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Effect of Inter Row Spacing on Yield Components and Yield of Soybean [*Glycine Max* (L.) Merrill] Varieties in Dale Sedi District, Western Ethiopia

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Abstract

Soybean is an important crop in the tropical, hot sub-moist agro-ecological zone of western Ethiopia. However, the yield of the crop is limited due to lack of appropriate plant density for the varieties. Therefore, the experiment was conducted to determine the effect inter row spacing on growth, yield components and yield of soybean varieties during 2016 cropping season in Dale Sedi District, western Ethiopia. Four inter row spacing (30, 40, 50 and 60cm) were evaluated on three soybean varieties (Nyala, Wello and Dhidhessa). The experimental design was randomized complete block design in factorial arrangement with three replications. Highly significant differences were obtained on days to 50% flowering, days to 90% physiological maturity, plant height and hundred grains weight (g) due to the main effect of the variety. Variety Nyala was earlier in attaining flowering (57.12 days), physiological maturity (115.6 days), variey Wello was the longest (84.70cm) and variety Nyala gave higher hundred grain weight (19.91g) than varieties Wello and Dhidhessa. The interaction effect of variety and inter row spacing were highly significant on number of primary branches, on crop stand count percentage at harvest, grain yield and harvest index, number of pods per plant, grain yield and harvest, where the highest numbers of primary branches per plant (4.57) and highest number pods per plant (49.83) were recorded for variety Wello at 60 cm, inter row spacing and the highest crop stand count percentage(99.77), the highest grain yield(3805kgha-1) and the highest harvest index (52.40%) were recorded from variety Nyala at 40 cm, inter row spacing. However, this tentative generalization based one season at one location requires further studies over years and locations to give a valid recommendation.

Keywords: Dhidhessa; Grain yield; Nyala; Pods per plant; Wello

Abbreviations: HARC: Haro Sabu Agricultural Research Center; RCBD: Randomized Complete Block Design; DAP: Diammonium Phosphate; LSD: Least Significant Difference

Introduction

Soybean [*Glycine max* (L.) Merrill] cultivation is originated in China around 1700-1100 B.C. Soybean is now cultivated throughout East and Southeast Asia, North America, Brazil and Africa where people depend on it for food, animal feed and medicine. It is highly industrialized in developed countries, providing more than a quarter of world's food and animal feed requirement in addition to protein [1]. Its domestication began in Eastern Asia in the 11th century B.C. and continues today to be the foundation of East Asian nutrition and cuisine [2].

Soybean was first introduced to Ethiopia in 1950's because of its nutritional value, multi-purpose use and wider adaptability in different cropping systems [3]. It is a crop that can play major role as protein source for resource poor farmers of Ethiopia who cannot afford animal products. Besides, it can also be used as oil crop, animal feed, poultry meal, for soil fertility improvement and more importantly as income for the country [4]. In Ethiopia, soybean has adapted to diverse ecological niches and provided wider yield range [3].

The crop is amenable to agronomic as well as genetic improvements and has a high yield potential under good conditions and perform better in different cropping systems. Soybean production in Ethiopia was 38,166.04 ha from which 81241.833 tons produced with productivity of 2.129 tons ha^{-1} and in Oromia region 14,626.78 ha was cultivated with production of 31,832.611 tons and a productivity of 2.176t ha^{-1} in 2015/2016 cropping season [5]. Particularly in Kellem Wollega Zone, the crop has good potential in Dale Sedi district and in the many mandate area of Haro Sabu Agricultural Research Center (HARC); it is being widely used as supplementary meals, as bread combined with maize flour, wot with peas, teff (injera) and milk for babies as well as for adults.

In Ethiopia, most people, especially members of the Ethiopian Orthodox Church, consume diets free of animal products during their fasting period. Thus soy-based meat and dairy alternatives can serve as good alternatives for these people while they are fasting [6]. Though soybean can be grown in different parts of Ethiopia, the major areas currently growing the crop are situated in the western and south western parts of the country, notably Benishangul Gumuz, Gambela and parts of Oromia Region. Oromia and Benishangul Gumuz regions account for the highest production of soybean in the country, 51% and 40%, respectively [7]. These areas have vast fertile land and a favorable agro-climate suited to growing soybean. Entry of largescale commercial farmers, including government sugarcane-soybean intercropping programs, and research in soil fertility rehabilitation have made soybean a favorite crop [7].

