Lupin Hay as an Organic Fertilizer for Production of 'White Acre' Cowpea

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ABSTRACT

In many countries, sources of fertilizer are scarce or unaffordable by small fanners. In the U.S., many farmers wish to use organic sources of fertilizer in production of crops. However, information is lacking on potential use of home grown legumes as a source of complete fertilizer. During the Fall 1996 in Gainesville, FL, a field study was conducted to determine the effects of the incorporation of air-dried lupin *(Lupinus angustifolilus)* hay into the soil on 'White Acre' cowpea *(Vigna unguiculata)* yield and soil quality. Ten treatments of air-dried lupin were applied at rates of 1000 lb/a from 0 lb/a to 9000 lb/a Analysis of nutrient concentrations in the soil and diagnostic leaf were used to indicate the result of treatment effects Pod yields at two harvest dates, as well as plant part yields were also determined. Results indicated increasing rates did not have an affect on pod yield at the first harvest date, but pod yield was affected at the second harvest with increasing application rates. Soil analysis indicated lupin was significant in increasing K ($p=0.01$) and Mg ($p=0.10$) in the soil with increasing rates of lupin. Diagnostic leaf N and P concentrations increased with increasing lupin rate. Treatment rate was significant in whole plant, pod, and stem yields in the undried fresh plant parts. Data indicated whole plant yield would be optimal between 4000 and 6000 lb lupin hay/a

INTRODUCTION

Cowpea *(Vigna unguiculata* L.), has become a most important food legume in the semihumid and humid tropics, effectively providing high protein and essential nutrients. However, due to its high protein content in the grain, this crop demands a significant supply of N. As a legume, much of this supply can be obtained through N fixation (Fernandez and filler, 1986), but additional N and other essential nutrients must be obtained from the soil for successful growth.

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Recent studies indicate at least half of the N in cowpea is supplied from atmospheric N^2, and the other half is provided by soil N or via fertilizers (Awonaike et al., 1991). Awonaike et al. (1991) showed that 80% of the N in the aboveground plant parts in cowpea was provided by the soil until the late vegetative stages. During the reproductive stages, most of the N was supplied from the atmosphere (Awonaike et al., 1991). These studies indicate soil N content is especially important in the early stages of cowpea development. Therefore, adjusting soil properties early during planting is essential for obtaining optimal yields.

Nutrients can be made available in the soil through recycling of nutrients or by addition of organic or inorganic fertilizers. Many tropical soils containing low concentrations of inorganic nutrients rely partly on the recycling of nutrients, but find it is still necessary to amend the soil by adding organic or inorganic fertilizers to provide additional N, as well as other essential nutrients (Lindsay et al., 1993).

With the movement towards sustainable agriculture, use of organic fertilizers is becoming increasingly important and has shown to be effective in helping to amend soil quality. Either by the use of multiple cropping systems or use as a mulch, green manure or cover crop, many crops successfully provide an organic source of nutrients which aid in plant development (Hagendorf and Gallaher, 1992; McSorley and Gallaher, 1994). Of particular interest in this research is the use of green manures as fertilizer sources. These amendments have been found to help improve soil properties including organic matter content, water holding capacity, cation exchange capacity (CEC), water conservation, and soil aeration. Unlike many inorganic fertilizers, green manures are capable of supplying a wide range of N and minerals as well as improving overall soil quality.

When applying organic fertilizers, it is especially important to know their nutrient concentrations. Since nutrient concentrations in organic fertilizers vary depending on previous cultural methods, determining nutrient concentrations in green manures is essential when determining application rates needed. The decomposition rate of these materials is also important in determining when these nutrients are available for the plant. In particular, N mineralization has been shown to be dependent on incubation time and incorporation rate (Li and Mahler, 1995).

Of interest in this research is the effect of the incorporationof lupin *(Lupinus angustifoilus* L.) into the soil. The purpose of this experiment was to determine the fertilizer treatment effects caused by 'Tilt Blue 78' lupin on 'White Acre' cowpea yield. Lupin treatment effects on soil properties and nutritional sufficiency was examined.

