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Growth Responses, Nutrient Leaf Concentrations and Interelement Relationships of Snap Beans as Affected by Fertilizer Treatment[1]

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Abstract. **'Bush Blue Lake 283' beans (*Phaseolus vulgaris* L.) were grown with 16 fertilizer treatments at 16 commercial sites in Pennsylvania in 1973-74. No treatment gave significantly higher combined yield at one harvest than the NP treatment (28 kg/ha of each). This treatment resulted in increases of 27% in vine weight and 9% in yield while leaf concentration of Ca and Mg were enhanced by 19% and 36% respectively and K concentration was decreased by 17%. Added K which further increased vine weight but not yield, depressed Mg leaf concentration but this was more than compensated for by the NP enhancement. Although added Mg did not affect growth responses, it increased Mg leaf concentration, decreased Mn concentration and tended to decrease P and Ca concentration but did not lower K leaf concentration. When both K and Mg were added, Mg leaf concentration was no higher. Diammonium phosphate had no injurious effects.**

The snap bean is an important crop in Pennsylvania but little is known of its specific fertilizer requirements. Preliminary studies show that results from other areas (1, 6) do not apply directly because of soil differences. Efficient use of fertilizer requires knowledge that any fertilizer component affects several other nutrients besides that applied. Thus it is important to determine the nutritional consequences of fertilizer application.

Understanding interelement effects can play an important role in making fertilizer recommendations for commercial vegetables. Probably the best known of these is the effect of K antagonism in reducing the leaf concn of Ca and especially Mg (5) and in addition, P (7, 9). Calcium and Mg leaf concn are enhanced by some N sources (1, 3, 6) and by P (7) but Ca and Mg have been reduced by NH_4-N additions in some nutrient solution studies with tomato (11).

These experiments were carried out to test a wide range of nutritional treatments on snap beans grown in several major production areas of Pennsylvania where soil and climatic conditions varied greatly. Since growers rely primarily on soil testing to determine fertilizer needs, results were related to soil tests from samples taken prior to planting. On the basis of preliminary experiments and reports from several other states, where poor responses to high fertilizer rates were obtained, relatively low amounts were used for all nutrients.

Materials and Methods

Eight cooperative snap bean nutrition experiments were carried out in 1973 in important production areas of Centre, Clinton, Northumberland, Columbia, Crawford, Erie and York counties on sites used in commercial snap bean production. These were repeated in 1974 at similar sites but not in the same fields except a site in adjacent Snyder county was substituted for that in Northumberland county. At each of the 16 sites, 'Bush Blue Lake 283' beans were grown using a randomized block design with 16 fertilizer treatments and 4 replications giving a total of 1024 plots.

Before planting, a soil sample was taken from each replication and analyzed for pH, P, K, Ca, Mg and C.E.C. by the Soil Testing Laboratory of the Pennsylvania State Univ. (Table 1).

The fertilizer treatments (Table 2) were basically made up of 1 or 2 28 kg/ha increments of N, P, K and Mg some singly, and others in various combinations so that the effects of individual nutrients could be determined. These were applied as urea, triple superphosphate, muriate of potash, and Magox (trademark of Basic Chemicals), respectively. Two special treatments involving dolomitic lime and zinc sulfate were included. Diammonium phosphate (DAP) at the 2 increment P rate was tested against 2 comparable treatments supplying exactly the same amounts of N and P but using sodium nitrate or urea as N sources and triple superphosphate as the P source.

In each 6.1 m plot row 250 seeds were planted at 0.96 m row spacing to determine the effects of the fertilizer treatment on emergence. The fertilizer treatment was simultaneously applied in a single band, 5 cm to the side of and 5 cm below the seed using a specially developed tractor-mounted belt planter. After emergence counts were made plants were thinned to a stand of 23/m.