According to FAO [8], cited by Tesfaye [9], an average productivity of soybean in Ethiopia was 1.79t ha^{-1}; which is low as compared to world average of 2.5t ha^{-1}; however, this level is very low compared to its potential, which could go up to 4 tons per hectare if improved varieties are used [7]. This low yield may be attributed to the combination of several production constraints among which poor soil fertility, periodic moisture stress, diseases and insect-pests, weeds, non-optimum plant population and untimely field operations play a major role [10].

Moreover, some soybean varieties that are categorized into three maturity groups: early, medium and late maturing varieties, are recommended for different agro-ecological zones of Ethiopia. Growers traditionally use either 40cm or 60cm row spacing with 5cm intra row spacing, regardless of the maturity groups and growth habit of the varieties, soil fertility and moisture conditions of the location.

Establishment of an optimum plant density per unit area is a non-monetary input factor for enhancing the production of soybean. There is a considerable scope for increasing soybean yield by optimizing the plant population and plant geometry [11]. However, in Flavanols of southern Ethiopia, a decrease in the number and dry matter of nodules with increasing plant density was observed [12]. Other parameters, such as the dry matter of plant components, harvest index, grain yield per plant and per unit area, and protein content of soybean varieties also changed with variable plant density [13]. Since a number of factors such as fertility status of the soil, moisture availability, growth pattern of the varieties and cultural practices influence both inter row and intra row spacing, optimum planting density should be determined to specific area and to specific soybean varieties through conducting experiment. Therefore, the objective of this study was to assess the effect of inter and intra row spacing on growth, yield components and yield of soybean varieties.

Materials and Methods

Description of the study area

The study was conducted at Haro Sabu Agricultural Research Center (HSARC) during the main cropping season from June to November 2016. The Center is located in Kellem Wollega Zone of Oromia Region at 555km away from Addis Ababa in the western part of Ethiopia. It is located at latitude of 8o 52’51” N and longitude of 35o13’18’’ E and altitude of 1515masl.

According to National Meteorological Agency, Asossa Branch Directorate, (2016) Haro Sabu has a warm humid climate with average minimum and maximum temperatures of 12.44 °C and 28.5 °C, respectively. It receives average annual rain fall of 1492mm and its distribution pattern is uni-modal. The rain periods cover from April to October. The soil type of the experimental site is reddish brown and sandy clay loam in texture and its pH is 5.55. The area is characterized by coffee dominant based farming system and crop-livestock mixed farming system in which maize, sorghum, finger millet, common bean, soybean, sesame, banana, mango, sweet potato and coffee are the major crops [14].

Experimental materials

Three soybean varieties Nyala, Wello (TGX-1895-33F) and Dhidhessa (PR-149-81-EP-7-2) were used as planting material. These varieties were adapted at the study area and selected based on their maturity group and better performance in the area. Early maturing groups and medium maturing groups have maturity dates of 90-120 and 120-150 days, respectively [15,16].

Treatments and experimental design

The treatments consisted factorial combination of three soybean varieties with four inter row spacing (30cm, 40cm, 50cm and 60cm). The experiment was laid out in Randomized Complete Block Design (RCBD) and replicated three times per treatment in factorial combination with a total of twelve treatments.

Management of the experiments

The experimental field was ploughed with tractor to a fine tilth. The plots were leveled manually, and the sowing was done on June 23, 2016. The seeds were planted by hand at a specified spacing by placing two seeds per hill and thinning was done to one plant at each specific intra row spacing ten days after seedling emergence to achieve the desired plant density in each row. Uniform dose of recommended diammonium phosphate (DAP) (46% P_2O_5 and 18% N) fertilizer was applied to all treatments during planting. All the other agronomic practices were followed as per the recommendation for the crop.

Crop data collection and measurement

Crop phenology and growth: Days to 50% flowering: This was determined as the number of days from sowing to the time when 50% of the plants started to be flowering through visual observation.

Days to 90% physiological maturity: Days to maturity was determined as the number of days from sowing to the time when the plants reached 90% physiological maturity based on visual observation. It was identified by the senescence of leaves and yellowing of pods.

Total number of nodules per plant: Nodulation was assessed at 50% flowering stage (at mid flowering stage) of the plants. Five randomly taken plants from destructive rows were uprooted for

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nodulation parameters and the number of nodules per plant was recorded by counting and was averaged per plant.