MATERIALS AND METHODS

The experimentwas conducted at the University of Florida Agronomy Soil Teaching lab off Museum Road in the Fall of 1996. The design was a randomized complete block with four replications. Plots were marked off, 4 rows each, 8 ft long x 10 ft wide with the two outer rows acting as border rows. Initial soil samples were taken from the site 27 August, and were sent to the IFAS Soils Testing Laboratory at the University of Florida for analysis and recommendations. On 29 August, 10 rates of air-dried 'Tift Blue 78' lupin were applied to the corresponding plot at 0, 1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, and 9000 lb/a and were rototilled into the *soil* to a depth of 6 in. It later rained 1.5 in to wet the soil to a depth of 6 to 8 in. On 30 August, 'White Acre' cowpea was planted at a rate of 12 seeds per ft of row. On 1 September, it rained 2.0 in. Rainfall or irrigation, by means of an overhead sprinkler system, was used when necessary to maintain a minimum of 1.25 in water per 6 days. On 26 September, soil samples were taken from each of the plots. Three samples were collected between every two rows, 6 samples per plot. Soil sampleswere air dried in open paper bags. The soil was sieved using a 2 mm stainless steel screen and placed in new bags before analysis. Tests were conducted to determine soil organic matter, soil pH, buffer pH, Kjeldahl N, and Mehlich I extractable nutrients (Peech, 1965; Jackson, 1958; Horwitz, 1975; Gallaher et al., 1975; Mehlich, 1953).

On 8 October, diagnostic leaves were taken from the inner two rows of each plot following Jones' et. al. (1991) recommendations. Ten of the most newly developed leaves were collected from each plot and placed in paper bags. Each samples was washed, dried, and weighed (Futch and Gallaher, 1994; Gallaher, 1995).

The diagnosticleaves were then ground to pass a 2.0-mm stainless steel screen using a Wiley Mill and placed in labeled plastic bags. Previous to analysis, all bags were reopened and redned for 2 hours at 70C. Nitrogen concentrations and the concentrations for the extractable nutrients P, K, Ca, Mg, Cu, Fe, Mn, Na, and Zn were determined (Gallaher, et al., 1975).

A Perkin-Elmer Atomic Absorption Spectrophotometer was used in determining elemental concentrations. Potassium concentrations were determined using atomic emission spectrophotometry, and atomic absorption spectrophotometry was used to determine Mn, Fe, Cu, Zn, Ca, and Mg concentrations. Phosphorous concentrations were determined using a colorimeter.

On 11 November, the first cowpeas were harvested for each of the treatments. All mature pods were removed from the inside *two* rows of each plot (40 sq ft) and placed in paper bags. On 21 November, all mature and immature pods were removed from the inside two rows of each plot. At each harvest date, fiesh pods were weighed and used to determine fiesh cowpea pod yields for each of the treatments. On 15 November, plants were removed from a 1 square meter area from the inside border row of each plot. Roots, stems, leaves, and pods were separated and weighed fiesh.

Data were entered into a Quattro Pro spreadsheet (Anon., 1987). All analysis ofvariance and lsd mean separation statistical analysis was computed using MSTAT software (Freed et al., 1987).

RESULTS AND DISCUSSION

Table 1 gives the average nutrient concentrations for N, P, K, Ca, Mg, Cu, Fe, Mn, and Zn for air-dried lupin. Actual nutrient contents applied to each of the 10 treatments can be calculated from the nutrient concentrations. For example, 1000 lb lupin hay would contain 14.4 lb N, 2.15 lb P, 15.5 lb K, 5.3 lb Ca, 2.0 lb Mg, 4.5 g Cu, 205 g Fe, 55 g Mn, and 45 g Zn. Therefore, the lupin hay is a complete fertilizer source. Initial soil tests analyzed by the UF IFAS Soil Testing Laboratoy recommended that 65 lb N/a be applied to the soil when growing this crop. Lupin treatments between 4000 lb/a and 5000 lb/a with N nutrient contents of 57.6 lb/a and 72.0 lb/a respectively would be expected to provide adequate N for growth and development. Initial soil tests found P, K, and Mg to be in high concentrations in the soil. Initial pH was 6.0 previous to lupin fertilizer applicationswith a buffering pH of 7.82. Table 5 shows the results of the soil pH, buffering pH, CEC, organic matter, Mehlich I extractable elements and Kjeldahl N taken on 26 September, approximately one month after fertilizer application. Magnesium concentrations were significant at $p=0.10$, and K concentrations at $p=0.01$. The fertilizer rates did show an increase in K in the soil with increasing rates of lupin. Magnesium concentrations peaked at a lupin rate of 6000 lb/a applied. There was an increase in K concentration in the soil as treatment rate increased with the exception of the plants treated with 2000 lb/a lupin applied having a slightly higher K concentration at 47.4 ppm versus the following treatment, 3000 lb/a lupin, having a K concentration of 43.6 ppm. Potassium availability increased with increasing rates of lupin applied. The corresponding Mg concentrationsprobably resulted from the classical K:Mg relationship interaction. When 6000 lb/a was applied, the Ca, Mg, and K concentrations all were near their peaks indicating this rate may be optimal in providing high concentrations of each of these nutrients to the soil. Sodium was also significant at p = 0.01, Cu at p=0.10, and Zn at p=0.05. Neither the soil pH nor the buffering pH appeared to be affected by treatment differences (Table 5). Neither a significant acidifyingnor a liming affectoccurred indicating lupin may be useful for soils which do not need pH adjustment. The CEC, organic matter, N, P, Ca, Fe, and Mn did not show statistical differences in treatments at this date either Takingmeasurements at a later date may have resulted in treatment differences. Further studies would be useful in determining the decompositionrate of lupin. This would also provide an understanding as to when specific nutrients become available.

