

Response of Soybean [*Glycine max* L.] Varieties Grown Under Varying Inter Row Spacing in ManaSibu District, Western Oromia, Ethiopia

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Abstract

Current decline in soil fertility and inappropriate agronomic practices are among the main factors for low productivity of soybean. Thus, this study was initiated with the aim of investigating the response of varieties and inter row spacing on yield and yield components of soybean. Treatments consisting of 4x4 factorial combination of soybean variety with inter row spacing was laid out using RCB design with three replications at ManaSibu District, western Oromia, Ethiopia. The findings revealed that the main effect of variety at varying inter row spacing was highly significant ($P < 0.01$) for number of pods per plant, above ground biomass, grain yield and harvest index. While main effect of variety was also highly significant for hundred seed weight but significant ($P < 0.05$) for number seeds per pod. While the interaction effect of variety and inter row spacing was also highly significant effect ($P < 0.01$) on grain yield while significant on number of pods per plant and harvest index. Soybean Variety 'Dhidessa' gave the highest number of pods per plant (78.8) at 50 and 60 cm inter row spacing as well as maximum hundred grain weight (18.3g), grain yield (3703.7kg/ha) and harvest index (58.82%) at 50 cm inter row spacing. Generally, it can be concluded that 'Dhidessa' variety gave superior in grain yield at 50 cm inter row spacing at ManaSibu area and may be also suitable for similar agroecology.

Keywords: Soybean, grain yield; plant population, yield components.

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Introduction

The soybean [*Glycine max* (L.) Merrill, family Leguminosae, subfamily Papilionoidae] is one of the world's most important legumes in terms of production and trade. It has been a dominant oilseed sources since the 1960s (Smith and Huyser 1987). Soybean is an essential source of mainly protein, oil and micronutrients in human and animal feed in worldwide (Graham *et al.* 2003) and soybean contains up to 42% protein (O'Keefe *et al.*, 2015) and up to 22% oil, which is widely consumed as cooking oil (Popovic *et al.* 2013). Soybean production in Ethiopia has the productivity of about 2.3 tha^{-1} (CSA, 2019). However, reports indicate that the national average productivity of soybean in Ethiopia is low as compared to its world productivity (2.8 tha^{-1}) which is growing linearly for many years (FAOSTAT 2018) presents a challenge due to lack of proper agronomic practices is among major constraints for the low soybean production (Mesfin and Abush 2018).

Plant density is one of the essential agronomic practices as it is a major management variable used in matching crop requirements to the environmental offer of resources (Ferehewiot and Tekalign 2017). Optimizing the plant population and plant geometry of soybean, there is a considerable scope for increasing yield (Awasarmal *et al.*, 2011). A recent study in southwestern Ethiopia on the responses of early and late maturing soybean varieties to planting density showed greater yield and yield components per unit area as plant density increased plants per unit area (Mohammed and Tessema 2011). 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 (Daniel *et al.* 2012). Moreover, plant population had significant influences number of pods, number of seed per pod, hundred seed weight, biomass yield, and grain yield (Habtamu *et al.* 2018).

Thus, improving soybean production not only contributes to food consumption but also improves the income and food security of farmers. Though soybean crop has high production potential in west Wollega Zone, Ethiopia, ManaSibu district and the surrounding areas but yet its productivity has been low. Therefore, identifying adaptable high yielding soybean varieties and optimum planting density has been among major constraints in the study area. Hence, the aim of this study was to investigate the performance of soybean varieties under varying inter-row spacing at ManaSibu district, western Ethiopia.

Materials and Methods

Experimental site: The experiment was conducted at ManaSibu district, Kela Dabus, western Ethiopia during 2019 which is located in west Wollega zone at 601 km away from Addis Ababa (Figure 1). The site is located at

latitude of 8° 52'51" N and longitude 35°13'18" E and altitude of 1455 m.a.s.l. It has a warm humid climate with average minimum and maximum temperature of 14 and 30°C, respectively.