Effective number of nodules: The color inside of nodule was observed by cutting with the help of sharp blade. Pink to dark-red color has to be present to be effective.

Number of primary branches per plant: It was determined by counting the total number of branches from randomly taken ten plants from harvestable rows at physiological maturity.

Plant height: Plant height was measured at 90% physiological maturity from the ground level to the tip of plant from randomly taken ten plants of harvestable rows.

Yield components and yield

Crop stand count: The plants from the net plot area were counted after thinning and at crop harvesting to determine the change in stand count.

Number of pods per plant: It was recorded based on ten randomly pre-tagged plants in each net plot area and the average was taken as number of pods per plant.

Number of seeds per pod: The total number of seeds in ten randomly taken pods from the net plot was counted and divided by total number of pods to find the number of seeds per pod.

Hundred grain weights (g): The weight of 100 grains was taken from seed of each plot and weighed using a sensitive balance at designated moisture content of 10%.

Above ground dry biomass (kg ha^{-1}): At physiological maturity, from the destructive rows the above ground dry biomass of randomly ten plants was taken and measured after drying till a constant weight. For obtaining the total above ground dry biomass, the dry biomass per plant thus obtained was multiplied by the total number of plants per net plot and was converted into kg ha^{-1}. This was used to calculate the harvest index also.

Grain yield (kg ha^{-1}): This was recorded from net plot area of each plot after sun drying for 10 days. The grain yield was adjusted to the designated moisture content of 10%.

Harvest index: Harvest index was calculated by dividing grain yield per net plot area by the total above ground dry biomass yield per net plot area and was multiplied by 100.

Statistical data analysis

All the recorded data were subjected to analysis of variance using 18th edition Gen Stat statistical software procedure [17]. Fisher's Protected Least significant difference (LSD) test was used to compare treatment mean differences at the probability level of 0.05.

Results and Discussion

Properties of the soil of experimental site

The laboratory analysis of soil samples (0-30cm) taken before planting was done for the major soil physical and chemical properties at Nekemte Soil Laboratory. The results of the analysis are summarized below in Table 1 [18-24].

Table 1: Major physical and chemical characteristics of the soil of the experimental site.

Soil Properties	Value of Analysis	Rating	Reference
Soil Texture			
Sand (%)	51		
Silt (%)	25		
Clay (%)	24		
Textural Class	Sandy clay loam	-	Singh [18]
Soil pH (1:2.5 H_2O)	5.55	Moderately Acidic	IITA [19]
Organic Matter Content (%)	4.6	Medium	Berhanu [20]
Total Nitrogen (%)	0.23	High	Murphy [21]
Phosphorus (ppm)	6.345	Medium	Olsen et al. [22]
Cation Exchange Capacity (cmol (+)/kg soil)	39.657	High	Hazelton and Murphy [23]
Exchangeable Potassium (meq/100g soil)	0.216	Low	Hazelton and Murphy [23]
Exchangeable Magnesium (meq/100g soil)	2.707	Very low	Alemu et al. [24]
Exchangeable Calcium (meq/100g soil)	8.18	Very low	Alemu et al. [24]

Crop phenology and growth parameters

Days to 50% flowering: The main effects of variety showed highly significant (P<0.01) effect on days to 50% flowering, but the main effect of inter row spacing and the interaction effect were not significant. Variety Nyala took 57.12 days to flower initiation as compared to Wello (66.8 days) and Dhidhessa (71.17 days) (Table 2). Significant difference observed between the varieties might be attributed to the fact that days to flowering in soybean are considered to be varietal characteristics, which is genetically controlled and individual varieties have different growing habit, flowering and maturity days. Previous reports also showed that variety Nyala to be earlier than varieties Wello and Didessa [25-27]. Similarly, Tadesse & Sentayehu [28], reported that Nyala was earlier in days to flowering and days to maturity.

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Days to 90% physiological maturity: The main effect of variety showed highly significant (P<0.01) effect on the days to 90% physiological maturity while the main effect of inter row spacing and the interaction was not significant. Variety Nyala mature significantly earlier than Wello and Dhidhessa, where there was no significance difference between the two varieties. Significantly more days (134.6 days) were for variety Dhidhessa while the lowest days (115.6 days) was for variety Nyala (Table 2). This difference was a varietal character as variety Dhidhessa and Wello were medium in maturing while variety Nyala was early in maturity.

Table 2: Main effect of variety on days to flowering, days to maturity and total number of nodules per plant.

