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Response of Leek (Allium ampeloprasum var. porrum L.) Varieties to Plant Spacing at Boloso Bombe, Southern Ethiopia

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Keywords: boloso bombe; intra spacing; inter spacing and pseudo stem yield.

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Keywords: boloso bombe; intra spacing; inter spacing and pseudo stem yield.

I. Introduction

Leek (*Allium ampeloprasum* var. *porrum* L.) belongs to the genus *Allium* of the family *Alliaceae* (Hanelt, 1990). It is closely related to the onions. It is a biennial plant and its reproductive system is predominantly cross-fertilization although self-fertilization is possible (Meer and Hanely, 1990). It is a slow growing monocotyledonous species of the genus; it is characterized by broad, flat, tightly wrapped, dark green leaves, a long, thick white stalk, and a slightly (to some extent) bulbous end. It is very tolerant to cold weather, although the optimum temperature for vegetative growth is around 20°C. The leaves and long white blanched stem are eaten cooked or can be added to salads (Theunissen and Schelling, 1998).

It is one of the most important pseudo-stems crops cultivated commercially in nearly most parts of the world (Simon, 1992). It contributes significantly to nutritional value of the human diet and is primarily consumed for its unique flavour or for its ability to enhance the flavor of other foods. Its distinctive pungency is due to the presence of a volatile oil. The mature bulb contains some starch, appreciable quantities of sugars, some protein, and vitamins A, B, and C (Decoteau, 2000). It is also used as preservative and medicine (Vohra *et al.,* 1994).

In Ethiopia, the *Alliums* group are among the most important bulb crops produced by small farmers and commercial growers both for local uses as well as for export Metasebia (1998) Leeks are spread throughout the country, being cultivated under both irrigated as well as rain fed conditions in different agro-climatic regions. The best growing altitude for onion, shallot and leeks under Ethiopian condition is between 700 and 1800 m a.s.l (Lemma and Herath, 1992; Aklilu, 1997). Statistics on the production of Vegetables in Ethiopia showed that about 349,079ha of land are cultivated and 2,789,202 hectares produced (CSA, 2017). However, currently, there is no information about the area and the status of leek production in Ethiopia (FAOSTAT, 2010; (CSA, 2017).

The commercial product of leek is its pseudo-stem and leek's pseudo-stem yield varies depending on cultivar, sowing date and planting density (Mondal, 1985). The author further indicated that bulb yield increases with plant density and that this positively correlates with the percentage light interception by the crop leaf canopy. In addition, Brewster (1994) reported that leek bulb yield increased asymptotically as plant density increases and that mean bulb size correspondingly declined.

Considering the importance of leek as one of the potential vegetable crops for both domestic consumption and export in Ethiopia, but there are many constraints that reduce leek production and productivity among which lack of improved varieties and non optimum plant spacing are the majors. It is very important to increase its productivity along with

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appropriate management practices. However; there is no location and variety specific recommendation on the plant spacing of leek cultivars in study area. In view of the above facts, this study was initiated with the objective to determine the effect of plant spacing on growth, yield components and yield of leek varieties.

II. Materials and Methods

a) Description of the Study Area

A field Experiment was conducted during 2016 off cropping season at Farawoch fruit vegetable nursery site of Boloso Bombe in Southern Ethiopia. A geographical coordinates of the study site is located at 7°08′15.1"N latitude and 37° 41''.330' E longitude having an altitude of 1730 meter above sea level. The experimental site is characterized with bimodal rainfall distribution pattern which extends from March to September and receiving mean annual rainfall of 1459.1 mm. The mean annual minimum and maximum temperature of the site was 15 and 26°C, respectively. Soil types of the study area is sandy loam (BBWARDO, 2011).

b) Description of Experimental Materials

The Leek varieties used in the study were: Carentan Giant (CG), 'Lancelot' and 'Dawn Giant' which were obtained from Haramaya University.

