Preliminary Evaluation of White Lupin (*Lupinus albus* L.) as a Forage Crop in the Mid-Atlantic Region of the United States of America

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Abstract

White lupin (*Lupinus albus* L.), a winter legume, is being evaluated in Virginia as a grain and a winter legume cover crop. There is however scanty information available about lupin's potential to provide forage. This study was, therefore, conducted to determine the potential of white lupin as a forage crop and to characterize effects of genotypes and growing locations on forage yield and quality. Twenty lines were grown at three locations in Virginia (Orange, Petersburg, and Suffolk), during 2003-04 crop growing season using four replications of a Randomized Complete Block Design. Data on fresh and dry matter yield, crude protein, and acid detergent fiber (ADF) were recorded. The fresh matter yields varied from 6.5 to 12.6 Mg/ha with Petersburg location exhibiting the highest fresh matter yield whereas Orange location exhibited the lowest fresh matter yield. This was also true for dry matter yields which were 0.8, 2.0, and 1.1 Mg/ha for Orange, Petersburg, and Suffolk locations, respectively. The mean crude protein contents were 16.7, 21.3, and 18.1 percent whereas the mean ADF contents were 18.9, 21.2, and 30.4 percent for the Orange, Petersburg, and Suffolk locations, respectively. These differences were attributed to differences in temperatures during lupin growth and soil types at different locations. The Orange location is considered a cooler environment whereas Suffolk is considered a warmer environment with Petersburg being intermediate in temperature. The soil type and soil pH at Orange, Petersburg, and Suffolk locations were Star silty clay loam and 6.9, Abel sandy loam and 6.2, and Rains fine sandy loam and 5.6, respectively. Auburn-04 was identified to be a high yielding white lupin lines for forage yield (10.7 Mg/ha) and protein content (19.1 percent). The results of this preliminary study indicated that white lupin is a potential forage crop for the mid-Atlantic region of the United States of America. We suggest that further studies be conducted to confirm our results and to determine lupin's forage yields under additional environments in the mid-Atlantic region of the United States of America and elsewhere.

Keywords: *Lupinus albus* L., Grain legume, Winter legumes, Crude protein content, ADF

1. Introduction

Lupin is a cool-season legume plant native to the Mediterranean region, North Africa, and North and South America. More than 300 *Lupinus* species have been described, but only following five species are important: white lupin (*Lupinus albus* L.), blue or narrow-leafed lupin *(L. angustifolius* L.*)*, yellow lupin *(L. luteus* L.*),* Andean lupin from South America *(L. mutabilis* L.), and the West Australian Sandplain lupin (*L. consentinii* L.). The last three species are grown on a limited basis because of their hard seed and high alkaloid content (Field and Putnam, 1993).

White lupin has a long history in the United States as a green-manure nitrogen source. By the 1940s, it was so prevalent that southern Coastal Plain was nicknamed "*The Lupin Belt (*Reeves et al., 1990*)"*. At one time, over 2.5 million acres of blue, yellow, and white lupin were grown in the Southern USA as green manure for cotton. Consecutive hard freezes, cheap fertilizers, and government programs favoring other crops contributed to the lupin's demise so that by the 1960s it had essentially disappeared (Reeves et al., 1990). Recently, the crop is again being investigated as a potential forage and grain crop (Bhardwaj, 2002; Bhardwaj et al., 1998 and 1999; Noffsinger et al., 1998. Extensive research has been conducted by Auburn University in Alabama (Southern United States of America) indicating that lupin has potential as a forage and a silage crop. No information is, however, available about lupin's potential to provide forage in Virginia (mid-Atlantic region of United States of America). Such information is needed because the environmental conditions in Alabama are different from those in Virginia. A survey of historic data indicated that average annual temperature from September to April, the duration for lupin planting and forage harvest, was 45.8 for Virginia and 57.4 for Alabama. Additionally, the soils at both locations are different. This information along with considerable success in developing white lupin as a grain legume crop in Virginia prompted us to evaluate white lupin as a forage crop.

The objectives of this effort were to determine the potential of white lupin as a forage crop in Virginia and to characterize variation in lupin forage yield and quality as affected by growing locations and genotypes.

2. Materials and Methods

2.1 Sites and Their Characteristics

The field experiments were conducted at three locations in Virginia: Orange, Petersburg, and Suffolk in the 2003-04 crop growing season. The soil type at Orange was a Starr silty clay loam with a pH of 6.9, the soil at Petersburg was an Abel sandy loam with a pH of 6.2, and the soil at Suffolk was a Raines fine sandy loam with a pH of 5.6.

2.2 Treatments and Experimental Design

Twenty lines of white lupin (*Lupinus albus* L.), 17 F_8 lines and three cultivars (Line 310, Lucyanne, and Ludet), all from Auburn University, were evaluated for forage yield using randomized complete block designs with four replications at each location.