Factor	Days to Flowering	Days to Maturity	Total Number of Nodules Per Plant
Variety			
Dhidhessa	71.17[a]	134.6[a]	19.15
Wello	66.88[b]	133.6[a]	18.31
Nyala	57.12[c]	115.6[b]	24.22
LSD (0.05)	1.489	3.338	NS
Inter Row Spacing (cm)			
30	64.17	127.39	24.9
40	65.94	129.28	15.9
50	65.06	128.17	20.6
60	65.06	126.89	20.9
LSD (0.05)	NS	NS	NS
CV (%)	3.5	3.2	56.5

Means in column followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation; NS = Non-significant

Total number of nodules per plant: The analysis variance for total number of nodules per plant revealed no significance in all main effects and the interaction. This might be due to higher total nitrogen percentage in the experimental soil (Table 1) of the study area which may limit nitrogen fixing ability of the crop. This result was in line with the finding of Mahama [29], who reported no significant difference among row spacing and soybean varieties on total number of nodules per plant. Similarly, Daniel et al. [12], reported no significant effect of plant densities and varieties of soybean on total number of nodules per plant and attributed this to the nitrogen fixation that began between two to three weeks after planting reached climax during mid-flowering and declines as competition begins for carbohydrates during seed filling.

Effective number of nodules per plant: The analysis variance for number of effective nodules per plant revealed that the main effects of variety and inter row spacing as well as their interaction were not significant (P<0.05).

Number of primary branches per plant: Analysis of variance revealed that main effects of inter row spacing was highly significant (P<0.01), while the main effect of variety and the interaction effect of variety and inter row spacing showed significant effect (P<0.05) on the number of primary branches per plant. Varieties Wello (4.56) and Dhidhessa (4.25) gave significantly higher number of primary branches at 60 cm inter row spacing (Table 3).

Table 3: Interaction effect of variety and inter row spacing on number of primary branches per plant of soybean.

Variety	Inter Row Spacing (cm)				Mean
	60	50	40	30	
Wello	4.567[a]	4.100[ab]	2.950[def]	2.333[f]	3.488
Dhidhessa	4.250[a]	3.967[abc]	3.500[bcd]	2.283[f]	3.5
Nyala	3.183[de]	3.317[cd]	2.833[def]	2.567[ef]	3.111
Mean	4	3.795	3.094	2.394	
LSD (0.05)	0.69				
CV (%)	17.8				

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Thus, the presence of significant effect of variety and inter row spacing on the number of primary branches indicated the differential response of the varieties for the inter row spacing. This result was in line with the finding of Mehmet [30]; and Dereje [31], who obtained increased number of branches at the wider plant spacing from 4.47 in 30cm inter row spacing to 5.95 in 60cm

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inter row spacing for soybean varieties and attributed this to more interception of sunlight for photosynthesis with wider spacing, which may have resulted in production of more assimilate for partitioning towards the development of more branches. Similarly, Mahama [32], reported that soybean variety and row spacing showed significant effect on the number of primary branches per plant and gave higher number of primary branches at wider spacing (60cm and 50cm) than narrow spacing (40cm and 30cm).

Plant height: Plant height was highly significantly (P<0.01) affected by the main effects of variety. However, the main effect of inter row spacing and the interaction effect did not show significant effect.

The highest plant height (84.7cm) was observed for variety Wello and the lowest plant height (42.3cm) was recorded for variety Nyala (Table 4). The highly significant effect of variety on plant height might be due to different maturity group of varieties with early maturing variety Nyala having the shortest plant height.

Table 4: Main effect of variety, inter row spacing and intra row spacing on plant height of soybean.

Factor	Plant Height(cm)
Variety	
Wello	84.70^{a}
Dhidhessa	76.69^{b}
Nyala	42.30^{c}
LSD(0.05)	3.14
Inter Row Spacing (cm)	
30	70.49
40	66.79
50	67.58
60	66.73
LSD (0.05)	NS
CV (%)	8

Means in column followed by the same letter (s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation, NS= Non-significant

In agreement with this result, Dereje [31], reported significant differences among the varieties of soybean for plant height and found that medium maturing soybean varieties were longer than early maturing soybean varieties. Similar results were demonstrated by Ngalamu et al. [33]; and Mahasi et al. [34], where they found that late maturing varieties are longer than early maturing soybean varieties; due to genetic composition and enough time to utilize the available resources optimally.

