Growth and Yield Responses of Sweet White Lupine (*Lupinus albus* L.) to Row Spacing and Rates of Blended NPSB Fertilizer

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ABSTRACT

Sweet white lupine (Lupinus albus L.) is economically an important crop in Ethiopia. However, its productivity is very low as compared to the productivity of world sweet white lupine which is attributed to poor agronomic practices like inappropriate seeding rate, row spacing, low soil fertility and lack of improved seed. Therefore, a field experiment was conducted to evaluate the effect of different rates of NPSB fertilizer and inter row spacing on yield and yield components of sweet white lupine. Five NPSB fertilizer rates (0, 50, 100, 150, 200 kgha^{-1}) and three inter row spacings (20, 30, 40 cm) were tested in factorial arrangement in randomized complete block design with three replications. The maximum values for total branches (14.18), effective branches (6.61), number of pods per plant (52.17), number of seeds per plant (158.58), and harvest index (31.96%) were observed at 40 cm inter-row spacing. These results were statistically similar to those at 30 cm spacing for most parameters, except for the number of pods per plant. On the other hand, the highest thousand seed weight (99.21) was obtained by 30 cm row spacing that was at par with 20 cm row spacing. Furthermore, the interaction effects of NPSB fertilizer rates and inter row spacing significantly affected plant height. Thus, the highest plant height (108.87cm) was recorded from the treatment applied with 150 kg ha^{-1} at 20cm inter row spacing. Whereas, yield components and yield of sweet white lupines were not statistically affected by rates of NPSB and inter row spacing. Also, from the partial budget analysis, application of 100 kgha^{-1} NPSB at 40cm inter row spacing gave the best profitable yields with the highest net benefit and marginal rate of return (6881.48) followed by those plot fertilized with 150 kgha^{-1} NPSB at 30cm row spacing (3144.29) and 50 kgha^{-1} NPSB at 40cm row spacing (2868.71). Based on the results obtained from the study, producing sweet white lupine at 40cm inter row spacing and applying 100 kgha^{-1} NPSB fertilizer rate gave better growth and yields and can be recommended for producers in the study area and the like.

Keywords: Growth, NPSB rate, row spacing, sweet white lupine; yield

INTRODUCTION

Agriculture is the fundamental driver for Ethiopia's economy and long-term food security as it offers about 80-85% of employment, more than 61% of the total export and 38.5% of gross domestic product of the country (Degaga and Angasu, 2017). Ethiopia has diverse agro-ecology that permits different agricultural systems and production of different crops. The existence of this diverse agro-ecology together with diverse farming systems, socio-economic, cultures and climate zones provided Ethiopia with various biological wealth of plants, animals, and microbial species especially crop diversity (Atnaf *et al*., 2015). Ethiopia agriculture yield production is almost entirely low due to low agricultural inputs, low soil fertility problems, lack of improved seed and problems of pests (Abreha, 2013).

Grain legumes are important sources of significant amounts of proteins, carbohydrates, fiber, vitamins and some minerals; and, they are used in many parts of the world for both animal and human nutrition (Osman, 2007). Moreover; they are fairly good sources of thiamin, niacin, calcium, and iron (EI-Adway *et al*., 2000; Asian productivity organization, 2003). Predominantly their consumption is wide in areas like the developing countries of Asia, Africa and South America (Frias *et al*., 2004). In these countries, legumes play a major role as protein source (EI-Adway *et al*., 2000; Asian productivity organization, 2003).

White lupine (locally known as "Gibto") is one of the legume crops produced in different parts of Ethiopia at an altitude of 1500-3000 m.a.s.l mainly by subsistent farmers (Yeheyis *et al*., 2010). The crop is known as a very easy crop to grow with a relatively high yield and minimal agronomic practice. In the 2015/16 cropping season, the total area under cultivation of white lupine was estimated to be 16,788.20 ha of land from which 187,166.88 quintals were produced and with a productivity of 11.15 q ha^{-1} (MoANR, 2016). The farmers produce the crop for its multipurpose benefits, such as soil fertility maintenance, nutritional values as snacks, local soup, and local alcohol preparation, and for traditional therapy purposes (Getachew, 2009; Yeheyis *et al*., 2010).