A leaf sample consisting of the second oldest trifoliate leaves from 10 plants was selected from each plot at the time of bloom. These samples were cleaned by dipping in a detergent solution and thoroughly rinsing in distilled water, dried and ground, and were analyzed for 12 elements; N using a Technicon Autoanalyzer with manual digestion (Industrial method No. 103-70A) and others through use of an optical emission spectrometer (2).

Plots were harvested at each site when about 20% of the pods were larger than sieve size #4 which was 50-59 days and 57-62 days from seeding in 1973 and 1974 respectively. At harvest, plants in a 4.6 m row were cut at ground level, weighed, and the

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Table 1. Soil, pH and fertility levels for each site in 1973 and 1974.

Site and county	Soil	pH	P (kg/ ha)	K (meq/ 100g)	Mg (meq/ 100 g)	Ca (meq/ 100 g)	CEC
		1973					
A. Northumberland	Chenango sandy loam	6.0[z]	679	.31	.7	3.6	8.7
B. Columbia	Chenango silt loam	6.4	402	.24	1.2	6.5	11.0
C. York	Chester silt loam	6.9	88	.28	.7	9.8	11.8
D. York	Cardiff slaty silt loam	6.0	365	.37	.9	6.9	12.0
E. Crawford	Venango silt loam	5.9	94	.29	1.6	6.8	13.0
F. Erie	Conotton gravelly loam	6.2	268	.28	1.0	6.0	10.6
G. Clinton	Ashton silt loam	5.7	293	.29	.7	6.9	14.6
H. Centre	Hagerstown silt loam	5.1	57	.29	.6	5.2	15.4
		1974					
A. Snyder	Pope silt loam	6.1	212	.35	1.1	6.3	11.3
B. Columbia	Lawrenceville silt loam	6.4	161	.35	.8	6.1	10.0
C. York	Chester silt loam	6.7	128	.40	1.0	10.0	12.9
D. York	Conestoga silt loam	6.6	108	.61	1.3	7.4	11.7
E. Crawford	Venango silt loam	6.7	268	.88	1.4	8.2	11.8
F. Erie	Conotton coarse sandy loam	5.6	512	.51	.6	2.9	9.1
G. Clinton	Ashton silt loam	5.4	189	.31	.4	2.5	9.3
H. Centre	Hagerstown silt loam	6.9	72	.40	.5	10.8	12.4

[z]Means of 4 replications.

pods were picked and weighed. Data were subjected to analysis of variance and mean separation was determined by Duncan's Modified (Bayesian) Test (10) where K=100 was considered comparable to the 5% level. Correlation coefficients were determined between soil, leaf and response data.

Results and Discussion

Growth responses. No fertilizer treatment had any consistent effect on emergence which averaged 87%.

In considering over-all plant responses from the 16 experiments combined (Table 2), no treatment was significantly higher in yield than treatment 4 (N+P each at 28 kg/ha) which increased vine wt by 27% and yield by 9% compared to those of the check. Both N and P contributed to this as shown in treatments 2 and 3, with N having a stronger effect on vine wt and P on yield.

When an increment of K was added to the NP treatment (trt. 5) vine wt was significantly increased but not yield. No favorable response in yield was obtained to K application at any site. Magnesium addition to NP (trt. 6) resulted in no significant differences in over-all vine wt or yield, although in the 1973 experiments there was a strong tendency for both vine wt and yield to be depressed. Seatz et al. (8) also showed no significant yield increases from Mg as sulfate up to 560 kg/ha. No fertilizer combination increased yield without increasing vine wt much more rapidly. No injurious effects from DAP were evident at any site.

Vine wt and yield responses to the P, NP and 2N2P treatments compared to the corresponding check at each site as related to soil P levels are shown in Table 3. When P was added (trt. 3), there was a tendency for a response in vine wt only at low P soil levels but this was not consistent and there was no response at 5 sites. Yield responses to P treatment were not correlated with soil P level. In the NP treatments, vine wt was increased at all sites but the extent of the increase varied substantially and was not related to soil P level. The NP treatment increased yield at 11 sites but was not related to soil P level. When 2 increments of N and P were applied (trt. 9) vine wt was further increased but not yield.