Yield components and yield

Crop stand count: The analysis variance showed the main effect of variety was significant (P<0.05) and the two-way interaction effect of variety and inter row spacing were highly significant (P<0.01).

The highest final percent stand count (99.77%) was recorded from variety Nyala at 50cm inter row spacing while the lowest final percent stand count (84.26%) was recorded from variety Dhidhessa at 30cm inter row spacing (Table 5). The high percent mortality with relatively higher population density might be due to crowding effect. There may be possibilities that at narrower inter row spacing plants became crowded and died due to intense competition for growth resources. Hence, at narrow inter row spacing there was a decrease in the survival rate of the plants than at a wider spacing. However, early maturing variety was advantageous at narrower spacing than wider spacing as compared to medium maturing variety because early maturing varieties are short in height with shattering and lodging resistance [35].

Table 5: Interaction effect of variety and inter row spacing on percent stand count of soybean at harvest.

Variety	Inter Row Spacing (cm)			
	30	40	50	60
Nyala	98.27^{ab}	99.77^{a}	93.38^{a-f}	95.06^{a-d}
Wello	87.55^{e-h}	87.55^{d-h}	93.8^{a-f}	92.52^{b-g}
Dhidhessa	84.26^{h}	88.07^{d-h}	96.76^{abc}	94.7^{a-e}
LSD (0.05)	7.22			
CV (%)	4.7			

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

At lower plant population comparatively, the availability of more space might have resulted in less competition for resources (nutrients, moisture and light) whereas at high density due to more inter specific competition the weaker plants might have died by the time the crop approached to maturity. Mahama [32], also reported that high population in narrow row spacing for early maturing cultivars potentially increase growth and yield components, as they are able to utilize environmental factors more effectively.

In agreement with this result, Almaz et al. [36], reported increased plant mortality rate as density of plant increased for faba bean variety in which the wider inter row spacing (50cm) had the maximum (93.3%) final stand count percentage as compared to 40cm (91.0%) and 30cm (90.1%) inter row spacing. The decreasing of final crop stand count at narrower spacing might be due to interplant competition as well as due to environmental conditions such as heavy rain and wind speed prevailing during the season.

Number of pods per plant: Main effect of variety and inter row spacing had highly significant (P<0.01) effect; and the interactions of variety and inter row spacing had significant (P<0.05) effect on the number of pods per plant. The highest mean number of pods per plant (49.83) was recorded for variety Wello at 60cm inter row spacing and the lowest number of pods per plant (21.67) was recorded for variety Nyala at 30 cm inter row spacing (Table 6). This result was in line with Dereje [31], who reported that higher number of pods per plant of soybean varieties at wider inter row spacing (60cm) and the lower pods per plant at narrower inter row spacing (30cm).

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Table 6: Interaction effect of variety and inter row spacing on number pods per plant of soybean.

Variety	Inter Row Spacing (cm)				Mean
	60	50	40	30	
Wello	49.83[a]	40.62[b]	33.13[cde]	28.5[ef]	38.02
Dhidhessa	36.7[bc]	34.35[cd]	30.97[de]	23.33[g]	31.34
Nyala	29.05[ef]	30.22[def]	25.78[fg]	21.67[g]	26.68
Mean	38.53	35.06	29.96	24.5	
LSD (0.05)	5.12				
CV (%)	13.8				

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation

In agreement to the result of this study, Cedrick et al. [37] and Dereje [31], reported decrease in number of pods per plant in soybean varieties due to a reduction in the number of branches per plant at the higher densities. The increase in number of pods per plant at low density (wider inter and intra row spacing) might be due to the highest number of primary branches at wider spacing which may contribute to produce higher number of pods per plant.

The decrease in the number of pods per plant with increased plant density might be due to increased plant density that might have induced competition between the former and later emerged flowers that could lead to flower abortion. The increase in the number of pods per plant with increasing plant spacing may also be due to increase in the number of pods per branches as the result of higher net assimilation rates and reduction of competition in wider spacing. In wider inter row spacing, however, the growth factors (nutrient, moisture and light) for individual plants might be easily accessible that retained more flowers and supported the development of lateral branches.

Number of seeds per pod: The main effects of variety and inter row spacing as well as their interaction had no significant effect on number of seeds per pod. This might be due the fact that the number of seeds per pod was primarily regulated by the interaction between the environment and the genotypes and, however, variation in the number of pods per plant depends on type of legume species.

