ORGANIC VERSUS INORGANIC SOURCE AND RATES OF N FERTILIZER FOR FALL-GROWN BUSHBEAN

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ABSTRACT

A study was conducted on bush bean (*Phaseolus vulgaris*) to compare the effects of N fertilization rates (0, 45, 90, 135, and 180 pounds N acre-1) and fertilizer sources (hairy vetch, *Vicia villosa*, versus ammonium nitrate) on plant nutrition and possible nutrient deficiencies. Fresh pod yield was determined at two harvest dates. The most recent, fully developed leaves were sampled and nutrient concentrations for N, P, and K measured. Analysis of variance was performed to identify differences between N application rates and N source material. Fresh pod yields were equal for the two N sources and average total yield of 6050 pounds acre-1 was achieved at 135 pounds N acre-1. Differences in diagnostic leaf dry matter were observed due to N source and rate. Data show that not only was the vetch a good organic source of N but that it also provided additional K compared to ammonium nitrate.

INTRODUCTION

Use of diagnostic leaf tissue analyses for crop management is fundamental to modern agriculture. Correcting deficiencies of specific elements may result in strong positive yield response as other non-limiting resources are subsequently used more efficiently. Individual crops have specific levels of nutrients that are present when normal health and expected rates of growth occur. These ranges form the basis for published guidelines for recommended nutrient levels in plant tissues at specific ages such as those presented by Mills and Jones (1996). It is important to understand the process by which nutritional status is determined and integrated into nutrient recommendations.

Leguminous plants are known to accumulate higher N concentrations within their tissues through biological fixation of N than other species on similar soils. Green manure cover crops and mulches from leguminous hay provide an avenue for supplying some of the N requirements of associated crops as decomposition and N mineralization occurs (Hagendorf and Gallaher, 1992). While bush bean (*Phaseolus vulgaris*) is known to fix N, particularly when appropriate rhizobia are present in the soil, this crop's short duration results in yield responses to N fertilization greater than what occurs with fixation alone (Thies et al., 1995; Blaylock, 1995). The fresh pod yield of bush bean has been shown to increase with the application of clover straw (*Trifolium incarnatum*) applied at 3960 pounds acre-1 (Wade et al., 1997).

Hairy vetch (*Vicia villosa L.*) has been demonstrated to be an acceptable replacement to ammonia fertilization when used as a green manure before wheat (*Triticum aestivum L.*) (Badaruddin and Meyer, 1990). Similar results in maize (*Zea mays*) crops show that Vicia mulch treatments resulted in increased maize growth, N assimilation and grain yields over those in non-mulched treatments (Corak et al., 1991). The use of vetch has also been demonstrated to suppress weed growth when grown as a cover crop (Brandsaeter and Netland, 1999). The use of hairy vetch as mulch has been compared with black plastic mulches in tomato (*Lycopersicon esculentum Mill.*) crops. Hairy vetch mulches promoted greater leaf area and increased leaf area duration in tomato crops than did black plastic. Total yields of tomatoes were increased with vetch mulch; however, yields were later than with plastic and occurred over a longer season (Teasdale and Abdul-Baki, 1997). Additional study is merited to examine the possible benefits of mulching bush bean with vetch mulch and to explore the impact of decomposition and mineralization on the recommended N fertilization rates.

The principal objective of this study was to compare bush bean responses to an organic source versus an inorganic source of N and to rates of N. A further objective was to relate plant nutrient concentrations in leaf tissue to differences in the management and yield.