2.3 Agronomic Practices

The field experiments were planted on October 10, September 27, and September 26, respectively for Orange, Petersburg, and Suffolk locations during 2003. Each plot consisted of four rows spaced 37.5 cm apart. Each row was 4.5 m long. The plot size was 6.75 m^2. All field experiments received 1 pint per acre of Treflan (Trifluralin) as a pre-plant incorporated herbicide approximately one week before planting.

2.4 Data collection and Statistical Analysis

At flower initiation during 2004 (April 20 at Orange, April 8 at Petersburg, April 16 at Suffolk), all plants from two rows were harvested by hand approximately 3-5 cm above the ground level and data on fresh yield were recorded for each plot. The harvested material was dried until constant moisture to record dry matter yield. All samples were analyzed for crude protein and acid detergent fiber by Forage Laboratory at Virginia Tech, Blacksburg, Virginia. All data were analyzed using SAS version 9.1 (SAS, 2003).

3. Results and Discussion

3.1 Effect of locations and genotypes on lupin forage yield and its components

The growing locations were a significant source of variation for fresh and dry matter yield, crude protein, and acid detergent fiber (ADF) contents. Genotypes also contributed significantly to the variation for these traits (Table 1). The interaction between locations and genotypes were significant for all traits. However, the magnitudes of location and genotype mean squares were considerably higher than those for location x genotype interactions (Table 1). Therefore, the means are reported over locations and genotypes.

The fresh matter yields varied from 6.5 to 12.6 Mg/ha with Petersburg location exhibiting the highest fresh matter yield whereas Orange location exhibited the lowest fresh matter yield (Table 2). This was also true for dry matter yields which were 0.8, 2.0, and 1.1 Mg/ha for Orange, Petersburg, and Suffolk locations, respectively. The mean crude protein contents were 16.7, 21.3, and 18.1 percent (Dry weight basis) whereas the mean ADF contents were 18.9, 21.2, and 30.4 percent (Dry weight basis) for Orange, Petersburg, and Suffolk locations, respectively. These differences could be caused by many factors including temperatures during lupin growth, soil types, etc. The Orange location is considered a cooler environment whereas Suffolk is considered a warmer environment with Petersburg being an intermediate location indicating that neither a warmer nor a cooler climate is conducive for lupin growth. There is a lack of lupin forage performance based on temperature regimes. However, we have observed similar results with canola (*Brassica napus* L.). Canola is also being evaluated in the mid-Atlantic region as a winter crop. Our results from canola production research at the same three locations used for the white lupin forage studies indicated that Petersburg location being intermediate for temperature was more conducive for canola yield (Hamama et al., 2003). Our results also suggest that neither clay nor sandy soils are conducive for lupin growth given that Orange, and Suffolk locations had clay loam and sandy loam soils, respectively. Our results also indicated that an intermediate soil pH is conducive for higher lupin forage yield given highest yield was obtained when soil pH was 6.2 (Petersburg) as compared to 6.9 (Orange) or 5.6 (Suffolk). We are not able to quantitatively distinguish between these factors but suggest that these factors are important and should be considered for future studies. Additionally, these results need to be substantiated by repeating such experiments.

3.2 Performance of the white lupin lines and cultivars

The results related to performance of twenty white lupin lines and cultivars for fresh and dry matter yield, CP, and ADF indicated that seventeen F_8 lines were superior in performance for the four traits than the three cultivars (Table 3). Averaged over three locations, the genotype means varied from 4.1 to 10.7 Mg/ha for fresh matter yield, 0.71 to 1.70 Mg/ha for dry matter yield, 17.7 to 19.7 for crude protein, and 22.1 to 25.2 percent for ADF. Auburn-04 was identified to be a high yielding white lupin lines for forage yield and protein content (Table 3). It had the highest fresh and dry matter yields of 10.7 and 1.70 Mg/ha, respectively. The crude protein content in forage of Auburn-04 was 23 percent (Dry weight basis) which was similar to the highest protein content of 24.7 percent for Auburn-03.

3.3 Correlations coefficients between yield and yield components

A highly positive correlation was observed between fresh matter yield and dry matter yield (0.97, significant at <.0001 level), between fresh matter yield and crude protein (0.36, significant at <.0001 level), and between dry matter yield and crude protein (0.33, significant at <.0001 level). A negative correlation existed between crude protein and acid detergent fiber (0.13, significant at 0.03 level). Positive correlation of crude protein with fresh and dry matter yields indicated that these traits can be simultaneously improved in white lupin i.e. selection for higher value for anyone trait would cause a correlated positive response in the other trait.

3.4 Potential of white lupin as a forage crop

The yield and yield components of white lupin were compared with well known and established forages such as alfalfa (*Medicago sativa* L.). This provided a basis for evaluating the potential of white lupin as a forage crop. In comparison with alfalfa, white lupin in our study had a mean ADF content of 23.7 percent with a range of 17 to 41 percent and a mean crude protein content of 18.7 percent with a range of 13 to 29 percent.