Plant density has been recognized as a major determining crop yield and is of a particular importance for larger seeded varieties (Mathews *et al*., 2001). Optimum plant density (*i.e* the minimum population that produces maximum yield) and suitable arrangement per unit area allow crops to exploit resource optimally and produce high yields (Sequire, 1993). However, optimum plant density varies depending on crop species or due to varietal differences in vigor, height, branching, time of sowing, and the nature of the season (Anderson *et al*., 2004). This can also depend on soil type, management practices like seedbed conditions and soil moisture, sowing depth, sowing time, fungicide dressing of seeds, presence of weeds and seasonal rainfall (Matthews *et al.,* 2001). The impact of sowing density on the agronomic properties of lupine depends on the cultivar and weather conditions during the growing season (Mülayim *et al*., 2002), depending on the yield ranges from 0.26-1.163 t ha^{-1} (Mülayim *et al.,* 2002).

Lupine can be grown on less fertile, acidic soils where other crops produce lower yield (Jensen *et al*., 2004; Doxastatis, 2007). It is very important for crop rotation; especially in organic agricultural production due to its positive impact on the yield of subsequent crops mainly cereals (Jensen *et al*., 2004). Yield and its formation process depend on genetic, environmental and agronomic factors as well as the interaction between them (Siduka and Bernotas, 2003). Therefore, there is a scope to increase the yield level of white lupine by using seed of higher yielding varieties and adopting proper management practices such row spacing, seed rate, fertilizer application and cultural operations. Optimum seed rate plays an important role in producing higher yield. Establishment of optimum plant density per unit area is a prerequisite for having increased grain yield. The plant density can be adjusted by the use of different seed rates and row spacing; which influence yield and yield contributing characters of sweet white lupine. Nutrient requirement of the crop can vary from location to location depending on various factors such as soil and cultural practices. For sustainable production of crops for a particular area specific fertilizer recommendations are very crucial. Thus, to produce the expected amount of yield we should have to know the optimum amount of blended (NPSB) fertilizer required by the sweet white lupine. Hence, the study aimed to evaluate the effect of inter-row spacing and different rates of blended NPSB fertilizer on the growth, yield and yield components of sweet white lupine.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Degem district, Ana JiruBisanDimo farmers' training centre during 2019 main cropping season. Crop growth duration for Degem is from Mid-June to December. Degem district is located at 125 km North of Addis Ababa and situated at 15 km West from the zonal capital town of Fitche. The area is found at longitude of 38^{0} 29**'** to 38^{0}44**'** East and latitude 9^{0}34**'** to 10^{0} 03**'** North. The altitude of the district ranges from 1500 to 3541 meters above sea level (m.a.s.l). According to the weather record from the Fitche meteorology station, the total rainfall of the study area during the main cropping season of 2019 was 1122mm. The mean minimum and maximum temperatures were 8.5 and 20 ^{o}C, respectively. The soil type of the area is acidic Nitisols (DANRO, 2013).

Soil Sampling and Analysis

Soil samples were taken from 10 representative spots of the experimental field at 0- 20cm depth before sowing and one composite surface soil sample was made out of it for the purpose of characterization. The composite soil sample was prepared for analysis and was air-dried as well as grinded to pass through a 2mm sieve. The soil sample was analyzed to determine soil pH, soil texture, available P, organic carbon content, extractable S, extractable B, cation exchange capacity (CEC) and total N using different methods and procedures in Horticoop Ethiopia (horticulture) PLC Soil and Water Analysis Laboratory. Total N was determined by Kjeldhal method (Chapman, 1965), while available phosphorus was analyzed following the procedure described by Olsen *et al.* (1954) method, and percent organic matter and organic carbon were also determined by using Wet Oxidation methods (Walkley and Black, 1934). Soil texture was analyzed following Bouyoucos hydrometer method (Day, 1965). Furthermore, soil pH was measured potentiometricaly in the supernatant suspension of a 1: 2.5 liquid mixture using pH meter in water (pH-H_2O) (Houba *et al*., 1989), while cation exchange capacity (CEC) was measured using 1M-neutral ammonium acetate (Jackson, 1962).