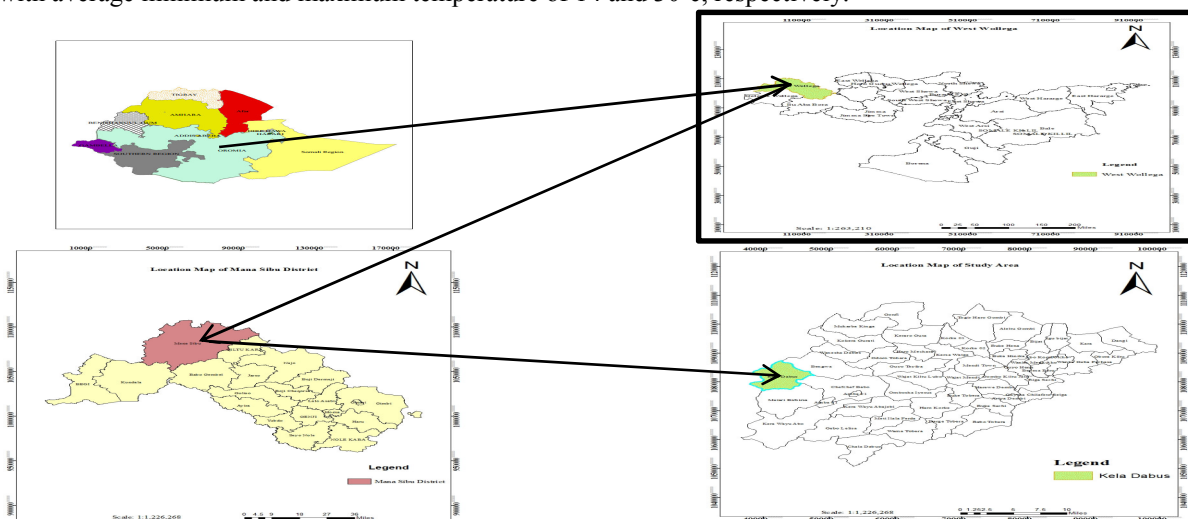


Figure 1: Map of the study area.

The area receives average annual rain fall of 900-1541 mm and its distribution pattern is unimodal (National Meteorology Agency (2019). The soil of the area is characteristically reddish brown loamy soil with Ph. ranges from 4.2-7 (Nekemte soil laboratory 2018).

Experimental Materials: Newly three soybean varieties ‘Dhidessa’ (PR-149-81-EP-7-2), ‘Cheri’ (Ipb-81-Ep7) BARC/OARI and ‘Pawe’ 03 (TGX-1987-62F) Pawe ARC/EIAR were used during the experiment. The former were medium type in their maturity duration (Table 1). And the local cultivar soybean commonly used by the farmers was included as a control during the experiment.

Table 1. Description of soybean materials used in the study.

No	Variety	Year of release	From	Maturity group	Altitude(m)	R.F(mm)	Maturity Day	tha ⁻¹
1	Didessa	2008	BARC	Medium	1200-1900	1000-1200	135	2.8
2	Cheri	2003	BARC	Medium	1300-1850	900-1850	137	2.1
3	Pawe 03	2016	AsARC	Medium	520- 1800	460- 1600	133	2.3
4	Local cultivar	-	Farmers	-	-	-	-	1.3

Source: MoANR, (2016) and Mesfin and Abush (2018)

Treatment and Experimental Design: The experiment consist two factors of soybean varieties at four levels [‘Didessa’(V1), ‘Cheri’ (V2), ‘Pawe’ 03 (V3) and local cultivar (V4)] combined with the treatments of inter row spacing at four levels (30, 40, 50 and 60cm). The experiment was laid out in factorial arrangement using RCBD in three replications. Four different soybean varieties combined with four varying inter row spacing totally 16 experimental treatments which were replicated three times on plot area of 3mx3m with 0.5m spacing between plots and 1m between blocks, respectively. The treatments were assigned to plots at random. The net plot size was 3x16x3x3=432m² and the total net area of the experimental field layout 11mx55.5m=610.5m².

Table 2. Description of Treatment Combinations.

No	Variety	Inter-Row spacing(IRS) (cm)	Treatments Combinations	
1	V1	30 cm	IRS1	V1 and 30cm IRS1
2	V1	40 cm	IRS2	V1 and 40cm IRS2
3	V1	50 cm	IRS3	V1 and 50cm IRS3
4	V1	60 cm	IRS4	V1 and 60cm IRS4
5	V2	30 cm	IRS1	V2 and 30cm IRS1
6	V2	40 cm	IRS2	V2 and 40cm IRS2
7	V2	50 cm	IRS3	V2 and 50cm IRS3
8	V2	60 cm	IRS4	V2 and 60cm IRS4
9	V3	30 cm	IRS1	V3 and 30cm IRS1
10	V3	40 cm	IRS2	V3 and 40cm IRS2
11	V3	50 cm	IRS3	V3 and 50cm IRS3
12	V3	60 cm	IRS4	V3 and 60cm IRS4
13	V4	30 cm	IRS1	V4 and 30cm IRS1
14	V4	40 cm	IRS2	V4 and 40cm IRS2
15	V4	50 cm	IRS3	V4 and 50cm IRS3
16	V4	60cm	IRS4	V4 and 60cmIRS4

Soybean varieties (V): V1='Dhidessa', V2='Cheri', V3='Pawe' 03 and V4=Local variety.