Table 1: The description of the varieties of Leek used in the study

Variety	Year of release	Area of adaptation		Maturity days	Yield (t ha^{-1})	
		Altitude(m)	Rainfall(mm)		On research field	On-farm Field
Carentan Giant	Un	1800-2400	700-1200	100-138	Unknow	2.1
'Lancelot'	Un	1800-2600	700-1200	120-150	2.0-3.5	1.5
'Dawn Giant'	2004	1800-2600	700-1200	70-120	150 stalks	---

Source: HoAA (2004).

c) Treatments and Experimental Design

The experiment was conducted using three factorial combinations of three Carentan, 'Dawn Giant' and 'Lancelot' varieties with three inter-row spacing (40, 30 and 20 cm) and two intra-row spacing (15 and 10 cm). It was conducted by using Randomized Complete Block Design with factorial arrangement and replicated three times. Plots having 40, 30 and 20 cm inter-row spacing accommodated 6, 8 and 12 rows, respectively from which the middle 4, 6 and 10 rows were harvested. Gross plot size was 2.4 m x 3 m (7.2 m^2). Spacing of 0.6 m and 1 m were allocated between plots and blocks, respectively.

d) Soil Sampling and Analysis

A composite initial soil sample of 0-30 cm soil depth was taken from the experimental site before planting and analyzed for physico-chemical properties. Then, taken sample was air-dried, ground using a pestle and mortar, and allowed to pass through a 2 mm sieve. The soil sample was taken to Soil Analytical Testing Service Laboratory and analysed at Wolaita sodo in Ethiopia. Analysis of organic matter content of the soil in a laboratory was determined by using Walkely and Black procedure (Walkely and Black, 1934) and total nitrogen by Micro Kjeldhal method (Jackson, 1958). Soil reaction (pH) was analysed using a pH meter with 1:2.5 soil to solution ratio via a glass electrode attached, and Cation exchange capacity was measured after saturating the soil with 1N ammonium acetate (NH_4OAc) and displacing it with 1N NaOAC (Chapman, 1965). Available phosphorous was determined by the Olsen method (Olsen *et al*., 1954) and exchangeable potassium by flame photometer. Soil texture analysis was performed by Bouyoucous hydrometer method (Bouyoucous, 1951).

e) Data Collection

The data on crop growth, yield components and yield were recorded from sampled plants randomly from middle rows of each plot.

Plant height (cm): It was measured in centimetres from the ground level to the top of the plant at 30 days after transplanting (DAT) and at maturity from15 randomly selected plants.

Days to maturity (No): The total number of days from emergence until 90% of the plants attained physiological maturity. This refers to the time required by the plant to reach the stage when 90% of the pseudo-stems (leaves) were having started to senesce.

Number of leaves per plant (No): This was counted as the total number of leaves and was recorded at 30 DAT and at maturity from 10 randomly selected plants per plot.

Leaf length (cm): The average length of long leaf of the plants was measured at 30 DAT and at maturity from 10 randomly selected plants.

Leaf width (cm): The diameter of the longest leaf at the time of maturity was measured from the sample plants and expressed in centimetre.

Pseudo-stem height (cm): The average pseudo-stem height was grouped into blanched edible parts of 10 randomly taken mature pseudo-stem after harvest.

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Pseudo-stem yield (marketable, unmarketable and total yield) (kg ha^{-1}): Marketable and unmarketable pseudo-stem number and weight per plot were recorded and by adding up both total pseudo-stem yield per plot determined. The data were taken from plants in the five middle rows at harvest. Unmarketable pseudo-stem was identified by experienced Leek trader through subjective evaluation and recorded as the weight and number of diseased, insect attacked and abnormal bulbs. The data were converted to estimate marketable, unmarketable yield per hectare (kg ha^{-1}).

Biological fresh matter yield (kg ha^{-1}): This was recorded as the total fresh weight of physiologically mature plant parts, including pseudo-stems, leaves and roots per plot, taking plants in the central rows of each plot and converted in to hectare (kg ha^{-1}).

f) Statistical Data Analysis

Collected data were subjected to analysis of variance (ANOVA) according to the Generalized Linear Model (GLM) of SAS version 9.1 and interpretations were made following the procedure of Gomez and Gomez (1984). Mean separations were done using Least Significance Difference (LSD) test at 5 % level of significance.

III. Results and Discussion

a) Physico- chemical properties of experimental soils

The laboratory analysis of soil samples from the top soil (0-30 cm) taken before planting was done for the selected physical and chemical properties of soil and has a rate of clay textural class.