Treatments and Experimental Design

The treatments consisted of 3x5 factorial combinations of inter-row spacing (20cm, 30cm and 40cm) and blended fertilizer rates (0, 50, 100, 150, 200 kg ha^{-1} NPSB). The treatments were arranged in a randomized complete block design (RCBD) with three replications.

Experimental Procedures

The experimental field was prepared to seedbeds of a fine tilth according to local practices ploughed two times by oxen before sowing. The plot was leveled manually to be suitable for planting and the treatment was assigned randomly to experimental units within a block. The gross plot size was 5.04m^2 (2.1m X 2.4m) containing 12 rows for 20cm, 8 rows for 30cm, and 6 rows for 40cm inter-row spacing; while, there were 30 plants in each row with intra-row spacing of 7cm. The outer most two rows from both sides for 20cm inter-row, two rows from one side and one row from other side for 30cm and one row from both sides for 40cm inter-row spacing were considered as the border rows. Five plants for intra-row spacing from each end of the rows were considered as the border plants. Thus, the net plot had 8, 5 and 4 rows under 20cm, 30cm and 40cm row spacing respectively, and the net plot size was 2.24m^2 (1.4m x 1.6m) for 20cm inter row spacing, 2.24m^2 (1.4m x 1.6m) for 30cm inter row spacing, and 2.24m^2 (1.4m x 1.6m) for 40cm inter row spacing. The space between blocks was 1m while spacing between each plot in a block was 0.5m.

Seed of sweet white lupine variety "Welela", which was released by Holeta Agricultural Research Centre in 2016, was sown at the site on 26th June 2019. Blended fertilizer (NPSB) (19% N, 38% P_2O_5, 7% S and 0.1% B) was drilled in furrows at the rate of 0, 50, 100, 150 and 200 kg NPSB ha^{-1} at sowing. The field was cultivated and weeded as needed manually during the cropping season of the study. Plot wise harvesting was done as the crops get matured in each plot.

Data Collected

Phenology and growth parameters

Phenological and growth parameters data were collected at their specific period of recording. Thus, days to 50% flowering was taken when the flowers were fully visible or produced above the sheath of the flag leaf on 50% of the plants from each plot that was determined by visual observation. Days to 90% physiological maturity was recorded by counting the number of days from date of sowing until when 90% of the plants changed green color to yellowish, loose its water content and attain to physiological maturity in each plot. It is indicated by senescence of the leaves as well as frees threshing of seeds from the pods when pressed between the thumb and the forefinger. Plant height was recorded from ten randomly selected plants from the net plot area of each plot using centimeters from the ground to the top of plant and means were taken. Number of effective (fertile) and total branches per plant were counted from ten plants per plot at maturity.

Yield and yield components

Yield and yield attributes data were collected at their specific period of recording. Thus, the total numbers of pod per plant was counted from ten randomly selected plants from each net plot at harvesting time. Number of seed per plant was counted from ten randomly selected plants from the inner rows of each plot and the mean seed number was taken at harvesting. Thousand grains weight were counted after threshing at random from each plot and their weights were measured with sensitive balance after adjusting the grain moisture content to 12.5%. Total biomass yield was measured by weighing the sun dried total above ground plant biomass (stubble + grain) from the net plot area of each plot; grain yield was measured by taking the weight of the grains threshed from the net plot area of each plot and converted to kilograms per hectare after adjusting the grain moisture content to 12.5%. Stubble yield was determined by subtracting grain yield from total above ground biomass; and harvest index of each treatment was calculated as the percent ratio of grain yield to the biological yield multiplied by 100.

Partial Budget Analysis

The partial budget analysis as described by CIMMYT (1988) was done to determine the economic feasibility of the input rate practices. Partial budget analysis was done using the prevailing market prices for inputs at planting and for output at the time the crop was harvested. It was calculated by taking account the additional input (fertilizer, seed) cost involved and the gross benefits obtained from input practices. The average grain and stubble yield data were adjusted downward by 10% and subjected to partial budget and economic analysis was performed following the CIMMYT partial methodology to reflect the difference between the experimental yield and the yield farmers could expect from the same input supply as described by CIMMYT (1988). Total costs that varied (seed and fertilizer) for each treatments were calculated and treatments were ranked in order of ascending total variable cost (TVC) and dominance analysis was used to eliminate those treatments costing more but producing a lower net benefit than the next lowest cost treatment. The prices of the inputs that were prevailing at the time of their use were considered for working out the cost of cultivation. The field price of white lupine and stubble yield was calculated as sale price (white lupine 18 birr per kg and stubble 0.5 birr per kg) minus the costs of fertilizer (15 birr per kg) and seed (25 birr per kg). The net benefit was calculated as the difference between the gross field benefit (ETB ha^{-1}) and the total costs (ETB ha^{-1}) that varied. According to CIMMT (1988), the minimum acceptable marginal rate of return (MRR %) should be between 50 and 100%.

