values indicate an r value ≥7.0 and statistical significance (p<0.05).

	N	P	Mg	K	Ca	S	B	Fe	Mn	Cu	Zn	Al	Cl
N	1.000	0.043	0.428	-0.033	0.507	0.239	0.089	0.399	0.421	-0.016	0.216	0.375	-0.518
		0.856	0.060	0.889	0.023	0.310	0.709	0.081	0.065	0.946	0.361	0.104	0.019
P		1.000	0.153	0.189	-0.042	0.493	0.352	-0.191	-0.422	0.780	0.477	-0.182	0.135
			0.521	0.425	0.859	0.027	0.128	0.419	0.064	<.0001	0.033	0.442	0.571
Mg			1.000	-0.643	0.827	-0.235	0.600	0.192	0.335	0.039	0.187	0.171	-0.495
				0.002	<.0001	0.319	0.005	0.417	0.149	0.869	0.430	0.471	0.026
K				1.000	-0.291	0.722	-0.401	0.089	-0.147	0.191	0.039	0.084	0.342
					0.213	0.000	0.080	0.708	0.537	0.420	0.871	0.724	0.140
Ca					1.000	-0.035	0.543	0.366	0.577	-0.155	0.030	0.312	-0.404
						0.885	0.013	0.112	0.008	0.513	0.900	0.181	0.077
S						1.000	-0.239	0.264	0.071	0.307	0.327	0.236	0.151
							0.310	0.260	0.765	0.189	0.159	0.316	0.525
B							1.000	-0.293	0.039	0.348	0.102	-0.324	-0.253
								0.210	0.871	0.133	0.668	0.164	0.281
Fe								1.000	0.453	-0.237	-0.040	0.992	-0.125
									0.045	0.314	0.866	<.0001	0.599
Mn									1.000	-0.520	0.196	0.415	-0.525
										0.019	0.408	0.069	0.017
Cu										1.000	0.294	-0.243	0.202
											0.209	0.302	0.394
Zn											1.000	-0.035	-0.412
												0.884	0.071
Al												1.000	-0.135
													0.569
Cl													1.000

Budget history

	Year 1	Year 2	Year 3
Aaron Heinrich (FRA) and Ed Peachey (Associate Professor)	6750	5000	5600
OPE (67%)	3470	3350	3472
Summer labor ($11/hr for 120 hrs)	900	1320	880
OPE (8%)	72	141	140
Data loggers	200	0	0
Fertilizer	40	100	100
To and from field sites	300	520	500
Land rental OSU Veg farm (1A @ $1385/A)	0	1385	693
Commercial fumigation	-	1500	-
Complete soil analysis (11*$13/sample)	-	143	117
NPK plant tissue (30*$11/sample)	-	330	352
P only plant tissue (64*$5/sample)	-	320	160
2013 lab analysis	1001	-	-
Total:	**12,733**	**14,109**	**12,014**