Table 2: Selected physical and chemical properties of the experimental site soil

No	Soil characteristics	Value	Rate	Reference
1	pH (by 1: 2.5 soil water ratio)	7.19	Neutral	Bruce and Rayment,1992
2	Total nitrogen	0.08%	Low	Bruce and Rayment,1992
3	CEC	5.34 cmol (+)/kg	high	Charman and Roper,2007
4	Available phosphorus	22.04mg/kg	High	Moody and Bolland,1999
5	Organic matter	1.93 %	High	Charman and Roper,2007
6	Exchangeable K	1.55 cmol (+)/kg	High	Brady,1984
7	Soil texture:			
	% clay	74		
	% sand	4		
	% silt	22		
	Soil textural class		Clay	Mcdonald *et al.*,1994

b) Days to Maturity

Highly significant differences (P<0.01)were recorded on the number of days to 90% physiological maturity due to main effects of variety, inter and intra-row spacing. The number of days taken to reach 90 % physiological maturity for varieties Carentan Giant, 'Dawn Giant' and Lancelot' leek were 111.50, 111.67 and 109.50 days, respectively (Table 3). Carentan Giant and 'Dawn Giant' varieties were matured late than that of Lancelot' variety. However, there was no significant difference between varieties; Carentan Giant and 'Dawn Giant' also differences among cultivars in time to physiological maturity of leek. This might be due to genetic variation of the leek varieties and again intra specific competition of the crop. In line with this, Ali et al.(1999) reported that as intra-row spacing decreased, days to maturity was found to be increased on shallot crop.

The main effects of inter-row spacing showed a highly significant effect (P < 0.01) on the number of days to 90 % physiological maturity, the number of days taken to 90 % physiological maturity increases as the inter-row spacing increases i.e. plots having 20 cm inter-row spacing matured earlier than 30 and 40 cm inter-row spacing. When inter-row spacing increases from 20 to 30 and 20 to 40 cm inter-row spacing, the maturity period increases by 1.55, 1.79%. Moreover; Plots having 10 cm intra-row spacing matured 1.78 days earlier than plots having 15 cm intra-row spacing (Table 3). In this study, it was generally observed that wider intra-row spacing delayed 90% physiological maturity. Similarly, Jilani (2004) reported that there was difference in physiological maturity of onion cultivars and also reported the intra-row spacing increased from 10 to 15 cm, the days to 90 % physiological maturity increases by 1.60%.

c) Plant height

Analysis of variance exhibited significant differences (P < 0.05) due to the main effects of variety on plant height at 90 % physiological maturity. The highest height of plant was recorded for variety Carentan Giant (41.24 cm) followed by 'Dawn Giant' (39.17cm) while the lowest height was recorded on variety Lancelot' (37.82cm). Variety Carentan Giant was significantly different from variety Lancelot'on plant height while variety 'Dawn Giant' was found with the same level of significance with both Carentan Giant and Lancelot' (Table 3). The variation in height might be due to genetic characteristics of the varieties for this trait.

Plant height was not affected significantly by the main effects of inter- and intra-row spacing. The non-significant effect of crop density on mean plant height observed in this study might be attributed to the fact that crop density has often, but not always been associated with increased plant height. Increase in plant population markedly would increase plant height of leek. All interaction effect also did not influence significantly the height of leek varieties. This result was in agreement with Mondal et al. (1986) who reported that genotypes of onion were significantly differed in plant height. And also Zamil et al. (2010) who reported that the widest spacing enhances growth and height of the plant which was significantly different from narrow spacing.

Table 3: Mean values of Leaf length, days to 90 % physiological maturity (DM), Leaf width and Plant height (PH) as affected by the main effects of variety, inter and intra row spacing in southern Ethiopia

Treatments	Leaf width (cm)	Leaf length (cm) Variety	DM (days)	PH (cm)
Carentan Giant	10.94a	40.78c	111.50a	49.24a
'Dawn Giant'	8.04c	39.17c	111.67a	48.50a
Lancelot'	9.66b	46.33b	109.50b	37.82b
LSD (5%)	0.62	0.89	1.32	2.23
Inter-row spacing(cm)				
20	10.11b	42.17b	109.50b	39.47
30	10.28a	42.94ab	111.22a	38.97
40	9.06c	43.50a	111.95a	39.80
LSD (5%)	0.17	0.89	1.32	Ns
Intra-row spacing (cm)				
10	69.57	42.07b	110.00b	39.61
15	74.90	43.67a	111.78a	39.21
LSD (5%)	Ns	0.73	1.08	Ns
C.V (%)	9.95	3.08	1.76	8.34

Means with in columns followed by the same letters are non significantly affected at 5 % probability level. LSD = Least significant Different and CV (%) =coefficient of variation

d) Yield Components

i. Leaf Length

The main effects of variety, inter and intra row spacing on leaf length of Leek plants showed significance difference (Table 3). Varieties Carentan Giant (40.78cm) and 'Dawn Giant' (41.50cm) as compared to 'Lancelot (46.33cm). Significant difference was observed between variety 'Lancelot and the other two varieties. This might be attributed to the facts that leave length in leek are considering variety characteristics, which is genetically controlled. The highest leaf length was recorded from Carentan Giant (43.50cm) in 40 cm inter row spacing followed by 'Lancelot' (42.9cm) in 30cm inter row spacing while the lowest leaf length was 'Dawn 42.17 cm in 20 cm inter-row spacing (Table 3). The 20 and 30 cm inter row spacing were found to be non significant to each other but they were significantly different from 40 cm inter row spacing. When the inter row spacing increased from 20 to 40 cm, leaf length increased.

