Cultivar and Growing Location Effects on White Lupin Immature Green Seeds

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Received: June 23, 2011 Accepted: July 7, 2011 Online Published: December 21, 2011

doi:10.5539/jas.v4n2p135 URL: http://dx.doi.org/10.5539/jas.v4n2p135

Abstract

Mature white lupin (*Lupinus albus* L., Fabaceae) seeds have been used as food for over 3000 years around the Mediterranean and for as much as 6,000 years in the Andean highlands. However, no information is available about use of immature green lupin seeds as human food similar to that of vegetable soybean (Edamame) and green peas. We studied yield and protein content of green immature seeds of ten white lupin cultivars grown at two locations in Virginia over 2005-06 and 2006-07 crop seasons. Location effects were, generally, non-significant whereas cultivar effects were significant for pod yield and number of pods per hectare and non-significant for number of seeds per pod, shelling percent, and protein content whereas location effects were significant only for protein content. The mean values for pod yield (kg.ha^{-1}), number of pods per hectare, number seeds per pod, shelling percent, and protein content of green immature white lupin seeds were 18098, 3402899, 4, 32, and 33, respectively. These results, when compared to literature values for Edamame and green peas, were encouraging and indicated that green immature white lupin seeds may have potential as human food.

Keywords: Lupinus albus L., Pod yield, Seeds per pod, Shelling percent, Human nutrition

1. Introduction

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

We are interested in developing white lupin (*Lupinus albus* L.) as a grain, forage, and green manure crop in Virginia and the mid-Atlantic region of the United States. Extensive research has identified winter-hardy lines and preliminary evaluation of mature seeds has indicated that lupin seed contain 32 to 43 % protein with a mean of 37 %, 3 to 7 % oil with a mean of 5%, and 5 to 9 % sugar with a mean of 7% (Bhardwaj et al., 1998).

Lupin seeds are an excellent substrate for both bacterial and fungal fermentations to make foods such as tempe, miso, and traditional soy sauces. Up to about 10 percent lupin flour can be mixed with wheat or wholemeal flours to make more nutritious breads. The blend of cereal and legume helps to balance out the amino acid profile resulting in a more complete food (Petterson, 1998). Lupin seeds lack the strength and elasticity of wheat gluten. Lupin seeds can also be germinated to make a big sprout for vegetable or salad use. Sprouting was shown to reduce alkaloids, phytate, and oligosaccharides in lupin seed (Dagnia et al., 1992). The use of immature lupin seed may also have potential as human food similar to the vegetable-type soybean which is receiving increasing attention by health-conscious consumers (Reviewed by Brar and Carter, 1993). However, information about potential yield, chemical composition, and nutritional quality of immature lupin seed is not available.

Our objectives were to characterize yield and other traits of green pods and immature seeds of white lupin. This study's idea stemmed from increasing interest in vegetable soybean and its potential use as a vegetable. White lupin is a winter crop that is, generally, planted in the fall and fully matures in June. This indicates that green pods and immature seeds from white lupin should be available approximately in mid May-June. This period is important given the lack of any such material for human consumption in this period. If use of white lupin as a vegetable develops, it could boost the establishment of white lupin as an agronomic crop to provide high-protein grains for food and feed.

2. Materials and Methods

Green pods were harvested from 2-3 meter row length from each of the three replications of ten white lupin lines grown at two locations in Virginia during 2005-06 (Planted on September 29, 2005 and October 4, 2005, respectively at Petersburg and Suffolk) and 2006-07 (Planted on October 13, 2006 and October 17, 2006, respectively at Petersburg and Suffolk). Average monthly temperatures, based on data from 30 years, during lupin production, generally, are, 71, 60, 51, 41, 37, 40, 49, 58, and 67 respectively for September to May. Approximately 100 seeds were planted in each row with a cone type manual planter at a depth of approximately 4 cm. These plots received no fertilizer applications because the seeds were inoculated with a commercial bradyrhizobial inoculum for N fixation and the field sites were known to have high levels of P and K. The soil type at Petersburg (Approximately 37^0-15' N and 077^0-30.8'W) was an Abel sandy loam and that at Suffolk (36° 40' 53" N and 76° 46' 49" W) was Rains fine sandy loam. Plots were manually kept free of weeds.