Field Management and Planting Method: Land preparation was done according to farmers practice in the area (oxen-plough three times) and all experimental plots were prepared as needed and the sowing was done on July 8, 2019. The seeds were planted by hand at a specified spacing by placing seeds per hill at each specific intra row spacing at the depth of 2-5. Uniform dose of recommended Nitrogen, Phosphorous and sulfur (NPS) fertilizer and other management practices were done according to recommended.

Data Collection: data was collected on number of pods per plant, number of seeds per pod, hundred seed weight/plot (g), grain yield (kg ha⁻¹)/plot, above ground dry-biomass per plot (Qt ha⁻¹) and harvest index.

Statistical Analysis: Data were subjected to analysis of variance (ANOVA) was performed to analyze the main effects of the two factors (Soybean variety level, inter row spacing) and their interactions using the statistical SAS software version 9.2 (SAS 2004) and the means were cross paired and compared using LSD at 5% of significance level.

RESULTS AND DISCUSSION

Plant density affects early ground cover, competitive ability of crops with weed, soil surface evaporation, light interception, lodging and development of an optimum number of fruiting sites in a crop canopy. It also affects canopy development, plant architecture and distribution of pods. Use of proper agronomic practices is one of the important factors which contribute for the increase of yield per unit area (Ferehewiot and Tekalign 2017). In addition to this, there is also varietal difference in response to the environment or plant density due to their genetic variations.

Number of pods per plant: The analysis of variance showed that the interactions of variety and inter row spacing had significant ($P < 0.05$) effect on the number of pods per plant (Table 3). And the main effect of variety and inter row spacing had highly significant ($P < 0.01$) effect on the number of pods per plant. The highest mean number of pods per plant (78.8) was recorded for variety 'Dhidessa' at 50 and 60cm inter row spacing and the lowest number of pods per plant (41.6) was recorded for local cultivar at 30 cm inter row spacing (Table 4). 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.

This result was in line with Dereje (2014), 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). Similarly, Kibiru (2018) reported that 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. Plant population affected pods per plant of soybean, throughout different study, as population increased, pods per plant decreased in a polynomial manner (Epler and Staggenborg 2008). There was a significant effect of plant density on pod number per plant; the pod number increase in the low plant density was as a result of extra branching of soybean (Gulluoglu *et al.* 2016).

Number of seeds per pod: The main effect of variety and their interaction effect had no significant effect on number of seeds per pod; while, the inter row spacing had significant ($P < 0.01$) effect on number of seeds per pod (Table 3). Number of seeds per pod is considered an important factor that directly imparts in exploiting potential yield recovery in leguminous crops. 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. This result conforms to Epler and Staggenborg (2008) report that the number of seeds per pod increased with decreased plant density (wider spacing)

of soybean which may be associated with increased plant capacity for utilizing the environmental inputs in building great amount of metabolites to be used in developing new tissues and increasing its yield components Almaz and Kindie (2017). Beside this, characteristics; such as number of seeds per pod and 100 seed weight are mostly influenced by genetic factors (Suhre *et al.* 2014).

Table 3: Analysis of Variance for Yield Components and Yield as affected by soybean varieties and inter row spacing at ManaSibu, Ethiopia in 2019 cropping season.

Source of variation	Degree of freedom	Mean Square					
		PPP	SPP	TAGB	GY	HSW	HI
Rep.	2	17.5	0.002	2934.7	21233.98	0.7	0.88
Variety	3	327.2**	0.0035 ⁿ _s	287730.96* _*	1195573.17* _*	132.67** _*	197.38* _*
Space	3	1946.7* _*	0.02* _*	119517.86* _*	796956.7** _*	0.7ns	97.27**
V*Space	9	130.8* _*	0.006 ^{ns}	17618.19ns	132529.4** _*	1.08ns	10.07* _*
Error	30	53.99	0.005	22029.775	30617.1	0.97	3.42
CV(%)		9.465	2.59	5.17	6.798	6.368	3.53

- PPP=Pod per plant SPP=Seed Per plant TAGB= Total Above ground biomass GY= Grain Yield HSW=Hundred Seed Weight HI=Harvest Index

Table 4: Interaction effect of variety and inter row spacing on number pods per plant, grain yield (kg ha⁻¹) and harvest Index (%) of soybean at Mana Sibu District 2019 cropping season.