MATERIALS AND METHODS

This study was conducted at the Statistical Design Field Teaching Laboratory of the University of Florida. A split plot design with N source, hairy vetch (2.67% N) versus ammonium nitrate (34% N) as the main effects in a randomized complete block design, and N application rate as the sub-effect was used. 'Roma II' bush bean was planted in four rows in plots 5 feet wide and 6.5 feet long. A 2-foot wide alley separated each plot. Split plots were blocked three times (3 replications) across the field to account for possible effects of soil fertility and differences in water availability. Nitrogen was applied at rates of 0, 45, 90, 135, and 180 pounds N acre-1. With the use of hairy vetch, this corresponded to application values of up to 6850 pounds of air dry material acre-1. Leaf tissue was sampled in the early morning at the early bloom stage of growth (Mills and Jones, 1996). Within each replication, 10 trifoliate leaf blades from the youngest fully mature leaves were randomly sampled from the inner two rows of all 10 treatments (two sources X five levels). Determination of leaf maturity was made on positional and morphological characteristics. Leaves were stored in paper bags and transported to the plant nutrition lab of the University of Florida. Weight per 10 leaves was measured using a mass balance.

Fresh leaf material was washed to remove soil and air contaminants from the leaf surfaces. Leaves were individually scrubbed in 1% liquinox, rinsed in de-ionized water, then washed in 3% HCl solution and rinsed a second time in de-ionized water (Futch and Gallaher, 1996). Leaf samples were dried in a forced air oven at 70 °C for 24 hours. Samples were weighed a second time and dry weight recorded. Samples were ground individually in a Wiley mill with a 1 mm stainless steel screen. Following grinding, samples were equilibrated for moisture concentration by redrying for a minimum of 2 hours at 70 °C in a convection oven.

Nitrogen digestion and analysis were made using a modified micro-Kjeldahl technique (Gallaher et al., 1975). After digestion of samples in H2SO4, N was measured as (NH4)2 SO4 using an autoanalyzer. Nitrogen concentration was calculated using a linear regression of response to known standards measured immediately before sample analysis. For N analysis a plant standard was used every 40 samples. A standard colorimetry test was conducted to estimate P concentration. Tissue concentrations of K were estimated from flame emission spectrophotometry. Emission of element-specific wave lengths was calibrated against known standards. Additionally, a known plant standard was analyzed every 32 samples.

Soil samples were collected from the control plot (0 N rate) for each treatment replication. Three subsamples from each main effect treatment were combined (6 total) and mixed giving a sample for that replication. Soil samples were prepared for P and K analyses using a double acid extraction solution containing 0.05 N HCl and 0.025 N H2SO4 (Mehlich, 1963). Soil samples were analyzed concurrently with plant samples for nutrient concentrations for N, P, and K using identical procedures. Additionally, soil organic matter, soil pH, and soil texture were measured. Soil organic matter was measured using a modified version of the Walkley Black method (Walkley, 1947) and a diphenylamine indicator. Soil pH and buffer pH were measured using a 1:2 soil to water ratio by volume. Adams-Evans solution was used in buffer pH measurement (Adams and Evans, 1962). Soil texture was determined by allowing soil fractions to settle out of a water column containing 5% calgon solution. A “Bouyoucos” hydrometer was used to measure density at 40 seconds for determination of silt and clay fraction and again at 2 hours for clay. Sand fraction was determined as the difference (Bouyoucos, 1936). The soils at the teaching laboratory are classified as sandy siliceous hyperthermic grossarenic paleudults and are characterized as Millhopper sand (Soil Survey Staff, 1984).

Statistical Analysis

A split plot experimental design was selected, treating the hairy vetch and ammonium nitrate sources as the main effects and N application rates of 0, 45, 90, 135, and 180 pounds acre-1 as the sub-effects. Two degrees of freedom were given to blocks, one df to main effects and four df to sub-effects. Interaction effects had four degrees of freedom. MSTAT statistical analysis software (Freed et al, 1987) was used to conduct an analysis of variance (ANOVA) for each independent variable. Model effects were blocks, N source, blocks X N source, rate, N source X rate and error. When significant effects were observed (=.05), mean separation was made using Fischer’s least significant difference (LSD). The hypothesis tested for each independent variable was that there were no differences of that variable due to N source or application rates. The alternative hypothesis was that there were significant differences.

RESULTS

Effects of N source (ammonium nitrate versus hairy vetch) and N rate on plant N, P, and K uptake were determined along with treatment effects on leaf dry weights and fresh pod yields at two harvest dates and total pod yields. Finally, results of soil analyses were examined and fertilizer recommendations specific for bush bean were made for crops on the Millhopper sand in north-central Florida.