Fonseca et al. (1999) reported that alfalfa forage contained 25 to 29 percent ADF and 20 to 22 percent crude protein whereas Cassida et al. (2000) reported that alfalfa ADF varied from 23 to 33 percent and crude protein content varied from 16 to 23 percent in alfalfa. White lupin forage yield, therefore, compared quite well with alfalfa. Buxton and Mertens (1996) reported that a plant with crude protein of 7 percent is suitable for mature beef cows whereas a plant with at least 19 percent crude protein is suitable as forage for high-producing, lactating dairy cows. Based on this observation, white lupin with an average crude protein content of 18.7 percent (Dry weight basis), has potential as a forage crop in Virginia and in other areas in the mid-Atlantic region of the United States of America.

4. Conclusion

Our results indicate that lupin is a potential forage crop for the mid-Atlantic region of the United States of America. However, our results need to be confirmed over times and under additional environments

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Table 1. Analyses of variance for selected sources for fresh matter yield, dry matter yield, crude protein, and acid detergent fiber of white lupin grown at three locations in Virginia during 2003-04 growing seasons

Source	df	FMY[z]	DMY[z]	CP[z]	ADF[z]
Replications(Loc)	9	64.68**	1.64**	19.87**	92.85**
Locations (L)	2	1181.16**	29.39**	439.78**	2856.31**
Genotypes (G)	19	45.40**	1.04**	3.70*	6.48*
L x G	37	17.09**	0.37**	2.67	5.83**
Residual Error	67	6.86	0.15	2.10	3.27
R^2		79.16	80.36	77.43	92.50
CV(%)		31.85	29.54	7.75	7.63

[z] FMY=Fresh Matter Yield; DMY=Dry Matter Yield; CP=Crude Protein in percent, dry matter basis; ADF=Acid Detergent Fiber in percent, dry matter basis.

*, **: Significant at 5 and 1 percent levels, respectively.

Table 2. Growing location effects on fresh matter yield, dry matter yield, crude protein, and acid detergent fiber of white lupin grown at three locations in Virginia during 2003-04 growing seasons

Location	FMY[z]	DMY[z]	CP[z]	ADF[z]
Orange	5.53 c	0.83 c	16.71 c	18.92 c
Petersburg	12.62 a	2.00 a	21.28 a	21.75 b
Suffolk	6.51 b	1.14 b	18.08 b	30.39 a

[z] FMY=Fresh Matter Yield Mg/ha; DMY=Dry Matter Yield Mg/ha; CP=Crude Protein in percent, dry matter basis; ADF=Acid Detergent Fiber in percent, dry matter basis. Means, over 20 lines, followed by different letters are significantly different from each other at 5% level according to Duncan's Multiple Range Test.

Table 3. Differences among white lupin lines for fresh matter yield, dry matter yield, crude protein, and acid detergent fiber grown at three locations in Virginia during 2003-04 growing seasons

Location	FMY[z]	DMY[z]	CP[z]	ADF[z]
Auburn-01	10.4 a	1.56 a	18.0 bc	23.6 a-e
Auburn-02	9.1 a	1.46 ab	18.6 abc	23.5 a-e
Auburn-03	9.3 a	1.43 ab	18.7 abc	24.7 ab
Auburn-04	10.7 a	1.70 a	19.1 abc	23.6 a-e
Auburn-05	9.1 a	1.47 a	18.5 abc	23.9 a-e
Auburn-06	9.0 a	1.44 ab	18.5 abc	24.2 a-d
Auburn-07	6.5 bcd	1.09 bc	19.7 a	22.1 e
Auburn-08	5.9 d	1.01 cd	19.6 a	23.8 a-e
Auburn-09	9.2 a	1.60 a	17.7 c	24.4 ab
Auburn-10	8.9 a	1.48 a	19.0 abc	23.7 a-e
Auburn-11	9.7 a	1.56 a	17.8 c	23.2 b-e
Auburn-12	8.6 ab	1.38 ab	18.4 abc	23.7 a-e
Auburn-13	10.0 a	1.59 a	18.2 bc	23.4 b-e
Auburn-14	6.4 bcd	1.01 cd	19.3 ab	23.6 a-e
Auburn-15	9.4 a	1.52 a	19.0 abc	24.1 a-d
Auburn-16	9.2 a	1.43 ab	18.5 abc	24.3 abc
Auburn-17	8.4 abc	1.33 abc	18.5 abc	23.7 a-e
Line-310	6.2 d	1.01 cd	18.9 abc	22.6 cde
Ludet	4.3 d	0.71 d	19.2 ab	22.5 de
Lucyanne	4.1 d	0.72 d	18.4 abc	25.2 a

[z] FMY=Fresh Matter Yield Mg/ha; DMY=Dry Matter Yield Mg/ha; CP=Crude Protein in percent, dry matter basis; ADF=Acid Detergent Fiber in percent, dry matter basis. Means, over three locations, followed by different letters are significantly different from each other at 5% level according to Duncan's Multiple Range Test.