Variety	Row spacing(cm)											
	Number of pods per plant				Grain yield				Harvest index (%)			
	30	40	50	60	30	40	50	60	30	40	50	60
‘Dhides sa’	45.2 _{fg}	52.1 ^c _f	78.8 ^a	78.8 _a	3074.1 _{cd}	3518.5 ^a _b	3703.7 _a	3518.5 _{ab}	49.9 ^c	55.7 _{ab}	58.8 _a	55.7 _{ab}
‘Cheri’	45.3 _{fg}	62.6 ^c _d	72.2 ^a _b	72.5 ^a _b	3407.4 _{abc}	3407.4 ^a _{bc}	3518.5 _{ab}	3333.3 _{bc}	53.8 ^b	54.7 _b	55.6 _{ab}	55.9 _{ab}
‘Pawe’ 03	42.3 _g	59.6 ^c _{de}	67.6 ^b _c	74.3 ^a _b	2925.9 _d	3074.1 ^c _d	3555.6 _{ab}	3222.2 _{bcd}	49.3 ^c	53.5 _b	55.8 _{ab}	54.4 _b
Local Cultivar	41.6 _g	55.4 ^c _d	59.9 ^c _{de}	60.1 ^c _{de}	2296.3 _e	2444.4 ^e	3148.1 _{cd}	3074.1 _{cd}	41.3 ^d	43.6 _d	50.3 _C	50.3 _c
LSD (0.05)	9.55				291.78				3.09			
CV (%)	9.46				5.49				3.53			
Mean	60.5				3188.8				52.3			
	2				8				7			

- 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.

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 on hundred grains weight (Table 3). Significantly higher hundred grains weight (18.3g) was recorded for variety ‘Dhidessa’ followed by variety ‘Cheri’ (16.7g), local cultivar (16.5g) and variety ‘Pawe 03’ (10.7g) (Table 5). This result was in conformity with the study by Wondimu *et al.* (2016) who reported that the number of 100 grains weight was significantly affected by main effect of soybean varieties. Similarly, Waswa (2015) 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 5: The main effect of variety and inter row spacing on Yield Components and Yield on soybean crop at ManaSibu district in 2019.

Variety	SPP	HGW (g)	TAGB (kg ha ⁻¹)
'Dhidessa'	2.77	18.28a	2787.03b
'Cheri'	2.77	16.72b	2796.29b
'Pawe' 03	2.76	10.70b	2796.29b
Local Cultivar	2.73	16.45c	3102.77a
LSD (5%)	NS	1.65**	247.5**
CV%	2.59	6.36	5.17
Mean	2.76	15.54	2870.59
Row spacing(cm)			
30	2.7	15.25	3010.18a
40	2.7	15.72	2847.21b
50	2.8	15.76	2851.84b
60	2.8	15.42	2773.14b
LSD (5%)	0.12*	NS	247.5**
CV%	2.59	6.36	5.17
Mean	2.76	15.54	2870.59

- Means in column followed by the same letter(s) are not significantly different at 5% level of significant; LSD = Least Significant Difference at 5% level; CV= Coefficient of variation; ns= Non-significant SPP=Seed Per plant, TAGB= Total Above ground biomass, HSW=Hundred Seed Weight

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 (Table 3). The highest above ground dry biomass ($3102.8 \text{ kg ha}^{-1}$) was recorded for local cultivar and the lowest for variety 'Dhidessa' ($2787.0 \text{ kg ha}^{-1}$) which was not significantly different from variety 'Cheri' ($2796.3 \text{ kg ha}^{-1}$) and 'Pawe' 03 ($2796.3 \text{ kg ha}^{-1}$) (Table 5). The highest biomass yield was from local cultivar which might be due to highest plant height of the local variety than variety 'Dhidessa', 'Pawe' 03 and 'Cheri'; as well as bush (thick stem) and half tailing type of its growing habit. The early and medium maturing genotype had significantly lower biomass than late maturing genotype. The highest above ground dry biomass ($3010.2 \text{ kg ha}^{-1}$) was recorded at inter row spacing of 30cm and the lowest biomass ($2773.1 \text{ kg ha}^{-1}$) was recorded at inter row spacing of 60cm (Table 5). In line with this finding, Nath et al. (2017) indicated dry matter weight is attributed to their genetic potential rather than the effect of external weather parameters in soybean. According to Vanlauwe et al. (2003) high biomass of soybean was obtained in late maturing varieties than in the early maturing.