Data Analysis

Data were subjected to analysis of variance (ANOVA) using SAS software program (SAS 9:0, 2002). Significant difference between and/or among treatments were delineated by Least Significant Differences (LSD at 5%). Correlation analysis was determined by calculating simple correlation coefficient between growth, yield and yield components as affected by row spacing and fertilizer rates. Interpretations were using procedure of Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Soil Physico-chemical Characteristics before Sowing

Results of the soil analysis showed that the proportion of sand, cay and silt were 12%, 56% and 32%, respectively; which is classified as clay based on the texture triangle classification system and this type of soil is conducive for crop production; since clay soils absorb and hold more water and exchangeable nutrients or cations than silty or sandy soils. Based on soil analysis, the pH of the experimental soil was 5.11, which is moderately acidic (Houba *et al*., 1989). The carbon content of the soil was 1.98% which was low. Soil organic matter content is not a quantitative indicator of the capacity of the soil to supply plant available nitrogen for plant growth even though soil with more organic matter contains more total N. Total nitrogen content of the experimental soil was 0.20% which is medium according to Havlin *et al*. (1999). Phosphorus content of the experimental soil was 9.34 mg kg^{-1} which is low (Olsen *et al.* (1954). Available sulfur was 21.93 which is high (>20). On the other hand, CEC of the experimental soil was found 19.50 Meq/100g which is moderate (available Ca, Mg, K and Na is 5.54, 1.42, 0.60 and 0.09 Cmol(+)/kg soil; respectively, and extractable Fe, Zn and Mo is 137.12, 1.75 and 0.16 mg kg^{-1} soil, respectively). Extraction of hot water-soluble boron is the most effective way to evaluate available boron to plants in most agricultural soils. The Boron content of the experimental soil was 0.15 which is very low according to Adriano (1986) rating in the soil solution less than 0.2 $mgBL^{-1}$ is considered deficient for crops; whereas, greater than $1mgL^{-1}$ is considered as toxic.

Effect of NPSB Fertilizer Rates and Row Spacing on Lupine Crop

Application of NPSB at different rates significantly affected only plant height; but non-significant effect on days to 50% flowering, days to 90% maturity, total branches number, effective branches number, pods per plant, number of grains per plant, biological yield, stubble grain yield, thousand grain weight and harvest index. Row spacing also significantly influenced plant height, total branches number, effective branches number, pods per plant, number of grain per plant, thousand grains weight and harvest index; but not significantly affected days to 50% flowering, days to 90% maturity, biological yield, grain yield and stubble grain yield. The interaction of NPSB rates and row spacing significantly affected only plant height (Table 1).

Table 1. Mean square values for growth, yield and yield components of sweet white lupine as influenced by the main and interaction effects of NPSB fertilizer rates and row spacing

Parameters	Fertilizer	Row spacing	Fertilizer x Row spacing
Days to 50% flowering	15.13^{ns}	41.09^{ns}	4.95^{ns}
Days of 90% maturity	13.97^{ns}	37.22^{ns}	4.83^{ns}
Plant height	86.96*	290.56^{*}	102.16^{*}
Total branch number	1.66^{ns}	17.01^{*}	0.93^{ns}
Effective branch number	0.78^{ns}	4.56^{*}	0.27^{ns}
Pod number per plant	95.36^{ns}	786.16^{*}	33.69^{ns}
Number of seed per plant	620.6^{ns}	9355.2^{*}	729.1^{ns}
Biological yield	1114429^{ns}	3416943^{ns}	828002^{ns}
Grain yield	121332.48^{ns}	295662.82^{ns}	219135.07^{ns}
Stubble yield	1441620^{ns}	4497473^{ns}	1434856^{ns}
Thousand-grain weight	0.23^{ns}	51.74^{*}	18.01^{ns}
Harvest index	77.65^{ns}	161.73^{*}	27.76^{ns}