Pod yields for each of the treatments is shown in Table 2. The first harvest did not show any statistical significanceamong treatments. Although the first harvest was not statistically significant, there appeared to be visually observed differences in the number of immature pods remaining on the plants, plant height, and leaf color. Plots treated with 9000 lb/a lupin were taller, greener, and appeared to have more immature pods than plots treated with 1000 lb/a lupin which were shorter, lighter green and yellow in color, and had fewer pods. The second harvest on 21 November showed treatment differences at p=0. 10 with an increase in pod yield with increasingfertilizerrates. Lupin applied at a rate of 4000 lb/a seemed to be at a peak for pod yield.

Additively, the two harvests were not statistically significant with the treatments applied. Although the lupin treatments between 4000 and 6000 lb/a at around the recommended N application rates did produce some of the highest pod yield values of 6942, 6853,6996 lb/a respectively with the exception of the highest fertilizer rate producing the most total pods at 7378 lb/a If using lupin as a fertilizer, determining soil N needs with a soil test may be the key in determining amounts of lupin to apply for optimal pod yield.

Fertilizer treatments affected yields of leaves, stems, pods, and whole plants, but not for roots Tables 3 and 4 illustrates yields of fresh and dried plant parts sampled over a 1 sq m area. Lupin rates were significant in fresh undned parts at p = 0.01 for the whole plant, stem, and pod, and p = 0.05 for leaves.

Fresh weights of whole plant and stem yield increases until 4000-5000 lb/a lupin is applied, at wluch point the curve tends to plateau (Table 3). Pod and leaf yield appears to follow the same trend as for whole plant and stem except the slope is not as steep. Fresh pods were affected by treatment with an increase in pod yield as treatment rate increased.

In comparison, Table 4 shows that the effects on dried White Acre cowpea parts follow a slightly different pattern than for fresh material. The whole plant appears to increase nearly linearly. The stem, pods and roots show similar trends. The dried pods did not show treatment affects, indicating differences in dried and undried pods was probably due to pod water retention.

Table 6 gives the plant nutrient concentrations obtained for each of the elements, N, P, K, Ca, Mg, Cu, Fe, Mn, and Zn for the diagnostic leaf obtained just prior to early bloom. For each of the elements, sufficiency ranges are listed (Table 6) according to Jones et al. (1991) and Hochmuth et al. (1991) in Florida. Nitrogen diagnostic leaf concentrations were lugh according to both sources indicating the plant were receiving more than necessary amounts of N from either soil residual N left by the previous crop or by symbiosis. Differences in sufficiency ranges between Jones et. al. (1991) and Hochmuth et. al. (1991) is dependent on sampling sites. Hochmuth's recommendations are specific to Florida, whereas Jones' recommendations are more general. Although concentrations may be slightly higher according to one source versus another, none of these elements seemed to show any visible toxic effects at the lupin rates applied.

Table 6 shows N, P, Cu, and Zn were affected by increasing treatment rates of lupin. Due to cowpea's ability to fix N, these treatment differences may not have been as great as they would be in a nonleguminous plant. Some of the N utilized by the cowpea plant may have been obtained via denitrification versus the uptake of N from the soil and/or all of the lupin may not have decomposed. Studies indicate 87% of the N found in the pods was contributed by denitrification versus fertilizer treatment (Awonaike et al., 1991).