Grain yield: The main effects of variety and inter row spacing revealed highly significant ($P < 0.01$) effect on grain yield while the interaction effect of variety and inter row spacing was significant ($P < 0.05$) on grain yield (kg ha^{-1}) of soybean (Table 3). The highest grain yield ($3703.7 \text{ kg ha}^{-1}$), ($3555.6 \text{ kg ha}^{-1}$), ($3518.5 \text{ kg ha}^{-1}$) and ($3074.1 \text{ kg ha}^{-1}$) were recorded for variety 'Dhidessa', 'Pawe' 03, 'Cheri' and local cultivar; at 50cm, 50cm, 50cm and 60cm inter row spacing respectively (Table 4). The main difference of grain yield among varieties might be due to difference in seed size (Dugje et al. 2009). Mushoriwa (2013) also stated that soybean grain yield is determined by seed size (100 grains weight) and seed number. And in Keyvan and Kobraee (2012) study also obtained highly significant variation was observed soybean varieties in response to grain yield. Nath et al. (2017) described as seed yield was highly influenced by varieties.

The reason for the difference in 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 (2011) finding who stated that narrow spacing for early maturing variety and wider spacing for medium and late maturing group soybean varieties. In contrast to this, Kolaric et al. (2014) reported that the highest grain yield ($4,868 \text{ kg ha}^{-1}$) was determined at the 20 cm inter-row spacing and it decreased equally at bigger row spacing (45 and 70cm) for 7.0-12.9% and the highest grain yield was achieved with 'Balkan' cultivar ($4,773 \text{ kg ha}^{-1}$), and the lowest with 'Dragana' cultivar ($4,284 \text{ kg ha}^{-1}$). Grain yield of soybean was not affected by plant geometry and it ranged from 1.3 to 1.9 t ha^{-1} at different spacing (Bhagirath et al. 2014). Other finding by Thandiwe and Schutte (2018) indicate that soybean planted in narrow rows of 19 cm have higher yield potential when compared to soybean planted in wider rows spacing's (50–76 cm).

Harvest index (%): Analysis of variance on the harvest index indicated that the main effect of variety and inter row space was highly significant ($P < 0.01$) and the interaction effect of variety and inter row spacing had a significant effect ($P < 0.05$) (Table 3). Variety 'Dhidessa' gave the highest harvest index value of 58.8% at 50cm inter row spacing, while local cultivar had the lowest harvest index 41.3% at 30cm inter row spacing, respectively (Table 4) indicating varieties that produce more yield would also produce more harvest index. 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 per unit area and the lowest harvest index (37%) was from 50 plants per unit area; which might be due to varietal differences on grain yields and above ground dry biomass of different varieties. Halis et al. (2017) reports showed that the highest and the lowest harvesting index (46.3 and 39.5%, respectively) were observed at 70cm x 10cm and 70cm x 4cm spacing, respectively; this indicate harvest index significantly decreased with reducing plant density.

The competition among the plants for absorption of nutrient and photosynthesis become severe and inhibit production and partitioning of food materials resulting tall, thin and slender stems under high planting density (Ohyama *et al.* 2013). This study was supported by previous findings reported by Daniel et al.(2014) who recorded a highly significant variation among varieties of haricot bean plants that were evaluated for harvest index. In contrast to this result, Habtamu et al. (2018) reported that the main effect of plant population did not show significant variations on harvest index of soybean cultivar. And, Sobko *et al.* (2019) reported that the main effect of inter row spacing on harvest index was stable characteristic within a cultivar and was not affected by planting density of soybean cultivar.

Conclusion

The result showed the main effect of variety and inter row spacing was highly significant ($P < 0.01$) for number of pods per plant, total above ground biomass, grain yield and harvest index. While, main effect of variety and inter row spacing was also highly significant ($P < 0.01$) for hundred seed weight and significant effect ($P < 0.05$) for number seeds per pod, respectively. Moreover, the interaction effect of variety and inter row spacing had highly significant effect ($P < 0.01$) on grain yield but significant on number of pods per plant and harvest index indicating influence of both factors on grain yield. It can be concluded that 'Dhidessa' variety showed superior grain yield performance at 50 cm inter row spacing at ManaSibu area and may perform in similar agro-ecology of western region.

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