TISSUE NUTRIENT CONCENTRATIONS

Nitrogen source and N rate did not affect leaf N concentrations (Table 1). The N sufficiency range of Mills and Jones (1996) for bush bean is 3.0 to 6.0 % (Table 9). Slight deficiencies were measured with application rates less than 90 pounds N acre-1 using ammonium nitrate and with application rates less than 180 pounds N acre-1 from vetch mulch. The CV of N analysis was 6.53 %.

Table 1. Concentration of N (%) in diagnostic leaf of Roma II bush bean

N Fertilization rate	Fertilizer source		
Pounds acre^{-1}	Hairy Vetch	Ammonium nitrate	Average
0	2.78	2.87	2.82
45	2.88	2.84	2.86
90	2.87	3.03	2.95
135	2.85	3.01	2.93
180	3.07	3.09	3.08
Average	2.89	2.97	

Main effects $_{NS}$ and sub-effects $_{NS}$. (=.05).

Table 2. Concentration of P (%) in diagnostic leaf of Roma II bush bean

N Fertilization rate	Fertilizer source		
Pounds acre^{-1}	Hairy Vetch	Ammonium nitrate	Average
0	0.35	0.34	0.34
45	0.32	0.33	0.33
90	0.32	0.31	0.31
135	0.32	0.30	0.31
180	0.33	0.31	0.32
Average	0.33	0.32	

Main effects $_{NS}$ and sub-effects $_{NS}$. (=.05).

There were no differences observed in the concentration of P in diagnostic tissues due to N source or N application rates (Table 2). The P sufficiency range for bush bean diagnostic tissues is 0.25 to 0.75 % (Table 9). All treatments observed had sufficient amounts of P by these criteria. The CV of P analysis was 12.05 %.

Both main-effects and sub-effects influenced potassium nutrition. Significant interactions occurred between N source and N application rate (Table 3). Potassium concentrations were higher in diagnostic leaves from plants receiving vetch mulch with N application rates of 135 and 180 pounds acre-1. No differences between N sources were observed at lower N application rates. For plants grown with vetch mulch, greater concentration of K occurred at 90, 135 and 180 pounds N acre-1 compared with 0 pounds N acre-1. The 180 pounds N acre-1 treatment also showed higher K concentrations compared to the 45 pounds N acre-1. When the N source was ammonium nitrate, no significant differences were observed due to application rate. The sufficiency range for K in bush bean diagnostic tissues is 1.80 to 4.00 % (Mills and Jones, 1996). Potassium deficiencies were observed when no nutrients were applied (0 pounds N acre-1). Under ammonium nitrate fertilization treatments, K deficiencies were present with application rates of 0, 45, 135, and 180 pounds N acre-1. The CV of K analysis was 20.3 %.

Table 3. Concentration of K (%) in diagnostic leaf of Roma II bush bean

N Fertilization rate	Fertilizer source		
Pounds acre^{-1}	Hairy Vetch	Ammonium nitrate	Average
0	1.54	1.69	1.62
45	2.08	1.48	1.78
90	2.68	2.00	2.34
135	2.97	1.60	2.29
180	3.21	1.773	2.49
Average	2.50	1.71	

Main effects* and sub-effects. Mean separation* of interactions by LSD = .738 (=.05).

Tissue Dry Matter

Dry leaf weights following oven drying were greatly affected by N fertilization rates. Significant interaction occurred between the N rates and the fertilizer type for leaf dry weights (Table 4). When the N source was hairy vetch, the greatest leaf weight was achieved by applying 135 pounds N acre-1. No difference was observed for rates below 135 pounds N acre-1. However, treatments that were fertilized at 180 pounds N acre-1 did not have a greater leaf weight compared to those receiving 45 pounds N acre-1. Ammonium nitrate fertilizer applied at 90 pounds N acre-1 had the highest leaf dry weight and values were greater than all other ammonium nitrate treatments. When comparing the source effects at each N application rate, ammonium nitrate fertilization resulted in greater dry weights at all treatment rates except 135 pounds N acre-1 which were equal. The CV for the analysis of tissue dry weight responses was 8.71%.