Where, NS- non-significant; * significant at 5% respectively

Effect of NPSB Fertilizer Rates and Row Spacing on Lupine Crop Growth Parameters

Plant height

Row spacing and different rates of NPSB fertilizer and their interaction had significant effects on lupine plant height (Table 1). Applying 150 kgha^{-1} NPSB resulted in taller plants (108.87cm) at 20cm row spacing, whereas the plot with the same NPSB amount at 40cm row spacing had shortest lupine plants (80.43cm) (Table 2). Application of NPSB at 150 kg ha^{-1} applied in 20cm row spaced plants significantly improved lupine height by 35.36% as compared to lupine planted at 40cm row spaced with same fertilizer applied to the largest height.

Plants may have been spaced too closely together, leading to intense competition between them. T his caused individual plants to grow taller with longer internodes, resulting in slender, thin, and w eak stalks due to poor light exposure and inadequate photosynthesis. Pholsen and Sornsungnoen (2004) reported that the height of sweet lupine variety at 50% and 100% flowering stage under different planting space was showed significant ($p<0.05$) differences; in closer row spacing, the space for plant spreading was less and hence plant height was increased significantly. Taj *et al.* (2002) and Fikadu (2017) also found the tallest plant in closer row spacing plots which might be due to the competition for light compared to the case in wider row spaced where light distribution was normal.

Table 2. The interaction effects of NPSB rates and row spacing on Lupine plant height (cm)

NPSB Fertilizer Rates (kg ha^{-1})	Row Spacing		
	20 cm	30 cm	40 cm
0	93.53^{cd}	96.73^{bcd}	91.87^{d}
50	99.80^{a-d}	98.10^{bcd}	98.15^{bcd}
100	101.27^{a-d}	98.60^{bcd}	98.63^{bcd}
150	108.87^{a}	97.27^{bcd}	80.43^{e}
200	105.87^{ab}	102.37^{abc}	97.30^{bcd}
LSD (0.05)	10.16		
CV (%)	6.20		

Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of significance.

Total and effective number of branches per plant

Analysis of the data indicated that the main effect of row spacing had significant effects number of branches per plant (Table 1). More number of total and effective branches plant-1 (14.18 and 6.61) was recorded in 40cm row spaced lupine without statistically differing from 30cm spaced rows; whereas, less number of total and effective branches per plant (12.15 and 5.51) was observed in 20cm row spaced (Table 3). The most branches per plant produced at 40cm row spacing were improved by 16.70% and 19.96% as compared to the fewest branch number obtained at 20cm row spacing, respectively.

This might be due to the plants making better use of available nutrients, water, and light, leading t o increased photosynthesis and better distribution of carbohydrates for growth. Conversely, plants placed closer together had fewer branches per plant, with the branch count decreasing as row spa cing increased. The result is in agreement with Al-suhaibai *et al*. (2013) who found a maximum number of branches per plant for faba bean under low plant population. Similar results were obtained by Sharma (2002a) and Mali and Choudhary (2013) who reported that more number and effective branches plant-1 occurred at wider row spacing as compared to the narrower row spacing.

Table 3. The main effect of NPSB fertilizer rates and row spacing on total and effective branches

	Parameters	
Fertilizer (kg ha^{-1})	**Total Branch Number**	**Effective Branch Number**
0	12.67	5.73
50	13.62	6.14
100	13.57	6.36
150	13.21	5.87
200	13.71	6.44
SE	0.741	0.429
LSD(0.05)	ns	ns
Row Spacing (cm)		
20	12.15^{b}	5.51^{b}
30	13.73^{a}	6.18^{ab}
40	14.18^{a}	6.61^{ab}
SE	0.574	0.333
LSD(0.05)	1.18*	0.68*
CV(%)	11.80	14.90

ns: non-significant; SE-Standard error; LSD-Least significant Differences; CV-Coefficient of variation. Means followed by the same letter(s) within a column are not significantly different at a 5% probability level.