Characteristics, such as number of seeds per pod and 100 seed weight, are mostly influenced by genetic factors [38]. Similarly, Solomon et al. [39]; and Teshome et al. [40], reported that number of seeds per pod was significantly not different due to the main effects of soybean varieties, plant densities and cropping system. In contrast, Mohammed & Tessema [41], reported significant effect of varieties on number of seeds per pod of soybean varieties regardless of row spacing and interaction of variety and row spacing. This difference might be due to different soybean varieties used in this study and their experiment. And also, this difference among the findings of different researchers might be due to the differences in varieties as they may differ in agronomic traits (FAO, 1994 cited by [42], environmental conditions and the soil types.

Hundred grains weight: The main effect of inter row spacing and the interaction of variety and inter row spacing had no significant effect on hundred grains weight of soybean while the main effect of variety had highly significant ($P<0.01$) effect. Significantly higher hundred grains weight (19.91g) was recorded for variety Nyala than variety Dhidhessa (15.03g) and variety Wello (13.26) (Table 7). The significant difference on hundred grains weight might be due to seed size of different varieties; because final crop yield is a function of the number and size of seeds [43]. This result was in conformity with the study by Wondimu et al. [44], who reported that the number of 100 grains weight was significantly affected by main effect of varieties. Similarly, Wycliffe [45], stated that inter row spacing did not significantly affect 100 grains weight of soybean genotypes across seasons and sites whereas genotype and season had significant influence on 100 grains weight.

Table 7: The main effect of variety on number of seeds per pod and hundred grain weight of soybean.

Treatment	Number of Seeds Per Pod	Hundred Grain Weight (g)
Variety		
Nyala	2.08	19.91[a]
Dhidhessa	2.01	15.03[b]
Wello	2.06	13.26[c]
LSD (0.05)	NS	0.78
Inter Row Spacing (cm)		
30	2	16.4
40	2.04	15.98
50	2.08	16
60	2.1	15.88
LSD (0.05)	NS	NS
CV (%)	7.2	5.9

Means in column followed by the same letter(s) are not significantly different at 5% level of significance; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of Variation; NS = Non-significant

Above ground dry biomass yield: The main effects of variety and inter row spacing had highly significant ($P<0.01$) effect on the above ground dry biomass yield (kg ha^{-1}) while the interaction was not significant. The highest above ground dry biomass (8857kg ha^{-1}) was recorded for variety Wello and the lowest for variety Nyala (6921kg ha^{-1}) which was not significantly different from variety Dhidhessa (7682kg ha^{-1}) (Table 8). The highest biomass yield for variety Wello might be due to highest plant height of the variety Wello than variety Dhidhessa and Nyala; as well as bush and half tailing type of its growing habit. The early maturing genotype had significantly lower biomass than medium maturing genotype. In this regard, varieties Wello and Dhidhessa (medium maturing varieties) had generally higher above ground biomass than Nyala (early maturing variety). The results therefore suggest that varieties with longer maturity period produce high amount of biomass. According to Vanlauwe et al. [46], high biomass of soybean was obtainable in late maturing varieties than in the early maturing.

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Table 8: Main effect of variety and inter row spacing on above ground dry biomass (kg ha-1), grain yield (kg ha-1) and harvest index of soybean.

Treatment	ADBM (kg ha^{-1})
Variety	
Wello	8857^{a}
Dhidhessa	7682^{b}
Nyala	6921^{b}
LSD(0.05)	764.49
Inter row spacing (cm)	
30	8785^{a}
40	8020^{ab}
50	7703^{b}
60	6773^{c}
LSD (0.05)	882.76
CV (%)	16.8

The highest above ground dry biomass (8785kg ha^{-1}) was recorded at inter row spacing of 30cm and the lowest biomass (6773kg ha^{-1}) was recorded at inter row spacing of 60cm (Table 8). The result indicates that as inter row spacing increased from 30cm to 60cm the above ground dry biomass decreased; which might be due to the higher number crop stand count at narrower spacing than wider spacing. However, there was no significant difference between 30 and 40cm inter row spacing.

Likewise, as intra row spacing increased from 5cm to 10cm the above ground dry biomass decreased; this also might be due to the higher number crop stand count at narrower intra row spacing than wider intra row spacing. The higher (8241kg ha^{-1}) and the lower (7399kg ha^{-1}) above ground dry biomass were recorded from 5 cm and 10 cm intra row spacing, respectively.