Table 4. Dry weight (g) (oven dried) per trifoliate leaf of Roma II bush bean treated with five N application rates from two fertilizer sources.

N Fertilization rate	Fertilizer source		
Pounds acre^{-1}	Hairy Vetch	Ammonium nitrate	Average
0	0.51	0.59	0.55
45	0.58	0.71	0.64
90	0.54	0.85	0.70
135	0.77	0.75	0.76
180	0.65	0.76	0.71
Average	0.61	0.73	

Main effects $_{NS}$ and sub-effects. Mean separation of interactions* by LSD = 0.10 (=.01) and LSD =0.08 (=.05) (Satterwaites procedure) for main effects at each sub-effect level.

Crop Yields

At the first harvest of fresh pods, N source did not affect pod weight (Table 5). Fertilization at 135 pounds N acre-1 resulted in higher fresh pod weights than rates of 0 or 45 pounds N acre-1. Rates of 90, 135, and 180 pounds N acre-1 had similar pod yields.

Table 5. Fresh pod yield of bush bean from use of two sources of N and five rates of N for first harvest.

	Fertilizer Source		
Nitrogen Rate	Hairy Vetch	Ammonium Nitrate	
Pounds acre^{-1}	First harvest date (pounds fresh pods acre^{-1})		Average
0	1763	1721	1742c
45	2639	2432	2536bc
90	2667	3317	2992ab
135	3451	4019	3735a
180	2509	3660	3084ab
Average	2606	3030 NS	

Main effects$_{NS}$ and sub-effects *. Mean separation of sub-effects by LSD = 1079 (=.05).

At the second harvest date, fertilizer source did not impact fresh pod yields. Nitrogen fertilization rates at 135 pounds N acre-1 resulted in higher pod yields than all other rates. Rates of 90 and 180 pounds N acre-1 produced greater yields than 0 pounds N acre-1 but were similar to the yields at 45 pounds N acre-1 (Table 6).

Table 6. Fresh pod yield of bush bean from use of two sources of N and five rates of N for second harvest.

	Fertilizer Source		
Nitrogen Rate	Hairy Vetch	Ammonium Nitrate	
Pounds acre^{-1}	Second harvest date (pounds fresh pods acre^{-1})		Average
0	1403	1263	1333c
45	1528	1685	1606bc
90	1955	2092	2024b
135	3404	2808	3106a
180	1906	2177	2042b
Average	2039	2005 NS	

Main effects$_{NS}$ and sub-effects **. Mean separation of sub-effects by LSD = 537 (=.05).

Table 7. Total fresh pod yield of bush bean from use of two sources of N and five rates of N fertilization for all harvest dates.

	Fertilizer Source		
Nitrogen Rate	Hairy Vetch	Ammonium Nitrate	
Pounds acre^{-1}	Total of two harvest dates	(pounds fresh pods acre^{-1})	Average
0	3166	2984	3075c
45	4167	4117	4142bc
90	4622	5409	5016b
135	6855	6827	6841a
180	4415	5837	5126b
Average	4645	5035 NS	

Main effects$_{NS}$ and sub-effects **. Mean separation of sub-effects by LSD = 1506 (=.05).

The total fresh pod yield during the cropping period was not influenced by the N fertilization source. A higher fresh pod yield was obtained when N was applied at 135 pounds acre-1 (Table 7). Yields were not different when either 90 or 180 pounds N acre-1 were applied although they were higher than the control which received no N fertilizer.

Soil Nutrient Concentrations

Soil samples from all three blocks were combined from both treatments and tested for the same nutrients as plant tissues. Nutrient levels are presented as means for the blocks (Table 8). Soil organic matter averaged 1.32% (data not shown). Unlike plant tissue tests, soil test results are more variable and are normally translated into categories. For making recommendations for fertilization of specific crops, additional factors must be taken into consideration.