Plant responses under field conditions showed that the snap bean has relatively low fertilizer requirements and that soils used in commercial production were capable of supplying a large portion of these nutrients. Instead of supplying large amounts of complete fertilizer, only small amounts of certain nutrients are required to balance out the nutritional needs of the crop. Brown et al. (4) also showed poor yield responses even though soil test showed low levels of P, K and Ca. Plant size is increased to a much greater extent than is yield by additions of N, P or K which presents a serious problem with mechanical harvesting. This increased vigor can be visually mistaken for a greater response to fertilizer than the actual yield increases justify.

Leaf analyses. When N was added alone (trt. 2) leaf concn of N, Ca, Mg, Mn and Zn were all increased significantly and the concn of no element was decreased (Table 4). When P was added alone (trt. 3), leaf concn of P, Ca, Mg, Mn and B were significantly increased but N and K concn were decreased. When both N and P were applied (trt. 4), N, P, Ca, Mg and Mn were all significantly increased and K was depressed. While increases in N and P concn were relatively small in the NP treatment, the overall increases in Ca and Mg leaf concn were 19% and 36% respectively and K leaf concn was decreased by 17%. Therefore, increases in Ca and Mg leaf concn were associated with a reduction in K leaf concn. Both urea and triple superphosphate

Table 2. Effects of fertilizer treatments on vine wt and yield of 'Bush Blue Lake 283' snap bean.

Treatments[z]	Vines[y] (MT/ha)	Yield (MT/ha)
1. Check	8.83h[x]	8.49d
2. N	10.51f	8.52d
3. P	9.53g	8.70cd
4. NP	11.21cde	9.26abc
5. NPK	11.99ab	9.41ab
6. NPMg	10.87def	8.85bcd
7. NPKMg	11.46bcd	9.01a-d
8. N2P	11.56bc	9.35ab
9. 2N2P	11.47bc	9.23abc
10. 2N2P2K	12.33a	9.01a-d
11. 2N2P2Mg	10.89def	8.76cd
12. NP+Dol. lime (mg=trt 6)	11.50bc	9.39ab
13. NP+Zn sul. (5.6 kg/ha Zn)	10.80ef	9.21abc
14. DAP (2P level)	11.86ab	9.35ab
15. Sod. nit. +2P(=trt 14)	11.63bc	8.92bcd
16. Urea +2P(=trt 14)	11.88ab	9.53a

[z]N, P, K and Mg were applied as urea, triple superphosphate, muriate of potash and Magox respectively (unless otherwise noted) in increments of 28 kg/ha in single band.

[y]Mean separation within columns by Duncan's Modified (Bayesian) LSD Test with K=100.

[x]Means of 8 sites and 2 years.

Table 3. Soil and leaf P levels and growth responses at each site to P, NP, and 2N2P treatments.