Effect of NPSB Fertilizer Rates and Row Spacing on Lupine Yield & Yield Components

Number of pods per plant

Number of pods plant^{-1} was significantly ($p<0.01$) affected by the main effect of row spacing; but, the main effect of NPSB fertilizer rates and their interaction did not significantly ($p>0.05$) affect the number of pods plant^{-1} (Table 1). The maximum number of pods plant^{-1}(52.17) was recorded from 40cm row spacing planted lupine. On the other hand, the minimum number of pods per plant (37.85) was recorded from 20cm row spacing. The increment due to wider spacing (40cm) was by 37.83% as compared to narrow spacing (20cm) (Table 4).

The rise in the number of pods per plant with wider row spacing could be attributed to the vigorou s growth of plants. These plants produced more branches, leading to a higher number of pods per plant. Conversely, in closer row spacing, plant growth was reduced, resulting in fewer pods per pl ant. In agreement with this, PosÞisil *et al*. (2015) found the highest number of pods plant^{-1} in wider row spacing as compared to closer spacing. The result is in line with Adel (2008) and Shad *et al*. (2010) who reported a decrease in the number of pods per plant in faba bean due to the reduction in the number of stems per plant at the higher plant densities.

Number of seeds per plant

Number of seeds per plant was significantly influenced by the main effect of row spacing; but not by main effect of NPSB fertilizer and their interaction (Table 1). The highest number of seeds per plant (158.58) was obtained from 40cm row spacing which was statistically similar with 30cm row spacing. However, the lowest number of seeds per plant (109.87) was obtained from 20cm row spacing (Table4).

The decrease in seeds per plant with narrow row spacing may be due to inadequate canopy develo pment in the early stages, limiting light absorption. As a result, plants compete against each other, leading to poor individual performance. In contrast, wider row spacing results in better individual plant performance due to reduced competition. This result is in line with Al-suhaibani *et al*. (2013) who reported higher number of seed per plant at wider row spacing. Singh and Singh (2002) also indicated that the yield potential of an individual plant is fully exploited when sown at wider row spacing. Similar result was obtained by PosÞisil *et al*. (2015) who reported that more seeds per plant werevobtained at wider row spacing as compared to narrow spacing.

Table 4. The main effects of NPSB fertilizer rates and row spacing on the number of pods and seeds per plant

	Parameters	
Fertilizer (kg ha^{-1})	**Number of pods per plant**	**Number of seeds per plant**
0	39.47	123.69
50	43.82	136.50
100	46.64	144.71
150	44.07	139.34
200	7.94	142.87
SE	4.04	13.19
LSD(0.05)	ns	ns
Row Spacing (cm)		
20	37.85^{b}	109.87^{b}
30	43.15^{b}	143.81^{a}
40	52.17^{a}	158.58^{a}
SE	3.10	10.22
LSD(0.05)	6.42*	20.94*
CV%	19.30	19.30

ns- non significant; SE- Standard error; LSD- Least significant Differences; CV- Coefficient of variation; Means followed by the same letter(s) within a column are not significantly different at a 5% level of significance.

Thousand Seed weight

The analysis of variance showed that row space had statistically significant ($p \leq 0.05$) variation on thousand seed weight; but, NPSB fertilizer rates and their interaction effects did not bring a change in thousand seed weight (Table 1). The heaviest thousand seeds weights (99.21g) were found from narrower row spaced (20 cm and 30cm); while the lightest thousand weights (95.99g) were recorded from the wider row (40cm) (Table 5). The heaviest thousand seed weight was advanced by 3.35% as compared to the lightest thousand weight obtained from 40cm row spaced which might be due to its capability to fix nitrogen for themselves. The result disagree with Yayeh *et al.* (2014), who reported that thousand seed weights of field peas did not significantly differ due to row spacing.

Table 5. Effect of NPSB rates and row spacing on thousand seeds weight and harvest index

	Parameters	
Fertilizer Rate (kg ha^{-1})	**Thousand seed weight (gm)**	**Harvest Index (%)**
0	98.00	29.97
50	98.39	28.68
100	98.00	34.55
150	98.13	27.54
200	98.17	27.43
SE	1.67	2.86
LSD (0.05)	ns	ns
Row spacing (cm)		
20	99.21[a]	25.87[b]
30	99.21[a]	31.13[a]
40	95.99[b]	31.96[a]
SE	1.29	2.21
LSD (0.05)	2.64*	4.54*
CV(%)	**3.60**	**20.5**

SE- standard Error; LSD- Least Significant Difference; CV-coefficient of variation; ns-non significant; Means of followed by the same letter(s) within a column are not significantly different at a 5% level of significance.