Research has shown that lupin can be grown without additional inorganic N (Ayisi et al., 1992). Using lupin in organic farming may be an economical organic crop when moving away from inorganic fertilizers since less N will be necessary for growth.

CONCLUSIONS

According to our data, it is recommended that approximately 5000 lb/a lupin be applied to maximize fresh cowpea pod yield. This study indicated there was an increase in N concentrations in the diagnostic leaves when using lupin. Further studies on nonleguminous crops may show the utilization of lupin more effectively. Sampling the soil at a later date may also show differences in soil N with the further decomposition of lupin. Lupin did appear to be an effective source of providing K to soil one month after application. Further studies are needed to confirm which rates would be most effective.

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Table 1. Plant nutrient analyses of air dried lupin used as an organic fertilizer for White Acre cowpea, Gainesville, Florida, 1996.

	Nutrient Concentration								
	N	P	K	Ca	Mg	Cu	Fe	Mn	Zn
	------	------	%	------	------	------	ppm	------	------
	1.44	0.22	1.55	0.53	0.20	4	183	49	40

Nutrient concentration values are the average of four replications

Table 2. Fresh cowpea pod yield at two dates from a 40 sq ft area when treated with air dried lupin hay, Gainesville, Florida, 1996.

Lupin Treatment	12 November	21 November	Total
lb/a	------	lb/a	------
0	3373	2341	5714
1000	3427	2554	5981
2000	3559	2554	6150
3000	3978	2857	6835
4000	3542	3400	6942
5000	3658	3195	6853
6000	3667	3329	6996
7000	3747	3097	6848
8000	3640	3355	6995
9000	3471	3907	7378
CV	15.9	21.6	12.0
Significance	NS	+	NS
Probability	----	0.06	0.17
LSD @ $p = 0.10$		792	

CV = Coefficient of variation, NS = Non significant; + = significant at $p = 0.10$; * = significant at $p = 0.05$; ** = significant at $p = 0.01$

Table 3. Fresh cowpea plant parts taken near maximum fresh pod maturity treated with air dried lupin, Gainesville, Florida, 1996.

Lupin Treatment	Root	Leaf	Stem	Pod	Plant
lb/a	----------	----------	lb/a	----------	----------
0	716	1007	5715	3176	10614
1000	679	1385	5990	3157	11211
2000	650	1474	6993	3253	12370
3000	724	1944	8192	3901	14761
4000	770	1668	7723	3530	13691
5000	863	1598	7988	4139	14588
6000	793	1645	8838	3988	15264
7000	724	1726	9317	3857	15624
8000	819	2612	10296	4456	18183
9000	789	1339	8128	3524	13780
CV	17.0	33.0	13.2	12.2	12.7
Significance	NS	*	**	**	**
Probability	---	0.02	0.00	0.00	0.00
LSD @ p = 0.05		773	1493	642	2543

CV = Coefficient of variation, NS = Non significant; + = sigrufcant at p = 0.10; * = sigruficant at p = 0.05; ** = significant at p = 0.01

Table 4. Dry cowpea plant parts taken near maximum fresh pod maturity treated with air dried lupin, Gainesville, Florida, 1996.

Lupin Treatment	Root	Leaf	stem	Pod	Plant
lb/a	----------	----------	lb/a	----------	----------
0	346	542	1363	1283	3516
1000	326	583	1489	1299	3697
2000	231	717	1549	1284	3781
3000	368	704	1788	1445	4305
4000	357	650	1663	1349	4019
5000	425	741	2054	1555	4775
6000	393	689	1790	1526	4298
7000	324	795	2094	1388	4601
8000	352	795	2072	1414	4633
9000	371	754	1901	1304	4330
CV	16.0	13.9	12.0	15.1	9.7
Significance	NS	**	**	NS	**
Probability	---	0.01	0.00	---	0.00
LSD @ p = 0.05		137	320		585

CV = Coefficient of variation; NS = Non sigrufcant, + = significant at p = 0.10; * = sigrufcant at p = 0.05; ** = significant at p = 0.01

Table 5. Soil pH, buffer pH, CEC, organic matter, Kjeldahl N and Mehlich I extractable elements from cowpea soil site treated with rates of air dried lupin, Gainesville, Florida, 1996.