Site	Soil P (kg/ha)	Leaf P check (% dry wt)	Vine wt (MT/ha) Check	P	NP	2N2P	Yield (MT/ha) Check	P	NP	2N2P
					1973					
H.	57	.22	3.65	6.81	7.78	7.84	6.16	6.37	9.64	7.64
C.	88	.29	9.37	10.02	11.05	11.63	6.61	6.99	7.19	8.36
E.	94	.29	9.77	7.64	10.60	10.67	9.88	8.99	9.77	10.85
F.	268	.29	4.44	6.81	5.47	7.58	3.92	4.75	5.65	6.68
G.	293	.21	12.46	15.93	18.56	17.46	9.95	12.46	12.98	12.39
D.	365	.27	10.87	10.47	12.15	11.43	8.23	7.60	7.64	5.72
B.	402	.31	9.05	10.80	10.09	14.52	12.77	13.29	10.98	13.04
A.	679	.30	8.36	8.81	11.25	11.95	9.97	11.05	12.64	12.01
Mean	281	.27	8.49	9.66	10.87	11.63	8.45	8.94	9.57	9.59
					1974					
H.	72	.34	8.74	9.88	11.70	11.77	8.81	8.81	9.64	10.40
D.	108	.28	9.77	11.43	12.15	11.18	9.32	9.37	8.47	8.43
C.	128	.30	5.27	6.30	7.13	6.93	5.92	6.43	6.03	5.33
B.	161	.38	9.44	9.05	13.04	13.04	9.46	9.82	10.02	11.18
G.	189	.19	10.29	10.53	13.63	14.28	7.58	7.08	9.53	8.88
A.	212	.37	10.33	9.39	12.77	11.50	10.47	10.09	11.18	9.19
E.	268	.29	10.47	10.87	11.81	10.98	7.96	7.44	7.78	8.23
F.	512	.30	8.94	7.84	10.35	11.05	8.92	8.67	9.12	9.37
Mean	206	.31	9.17	9.41	11.56	11.34	8.56	8.47	8.96	8.88

Table 4. Effects of fertilizer treatments on leaf concn of 10 elements in 'Bush Blue Lake 283' snap bean.

Treatment[z]	Leaf concn (% dry wt) N[y]	P	K	Ca	Mg	Leaf concn (μg/g dry wt) Mn	Cu	B	Zn	Na
1. Check	3.94f	.29fg	3.00c	2.91i	.44h	100j	13abc	24c	27cde	125c-f
2. N	4.30c	.28g	3.02c	3.13h	.52fg	162h	13abc	24c	31b	124c-f
3. P	3.78g	.32bc	2.84de	3.15gh	.50g	128i	13a	28a	29bcd	124c-f
4. NP	4.09de	.31cd	2.51fg	3.47abc	.60e	203ef	12bc	25bc	26de	120def
5. NPK	3.91fg	.31de	3.20b	3.51ab	.53f	237d	13a	25bc	29bcd	134c
6. NPMg	4.10d	.30def	2.53fg	3.16gh	.71a	174gh	12abc	24c	25e	115f
7. NPKMg	4.01def	.30ef	3.23b	3.18fgh	.62de	188fg	13abc	25bc	27cde	131cd
8. N2P	3.92f	.36a	2.39g	3.32c-f	.62cde	181gh	12abc	28a	27de	116ef
9. 2N2P	4.43ab	.34b	2.49fg	3.26e-h	.62cde	288b	12bc	24c	28b-e	116ef
10. 2N2P2K	4.33bc	.31cd	3.59a	3.15gh	.51fg	329a	12c	28a	27de	149b
11. 2N2P2Mg	4.46a	.31cd	2.73e	3.30d-g	.72a	210e	13abc	24c	31b	126cde
12. NP+Dol. lime (Mg=trt 6)	3.97ef	.31cd	2.53fg	3.40b-e	.68b	189fg	13abc	25bc	27cde	120def
13. NP+Zn sul. (5.6 kg/ha Zn)	3.89fg	.30def	2.54fg	3.41b-e	.60e	185fg	12c	27ab	38a	125c-f
14. DAP (2P level)	4.26c	.36a	2.44fg	3.23fgh	.61e	321a	13abc	26bc	31b	130cd
15. Sod. nit.+2P (=trt 14)	4.26c	.35ab	2.98cd	3.58a	.65bc	116ij	13ab	24c	22f	189a
16. Urea +2P (=trt 14)	4.38abc	.35ab	2.55f	3.45a-d	.65cd	267c	13abc	27ab	30bc	131cd

[z]N, P, K and Mg were applied as urea, triple superphosphate, muriate of potash and Magox respectively (unless otherwise noted) in increments of 28 kg/ha in single band.