Harvest index

The analysis of variance showed that harvest index was significantly ($p \leq 0.05$) influenced by row spacing, but NPSB fertilizer rates and the interaction between the two factors was non- significant (Table 1). The higher harvest index (31.91) was recorded from 40cm row spacing which was statistically similar with 30cm (31.13) row spacing; while minimum harvest index (25.87) was recorded from 20cm row spacing (Table 5). The higher the harvest index values indicate that they have got more resources used for plant growth; thus the greater the physiological potential of the crop for converting dry matter to grain yield. Harvest index had interrelationship with grain yield and above ground biomass yield that the highest harvest index was the result of greater grain yield. Lowest harvest index was mainly due to an increased plant height and increased biomass yield excessively rather than grain yield which lead to decrease in harvest index. A similar result was obtained by Sharma (2002a) the highest harvest index was recorded when the row spacing was wide.

Correlations Analysis of Growth, Yield and Yield Components of White Lupine due to NPSB Fertilizer Rates and Row Spacing

As indicated in (Table 6) the correlation study among sweet white lupine growth and yield parameters was quantified and a strong correlation was observed between some of the sweet white lupine components. According to the correlation analysis result of sweet white lupine characters, significant and positive associations were observed between days to 50% flowering, and days to 90% maturity (r=0.99), days to 50% flowering, and biological yield(r=0.49), effective branches number and pods number per plant (r=0.79), effective branches number and number of seeds per plant(r=0.57), pods number per plant and number of seeds per plant (r=0.81), grain yield and harvest index (r=0.72), biological yield and stubble yield (r=0.86). Moreover, a significant and positive correlation was observed between days to 50% flowering and thousand seed weight(r=0.31), days to 50% to flowering and stubble yield(r=0.44), total branch number and number of seeds per plant(r=0.47), plant height and grain yield(r=0.38) and plant height and stubble yield(r=0.34) (Table 6). Whereas, significant and negative correlations were observed between days of 50% flowering and pods number per plant(r= -0.33) and days to 90% maturity and pods number per plant(r= -0.31). A significant positive correlation of grain yield with all the yield and yield components was observed which indicates that grain yield could invariably increase by increasing those characters. Positive association of grain yield with days to 50% flowering (r=0.23), plant height (r=0.38), number of seeds per plant (r=0.08), biological yield (r=0.53), stubble yield (r=0.20), thousand seed weight (0.10) and harvest index (r=0.72) (Table 6). This result was supported by the findings of Teklay and Girmay (2016) who reported that a strong significant positive correlation between grain yield with plant height, panicle length, panicle seed weight, straw yield, and harvest index was observed on teff.

Table 6. Correlation analysis of growth and yield attributes due to NPSB rates and row spacing

Parameters	DF	DM	TBN	EBN	PH	PNP	NSPP	TSW	GY	BY	SY	HI
DF	1	0.99^{**}	-0.12^{ns}	-0.27^{ns}	0.02^{ns}	-0.33^{*}	-0.23^{ns}	0.31^{*}	0.23^{ns}	0.49^{**}	0.44^{*}	-0.07^{ns}
DM		1	-0.11^{ns}	-0.27^{ns}	0.28	-0.31^{*}	-0.20^{ns}	0.30*	0.23^{ns}	0.52^{**}	0.47^{*}	-0.09^{ns}
TBN			1	0.53^{**}	0.10^{ns}	0.53^{**}	0.47^{*}	-0.12^{ns}	-0.03^{ns}	0.04^{ns}	0.60^{ns}	-0.06^{ns}
EBN				1	-0.18^{ns}	0.79^{**}	0.57^{**}	-0.19^{ns}	-028^{ns}	-0.27^{ns}	-0.15^{ns}	-0.19^{ns}
PH					1	-0.17^{ns}	-0.09^{ns}	0.28^{ns}	0.38^{*}	0.49^{**}	0.34^{*}	0.01^{ns}
PNP						1	0.81^{**}	-0.27^{ns}	-0.12^{ns}	-0.19^{ns}	-0.16^{ns}	0.05^{ns}
NSPP							1	-0.18^{ns}	0.08^{ns}	0.06^{ns}	0.03^{ns}	0.10^{ns}
TSW								1	0.10^{ns}	0.22^{ns}	0.20^{ns}	-0.08^{ns}
GY									1	0.53^{**}	0.20^{ns}	0.72^{**}
BY										1	0.86^{**}	-0.17^{ns}
SY											1	-0.64**
HI												1