Observed soil P concentrations were 67 ppm and therefore classified as very high (Table 10). As a result, no yield response would be expected from higher levels of P and it is not recommended to apply additional P (Hochmuth and Hanlon, 1995). Potassium concentration in this soil was considered to be low (Tables 8 and 10). Fertilizer recommendations for Florida type conditions indicate that 90 pounds K2O acre-1 would be recommended per crop year with this level of soil K (Hochmuth and Hanlon, 1995).

Table 8. Concentration of macro-nutrients in soil samples from Roma II bush bean fertilization trials with soil pH and soil texture.

Nutrient	Concentration ppm	Soil texture fractionation	
N	430	Sand	94.3 %
P	66.8	Silt	3.2 %
K	32.4	Clay	2.5 %
Soil pH	7.3	Buffered pH	7.9

Table 9. Sufficiency ranges for essential elements in the tissues of bush bean (*Phaseolus vulgaris)*. Adapted From Mills and Jones, 1996 using data from the uppermost recently fully-developed leaves.

Element	Range
Nitrogen	3.00 - 6.00 %
Phosphorus	0.25 - 0.75 %
Potassium	1.80 - 4.00 %

Table 10. Interpretation of soil nutrient concentrations adapted from Kidder, et al., 1998; Hochmuth, and Hanlon, 1995.

Element	Very low	Low	Medium	High	Very high
			Soil concentration (ppm)		
P	<10	10-15	16-30	31-60	>60
K	<10	20-35	36-60	61-125	>125

DISCUSSION AND CONCLUSIONS

Using criteria for the growth of bush bean to interpret results, it is concluded that soil K concentrations were suboptimal for bush bean . Based on our soil test 90 pounds K2O acre-1 would have been recommended by the University of Florida Cooperative Extension Service for bush bean.

The use of ammonium nitrate as the sole fertilizer source for N application resulted in the deficiency symptoms according to the criteria of Mills and Jones (1996). These symptoms are consistent with low soil test values. Use of ammonium nitrate as the N source did not improve this condition. The use of hairy vetch mulch as a N source also provided K and thereby prevented K deficiency. A clear trend of increasing tissue K concentration with increasing vetch mulch rates was observed up to 6850 pounds of material acre-1. At N application rates with hairy vetch of 135 pounds acre-1, diagnostic leaf tissue K concentrations were within sufficiency ranges.

Although leaf N concentrations appeared to increase with N rate, this trend was not significant. This is explained by a dilution effect due to larger plant sizes under higher N nutrition. The increased pod yields indicate that greater amounts of N were being remobilized from the leaf tissue in treatments with higher N application rates.

Under vetch mulching, average leaf weight reached a maximum with a N application rate of 135 pounds acre-1 compared to maximum leaf weight with ammonium nitrate at 90 pounds N acre-1. Average leaf weight mass was greater with ammonia nitrate at all treatment levels except at 135 pounds N acre-1 where it was the same as with vetch mulch. A likely explanation for this difference is the rate of mineralization of organic N from vetch. Nitrogen from ammonium nitrate is rapidly made available to bean crops, but is also more susceptible to leaching in inorganic form. In comparison, all N applied as vetch straw does not become available immediately. Further research is required to verify whether this supposition is valid.

This study further examines bean fresh pod yield, the economic aspect of the crop. Leaf tissue dry matter appeared to provide a valid predictor of bean yields under vetch mulch to the extent that a large percentage of leaf nutrients are remobilized during pod filling in many leguminous crops. The use of vetch mulch may be a viable alternative for bush bean crops in sandy soils with pH values near 7.0. Current extension recommendations of 90 pounds N acre-1 year-1 for bean crops do not appear valid when using a vetch N source. Application rates of not less than 135 pounds N acre-1 year-1 based on vetch N concentrations are required to maximize leaf dry mass and fresh pod yield under the study conditions. The use of hairy vetch mulch has a further benefit of providing adequate K nutrition to bean crops at this application rate, indicating that it is a more complete fertilizer source for this crop.

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