[y]Mean separation within columns by Duncan's Modified (Bayesian) LSD Test with K=100.

[x]Mean of 8 sites and 2 years.

played a role in this enhancement of Ca and Mg with urea having a somewhat stronger effect.

When an increment of K as muriate of potash was added to the NP treatment the average increase in K leaf concn was 28% which more than compensated for the depression of K by the NP treatment. The K addition also resulted in a 12% decrease in Mg concn, a further increase in Mn concn, but did not significantly affect either P or Ca concn.

When an increment of Mg as Magox was added to the NP treatment, Mg leaf concn was increased by 18%, Ca and Mn concn were decreased significantly, but K concn was not affected. Magnesium concn was not affected when both K and Mg were added (trt. 7).

The second increment of P (trt. 8) increased P leaf concn to its highest level, increased B concn and decreased N and Mn concn. When 2 increments of N and P (trt. 9) were compared to the NP treatment, N, P and Mn concn were significantly higher but Ca was significantly lower. When 2 increments of K were added to 2N2P (trt. 10), K leaf concn was increased 44% while P and Mg were decreased and Mn increased to its highest concn. Thus, the higher K rate did depress P when added with higher rates of N and P. When 2 increments of Mg were added to 2N2P (trt. 11), Mg leaf concn increased but was only slightly higher than in the NPMg treatment but the P leaf concn was significantly decreased.

When dolomitic lime (trt. 12) was compared with Magox, (trt. 6) the increase in Mg leaf concn was 13% compared to 18% for the Magox treatment when both were compared to the NP treatment. This small quantity of dolomitic lime increased Mg about two-thirds that of Magox and did not depress Ca concn. When Zn was added to NP (trt. 13), leaf Zn concn was increased by 46%.

When DAP was compared with 2 treatments having the sa ıe amount of N and P (trt. 14-16) there were no significant differences in N or P leaf concn. Diammonium phosphate supplied P as well as any other P treatment. Leaf K concn in the DAP

Table 5. Soil and leaf Ca and Mg levels and the enhancement in leaf concn by the NP treatment at each site.

	Ca level				Mg level		
	Soil (% saturation)	Leaf (% dry wt)			Soil (% saturation)	Leaf (% dry wt)	
Site		Check	NP	Site		Check	NP
			1973				
H.	33.7	2.35	3.36	H.	4.3	.27	.34
A.	41.1	2.17	3.24	G.	5.5	.38	.78
G.	42.3	2.74	3.06	C.	5.9	.59	.65
E.	52.4	3.04	3.56	D.	7.7	.61	.70
F.	56.6	3.04	3.69	A.	8.9	.42	.56
D.	57.4	3.98	4.23	F.	10.0	.64	1.02
B.	59.4	2.28	2.43	B.	11.0	.56	.59
C.	83.0	4.63	5.42	E.	12.3	.77	1.11
Mean	53.2	3.03	3.62	Mean	8.2	.53	.72
			1974				
G.	27.4	2.23	3.27	H.	3.9	.31	.34
F.	31.5	1.83	2.20	G.	4.4	.20	.30
A.	55.9	3.28	3.84	F.	7.3	.31	.36
B.	60.6	2.97	3.44	C.	7.7	.31	.55
D.	63.8	2.99	3.08	B.	8.3	.33	.46
E.	69.3	2.63	3.06	A.	9.7	.50	.67
C.	78.5	2.66	3.35	D.	11.3	.49	.64
H.	87.0	3.73	4.28	E.	12.3	.45	.61
Mean	59.3	2.79	3.32	Mean	8.1	.36	.49

treatment was similar to the treatment with urea but lower than that with sodium nitrate. Leaf concn of Ca and Mg were significantly lower in the DAP treatment but still as high as those of the 2N2P treatment. Mn leaf concn was significantly higher than the treatment with urea and nearly 3-fold higher than the treatment with sodium nitrate which was similar to that of the check. The Zn leaf concn in the treatment with sodium nitrate was lower. No treatments had a meaningful effect on Fe or Al leaf concn which averaged 323 and 338 μg/g respectively.