The green pods were harvested over several days during each season when the pods were still green and were just starting to turn yellow approximately in middle of May in both 2006 and 2007. This stage of white lupin growth corresponds, in general terms, to physiological maturity in soybean (R6 stage, Fehr and Caviness, 1971). Green pods were separated from stems and were shelled manually to obtain immature seeds. Data were recorded on number of green pods, seeds per pod, and pod green weight. A sample of 25 pods was shelled manually to record fresh shelling percent for each plot. Number of pods per ha, pod yield per ha, number of seeds per pod, and shelling percentages were calculated.

All data were analyzed using version 9.1 of SAS (SAS, 2003) using ANOVA with 5 percent level of significance.

3. Results and Discussion

Years had significant effects on pod yield (kg.ha^{-1}), number of pods per hectare, seeds per pod, and shelling percent but not on protein content of immature green seeds (Table 1). Location effects were non-significant except for protein content. This being the first report related to lupin immature seeds, we are not comfortable in proposing a reason for year effects being non-significant while locations effects were significant for protein content. It could, however, be speculated that locations effects are more pronounced given that these effects represent cumulative effects of more factors then those for years i.e. fertility status of each location. In a similar study with vegetable soybean (Mebrahtu, 2008) effects of years on protein content were very pronounced as compared to other factors (Mean squares for years, genotypes, and genotype x year interaction were 94.34, 1.39 and 12.26, respectively). This study did not include locations. Ten cultivars differed significantly only for pod yield (kg.ha^{-1}) and number of pods per hectare.

The pod yield varied from 12564 to 21903 kg.ha^{-1} with L-310, a white lupin line developed by Auburn University, yielding the most and Ludet, a French cultivar, yielding the lowest (Table 2). The mean pod yield was 18098 kg.ha^{-1}. The pod number per hectare varied from 2614815 to 4251852 pods per hectare with a mean number of 3402899 pods per hectare. L-310 had the highest pod number per hectare. Differences among cultivars for number of seeds per pod, shelling percent, and protein content of green immature seeds with respective mean values of 4, 32, and 33, respectively were non-significant. Locations had significant effects only on protein content, seeds produced at Petersburg location had one percent higher protein content compared to those produced at Suffolk location (Table 3).

This is the first report regarding immature lupin seeds. We believe that white lupin immature seeds could be consumed by human beings similar to the vegetable soybean (Edamame) and green peas. However, lupin seeds are known to contain anti-nutritional factors such as alkaloids, phytate, and oligosaccharides (Dagnia, et al., 1992).

Lupin seeds are generally classified as "sweet" or "bitter" depending upon the content of alkaloids which can vary from 0.01 to 4% (Allen, 1998). The bitter seeds contain quinolizidine alkaloids such as lupanine, lupinine, and sparteine. The presence of these alkaloids limit the use of lupin seeds as food and feed (Muzquiz et al., 1994). The Australian standard is 0.02% as the upper alkaloid content limit for sweet lupins (Cowlings et al., 1998).

Before the development of sweet lupins, the bitter lupin seeds were debittered by soaking in running water and cooking/toasting (Aguilera and Trier, 1978). The lupin breeding work of Sengbusch in Germany during 1928-1929 laid the foundation for development of sweet lupin cultivars. Currently sweet cultivars are available in all four lupin species that are being used as agricultural crops in the world (Cowling et al., 1998). All cultivars used in our studies were classified as sweet. However, information about presence/and concentration of anti-nutritional factors in immature seeds is needed before use of immature white lupin seed can be recommended for human consumption. Such studies will be worthwhile given the increasing interest among consumers for novel plant products as evidenced by growing popularity of vegetable soybean.