Lupin Treatment	pH	BpH	CEC	OM	N	P	Ca	Mg	K	Na	Cu	Fe	Mn	Zn
lb/a			Meq/ 100g	%	%	ppm								
0	5.7	7.77	3.98	1.14	0.050	80.5	312	43.0	38.4	31.4	0.82	19.7	6.00	2.24
1000	5.6	7.77	3.54	1.14	0.051	76.8	236	34.5	38.7	22.2	0.77	21.2	6.03	1.63
2000	5.7	7.76	3.68	1.01	0.050	71.9	246	38.8	47.4	25.3	0.95	18.0	5.73	1.96
3000	6.0	7.79	4.18	1.06	0.049	79.8	380	44.6	43.6	23.9	0.71	15.7	6.48	2.06
4000	5.8	7.77	3.91	1.10	0.046	76.9	296	45.6	45.5	26.4	0.91	14.8	6.35	2.49
5000	5.8	7.77	3.91	1.18	0.048	79.0	298	43.7	46.1	24.0	0.85	14.8	6.25	2.43
6000	5.9	7.77	4.53	1.11	0.058	79.2	394	53.1	57.5	32.8	0.69	17.4	6.20	2.25
7000	5.8	7.76	4.03	1.18	0.056	78.8	281	46.5	56.3	30.9	0.76	18.1	6.43	2.12
8000	5.7	7.77	3.73	1.18	0.052	78.4	258	39.0	59.9	22.9	0.73	18.5	6.13	1.72
9000	5.9	7.79	4.09	1.18	0.059	80.2	342	51.7	64.8	23.9	1.06	17.8	7.33	2.12
CV	3.1	0.4	16.0	9.2	13.7	9.5	32.9	19.2	13.1	18.2	19.7	24.7	10.4	17.7
Significance	NS	NS	NS	NS	NS	NS	NS	+	**	**	+	NS	NS	*
LSD @ P = 0.10							10.0			0.17				
LSD @ P = 0.05								9.0	7.0				0.52	

CV = coefficient of vanation; NS = non significant; + = significant at p = 0.10; * = significant at p = 0.05; ** = significant at p = 0.01; CEC = cation exchange capacity; OM = organic matter

Table 6. Plant nutrient analyses of the diagnostic leaf of cowpea treated with air dried lupin, Gainesville, Florida, 1996.

Lupin Treatment	N	P	K	Ca	Mg	Cu	Fe	Mn	Zn
lb/a	%					ppm			
0	6.30	0.49	2.43	1.37	0.41	15.0	158	108	53.5
1000	6.49	0.50	2.49	1.17	0.41	13.8	173	109	52.5
2000	6.31	0.49	2.61	1.25	0.41	14.0	170	123	54.3
3000	6.35	0.49	2.43	1.39	0.40	13.5	155	102	48.0
4000	6.37	0.47	2.43	1.38	0.41	12.8	163	115	51.0
5000	6.55	0.52	2.40	1.17	0.39	16.3	173	94	55.0
6000	6.74	0.51	2.39	1.20	0.39	14.5	165	85	51.0
7000	6.32	0.48	2.37	1.24	0.40	14.3	188	98	49.3
8000	6.50	0.51	2.41	1.17	0.39	15.5	168	91	54.8
9000	6.66	0.52	2.47	1.14	0.38	15.0	163	90	51.5
CV	3.6	5.0	6.0	16.7	10.7	9.5	16.8	13.9	10.2
Signficance	+	+	NS	NS	NS	*	NS	**	NS
LSD @ p = 0.10	0.28	0.03							
LSD @ p = 0.05						2.0		20	
	Sufficiency Ranges by Jones et al. (1991)								
Low range	3.00	0.25	1.80	1.50	0.25	<6	40	<50	18
	3.99	0.29	2.19	1.99	0.29		49		19
Sufficient range	4.00	0.30	2.20	2.00	0.30	6	50	50	20
	5.00	0.60	3.00	3.00	0.50	25	100	300	100
High	>5.00	N.60	>3.00	>3.00	>0.50	>25	>100	>300	>100
	Sufficiency Ranges by Hochmuth et al. (1991)								
Low	<2.50	<0.20	<2.00	<1.00	<0.30	<5	<30	<30	<20
Adequate range	2.50	0.20	2.00	1.00	0.30	5	30	30	20
	4.00	0.40	4.00	1.50	0.50	10	100	100	40
High	>4.00	>0.40	>4.00	>1.50	>0.50	>10	>100	>100	>40

CV = coefficient **of** variation, NS = non significant; + = significant at **p =** 10; * = significant at p = 0.05; ** = significant at p = 0.01; refer to literature cited section for Jones et al., 1991 and Hochmuth et al., 1991.