The enhancement in the leaf concn of Ca and Mg by the NP treatment occurred at all sites in 1973 and 1974 but there was much variation in degree and significance (Table 5). Calcium and Mg values for soil and leaf were significantly correlated. Enhancement by the NP treatment increased the Mg leaf concn to a level as high as at those sites showing more than 10% Mg saturation except at site H in 1973 and at sites H, G, and F in 1974. Since a recommendation to apply Mg is made from the Pennsylvania soil test unless the Mg saturation is higher than 10%, these increases in leaf concn through NP enhancement were substantial enough at 6 sites to remove the need for a Mg recommendation based on the soil test.

Reduction in the K leaf concn by the NP treatment was shown at all but 3 sites, averaging 17% (Table 6). Soil and leaf levels of K were significantly correlated. When increases in vine wt were compared to the reduction in K leaf concn by the NP treatment, there was no significant correlation, showing that this was not a "dilution" effect. When an increment of K was added to the NP treatment, increases in K leaf concn were obtained at all sites except 1, averaging 28%, and more than compensated for the reduction in K leaf concn by the NP treatment.

Leaf analyses showed that the treatment giving the best overall yield response increased the leaf concn of N, P, Ca, Mg and Mn and decreased K leaf concn. The addition of either 1 or 2 increments of K showed that substantial increases in K leaf concn were realized with application of relatively small amounts of K. Applied K did depress the Mg leaf concn but applied Mg did not reduce K. Based on the results of these experiments, the merit of applying both K and Mg in the same fertilizer can be seriously questioned since the leaf Mg concn was no higher when equal amounts of both were applied than when neither was applied. The widely-held idea that Mg needs to be applied with K because K application creates a Mg deficiency was not valid here because when K was added to the NP treatment, the Mg leaf concn was depressed, but even at the higher K level Mg remained higher than that of the check because of the NP enhancement. Both urea and muriate of potash contributed to the substantial increases in Mn leaf concn so that Mn leaf concn in the 2N2P2K treatment was more than 3-fold higher than that of the check. This suggests that Mn toxicity may play a role in poor responses to higher fertilizer rates.

Table 6. Soil and leaf K levels, reduction in K leaf concn by the NP treatment as compared to vine wt, and increase in leaf K concn by K treatment at each site.

	Soil K	Leaf K (% dry wt)		Vines (MT/ha)		Leaf K (% dry wt)
Site	(% saturation)	Check	NP	Check	NP	NPK
			1973			
H.	1.85	1.99	1.47	3.65	7.78	2.15
G.	2.12	3.23	2.63	12.46	18.56	3.03
B.	2.15	1.81	1.84	9.05	10.09	2.35
E.	2.17	2.25	1.19	9.77	10.60	2.15
C.	2.37	1.51	1.56	9.37	11.05	1.91
F.	2.70	2.68	2.05	4.44	5.47	3.13
D.	3.07	2.53	2.15	10.87	12.15	2.73
A.	3.52	2.85	1.91	8.36	11.25	2.24
Mean	2.49	2.36	1.85	8.49	10.85	2.46
			1974			
A.	3.02	2.36	1.74	10.33	12.77	2.67
C.	3.10	3.31	2.76	5.27	7.13	4.43
H.	3.17	3.49	2.75	8.74	11.70	3.75
G.	3.25	3.80	4.03	10.29	13.63	3.98
B.	3.50	3.55	2.89	9.44	13.04	3.58
D.	5.25	4.16	3.96	9.77	12.15	4.02
F.	5.60	3.62	3.16	8.94	10.35	4.25
E.	7.42	4.91	4.00	10.47	11.81	4.85
Mean	4.29	3.65	3.16	9.17	11.56	3.94

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