DF- days to 50% flowering; DM-days to 90% maturity; TBN- total branch number; EBN- effective branch number; PH- plant height; PNP- pods number per plant; NSPP- number of seeds per plant; TSW- thousand seed weight; GY-Grain yield; BY- biological yield; SY- stubble yield; HI- harvest index

Partial Budget Analysis

Based on partial budget analysis, the highest net benefit (37642.5 Birr ha^{-1}) was obtained from the treatment combination of 150 kg NPSB ha^{-1} fertilizer with 30cm row spacing; while, the lowest net benefit (23053 Birr ha^{-1}) was obtained from the combination of 150 kg NPSB ha^{-1} fertilizer with 40cm row spacing (Table 7). The application of 150 kg NPSB ha^{-1} at 30cm row spacing was the most profitable with the highest net benefit and better marginal rate of return (3144.29) followed by fertilization with 50 kg NPSB ha^{-1} at 40cm (2868.71) and 150 kg NPSB ha^{-1} at row spacing of 40cm (6881.48).

Table 7. Partial budget analysis for sweet white lupine crop

Row Spacing (cm) by Fertilizer Rate(kgha^{-1})	Total variable cost(Birrha^{-1})	Average grain yield (kgha^{-1})	Adjusted grain yield (kgha^{-1})	Average stubble yield (kgha^{-1})	Adjusted stubble yield (kgha^{-1})	Gross benefit (Birrha^{-1})	Net benefit (Birrha^{-1})	Benefit to cost ratio B:C	MRR(%)
40/50	2143	2270.91	2044	4871.95	4385	38984.5	36841.5	17.19	2868.71
20/0	2785	1683.04	1515	5087.77	4579	29559.5	26774.5	9.60	D
30/150	4107	2446.43	2202	4696.43	4227	45749.5	37642.5	9.17	3144.29
40/200	4393	1931.23	1738	4839.6	4356	33462	29069	6.62	D
40/100	2893	2183.03	1965	3843.73	3459	37099.5	34206.5	15.67	6881.48
30/50	2607	2046.88	1842	5468.01	4921	35616.5	33009.5	12.66	D
30/200	4857	2202.98	1983	5386.31	4848	38118	33261	6.80	D
40/150	3643	1535.72	1382	4044.64	3640	26696	23053	6.33	D
20/200	5785	1722.74	1550	5828.3	5245	30522.5	24738	4.28	D
20/150	5035	1861.6	1675	6062.51	5456	32463.5	27429	5.45	D
20/100	4285	2225.45	2003	5140.84	4627	38367.5	34081	7.80	D
20/50	3535	1924.1	1732	5077.36	4570	33461	29926	8.47	D
40/0	1393	2270.83	2044	4127.96	3715	38649.5	37257	26.75	D
30/100	3357	2221.69	2000	4102.64	3692	37846	34489	10.27	D
30/0	1857	1900.3	1710	4572.89	4116	30780	28923	15.58	D

MRR- Marginal rate of return; D- Dominated treatments; Cost of seed 25 Birr per kg; planting cost Birr 120 per person per day; sale price of sweet white lupine 18 Birr per kg; sale price of sweet lupine stubble 0.5 birr per kg,; Cost of NPSB fertilizer 15 birr per kg, (111.4kgha^{-1} for 20cm, 74.3kgha^{-1} for 30cm and 55.7kgha^{-1} for 40cm row spacing used seed)

CONCLUSION

From the study results it is possible to conclude that sowing at 40cm row spacing with 150 kg ha^{-1} NPSB fertilizer gave better growth, yield components and grain yield (2446.43 kgha^{-1}) with the highest economy of sweet white lupine and can be advised for the study area and the like as the option to produce the white lupine crop.

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