One advantage of using white lupin immature fresh seeds is that these seeds become available in May-June whereas fresh Edamame, depending upon the maturity group, becomes available in August-September. The protein content of green immature white lupin seeds (Approximately 33 percent) compared well with that of Edamame (Approximately 36 percent, Rao et al., 2002; 38 percent: Mebrahtu, 2008) and green peas (Approximately 25 percent, USDA, 2010). White lupin green immature seed yield (18Mg/ha) and number of seeds per pod (Three) were comparable to that of Edamame (18, 5 and two, respectively (Rao et al., 2002). The green pod yield of vegetable soybean in Virginia has been reported to range from 7225 to 8355 kg.ha^{-1} (Mebrahtu and Mohamed, 2006) which is considerably lower as compared to 18,098 kg.ha^{-1} for white lupin.

Results of this study indicate that white lupin green immature seeds may have potential as human food and could be helpful in meeting needs of human beings for 3-5 servings of vegetables in daily diet. We propose that lupin should be studied, in detail, for its' production potential and nutritional quality traits, and consumer acceptability. In addition, production of white lupin for immature green seeds could provide an alternate cash crop for farmers.

Acknowledgements

Contribution of Virginia State University, Agricultural Research Station, Journal Article Series No. 281. Use of any trade names or vendors does not imply approval to the exclusion of other products or vendors that may also be suitable. Funding support from U.S. Department of Agriculture, National Institute of Food and Agriculture, 1890 Institutions Capacity Building Grant Program is greatly appreciated.

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Table 1. Partial analysis of variance (mean squares) for green pod traits of white lupin grown at two locations (Petersburg and Suffolk) in Virginia during 2005-06 and 2006-07 crop seasons

Trait	Y^x	L^x	C^x	L*C	Mean
Pod yield (kg.ha^{-1})	***	ns	**	Ns	18,098
Pods.ha^{-1}	***	ns	**	Ns	3,402,899
Seeds per pod	***	ns	ns	Ns	4
Shelling percent	***	ns	ns	Ns	32
Protein percent	ns	*	ns	Ns	33

x: Y = Year; L = Location; C = Cultivar. Means over two locations, three replications and two years.
*, **, ***: Significant at 5, 1, and 0.01 % levels, respectively.

Table 2. Cultivar effects on green pod traits of white lupin grown at two locations (Petersburg and Suffolk) in Virginia during 2005-06 and 2006-07 crop seasons

Cultivar	Pod yield (kg.ha^{-1})	Pods.ha^{-1}	Seeds.Pod^{-1}	Shelling %	Protein %
L-310	21,903	4,252,852	3.62	30.7	32.8
L-2405	23,432	4,106,667	4.02	49.7	33.3
L-2417	21,266	3,593,778	4.26	29.3	32.8
L-2418	14,737	2,808.254	3.83	31.0	33.1
L-2420	12,923	2,614,815	4.07	31.3	32.0
L-2423	15,962	3,026,667	4.34	24.8	33.0
L-2424	20,224	3,516,768	3.90	30.3	33.2
L-2425	21,933	4,290,370	3.62	31.7	34.0
L-2430	16,586	3,059,259	3.91	29.6	33.6
Ludet	12,564	2,775,556	4.02	28.2	32.0
LSD(.05)	6,409	995,814	ns	ns	Ns

x: Means over two locations, three replications per locations, and two years.

Table 3. Location effects on green pod traits of white lupin grown at two locations (Petersburg and Suffolk) in Virginia during 2005-06 and 2006-07 crop seasons

Location	Pod yield (kg.ha^{-1})	Pods.ha^{-1}	Seeds.Pod^{-1}	Shelling %	Protein %
Petersburg	17,770	3,284,598	4.01	29.7	22.5
Suffolk	18,431	3,523,275	3.86	34.2	32.5
LSD(.05)	ns	ns	ns	ns	Ns

x: Means over two locations, three replications per locations, and two years.