Table 9: Interaction effect of variety and inter row spacing on grain yield of soybean.

Variety	Inter Row Spacing (cm)				Mean
	30	40	50	60	
Nyala	2792^{cde}	3805^{a}	3055^{bcd}	2800^{cde}	3113
Wello	2709^{cde}	2698^{cde}	2805^{cde}	3523^{ab}	2933.75
Dhidhessa	2350^{e}	2575de	3149^{bc}	2400^{e}	2618.5
Mean	2617	3026	3003	2907.667	
LSD(.05)	495.1				
CV (%)	10.1				

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Grain yield: The main effects of variety and inter row spacing had a significant (P<0.05) effect while the interaction effect of variety and inter row spacing was highly significant (P<0.01) on grain yield (kg ha^{-1}) of soybean. The highest grain yield (3805kg ha^{-1}), 3523kg ha^{-1}, 3149kg ha^{-1} were recorded for variety Nyala, Wello and Dhidhessa at 40cm, 60cm and 50 inter row spacing respectively (Table 9). The main difference of grain yield of variety might be due to recent released variety gave higher yield than earlier released varieties and due to large seed size of variety Nyala, since soybean seed size varies among varieties [47]. Mushoriwa [48], also stated that soybean grain yield is determined by seed size (100 grains weight) and seed number.

The main difference of grain yield of the interaction effect might be due to response of different varieties of the same crop to different plant spacing because of their growth habit, number of branches per plant and plant height affected by inter row spacing. This result was in line with Dereje [32], who reported that narrow spacing for early mature variety and wider spacing for medium and late maturing group soybean varieties.

Harvest index: Analysis of variance on the harvest index indicated that the main effect of variety was highly significant (P<0.01) and the main effect of inter and the interaction effect of variety and inter row spacing had a significant effect (P<0.05). Variety Nyala gave the highest harvest index value of 52.4% at 40cm inter row spacing, while variety Wello and Dhidhessa had the lowest harvest index 25.4% and 26.19% at 30cm inter row spaing, respectively (Table 10). This indicated that varieties that produce more yield would also produce more harvest index.

Table 10: Interaction effect of variety and inter row spacing on grain yield of soybean.

Variety	Inter Row Spacing (cm)				Mean
	30	40	50	60	
Nyala	39.44^{b}	52.4^{a}	44.06^{ab}	43.22^{ab}	44.78
Wello	25.46^{c}	27.85^{c}	29.74^{c}	41.36^{b}	31.1025
Dhidhessa	26.19^{c}	27.67^{c}	44.45^{ab}	40.75^{b}	34.765
Mean	30.36	35.97	39.51	41.77	
LSD (.05)	9.645				
CV (%)	15.4				

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

This was in agreement with Daniel et al. (2011) who reported that harvest index of soybean increased with decreased plant density (wider plant spacing) where the highest harvest index (46%) was from 20 plants/m2 and the lowest harvest index (37%) was from 50 plants/ m2; which might be due to varietal differences on grain yields and above ground dry biomass of different varieties.

Summary and Conclusion

The study was conducted to assess the effect of inter and intra row spacing on growth, yield components and yield of soybean varieties in Dale Sedi District, Western Ethiopia. The evaluated treatments consisted of factorial combinations of three soybean varieties; (Nyala, Wello and Dhidhessa) with four inter row spacing (30 cm, 40 cm, 50 cm and 60 cm) which was laid out in RCBD with three replications. Results showed main effect of variety to be significant on days to 50% flower initiation, 90% physiological maturity, hundred grain weight and grain yield. Variety Nyala was

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earlier to initiate flower (57.12 days) and to reach physiological maturity (115.6 days). The main effect of variety revealed highly significant and significant effect on plant height, where the longest plant height (84.7cm) was for variety Wello and the shortest (42.30cm) was for variety Nyala. The main effect of variety inter row spacing had highly significant effect on number of pods per plant and above ground dry biomass.

The interaction effect of variety and inter row spacing revealed highly significant effect on number of primary branches per plant, on crop stand count percentage at harvest, grain yield and harvest index. From the results of this study it can be concluded that variety Nyala, Dhidhessa and Wello varieties gave superior in grain yield at 40cm; 50 and 60cm inter row spacing. However, since, this study was based on only one season and one location; it requires further study for recommendation of specific plant spacing for specific variety.

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