Similarly the intra row spacing increased from 10 to 15 cm, the leaf length increased by 3.66 % (Table 3). Plots having wider inter row spacing and intra row spacing length significantly larger than that of narrower inter and intra row spacing. In contrast to this finding, Hussain et al. (1998) and Marschner (2007) reported that the non-significant effect of plant population on plant length onion.

ii. Number of Leave per plant

The effects of variety, inter and intra row spacing ($p < 0.05$) and the interaction effects of variety, inter row spacing and intra row spacing was a significant influence on the number of leave plant^{-1} (Table 4). Variety 'Dawn Giant' at 40 cm inter row spacing gave the highest number of leaves (4.30) while variety Carentan Giant at 20 cm inter row spacing gave the lowest number of primary branches (2.03). The number of leaves of two varieties ('Dawn Giant' and Lancelot') decreased with decreased inter row spacing whereas; the inter row spacing increases from 20 to 40 cm, the number of leaves of varieties 'Dawn Giant' and Lancelot' increases by 32.09 and 31.76 %, respectively. The decreased inter row spacing resulted in more plants per unit area and hence less number of leaves plant^{-1} due to more competition for nutrients, light, water and air. Significant differences were recorded among varieties at all inter row spacing. Carentan Giant significantly gave lower number of leaves than the other two varieties at all inter row spacing but there was no significant difference between varieties. The significant difference among varieties in all inter row spacing could be due to the differences in growth habit. Similarly, Singh et al. (2005) reported that the increased in number of primary branches with decreased plant density in garlic crop.

Table 4: Leaves per plant as affected by inter spacing, intra spacing, variety and interaction in Southern Ethiopia

Inter-row spacing(cm)	Variety		
	Carentan Giant	'Dawn Giant'	Lancelot'
20	12.03d	12.92c	12.90c
30	12.35d	13.93ab	13.57b
40	12.47cd	14.30a	14.25a
LSD (5%)	0.54		
C.V (%)	13.25		
Intra-row spacing (cm)			
10	12.27c	13.60ab	13.20b
15	12.30c	13.83a	13.94a
LSD (5%)	0.60		
C.V (%)	13.25		

Means with in columns followed by the same letters are non significantly affected at 5 % probability level. LSD = Least significant Different and CV (%) =coefficient of variation

e) Pseudo-stem diameter plant^{-1}

Analysis of variance showed that significantly different at (P < 0.01) for Pseudo-stem diameter plant^{-1}. The highest Pseudo-stem diameter plant^{-1} was recorded for variety 'Dawn Giant' (27.59) followed by variety Lancelot' (24.88) while the lowest number of pods plant^{-1} was recorded for variety Carentan Giant (17.12) (Table 5). The differences in Pseudo-stem diameter plant^{-1} might be due to varietal differences and the productive capacity of Leek crop is ultimately considered by the Pseudo-stem diameter plant^{-1}. Significant variation was existed between 20 and the other inter row spacing but similar significance level were found between 30 and 40 cm inter row spacing. Higher pseudo-stem diameter plant^{-1} in 40 cm apart inter rows might be due to low competition of plants in the field which facilitated more aeration, greater light interception and more photosynthetic activity per individual plant. Similarly, Islam (1988) also reported that higher yields of pseudo-stem diameter can be achieved as row spacing is reduced where inter and intra row spacing's were none-significant. The main effects of varieties, inter and intra row spacing significantly affected. However, the highest pseudo stem yield of 19.07cm green part had occurred for variety Lancelot followed by variety Dawn (16.41cm) while the lowest seed yield was obtained for variety Carentan (15.93cm) and have a response in pseudo stem length of the green part of the Leek (Table 5). In contrast to this finding, Baker (1998) reported that in the narrow intra row spacing of leek crop were decrease in pseudo-stem length could be due to the presence of high competition for growth factors at wider spacing.

Table 5: The main effects of varieties, inter and intra row spacing on pseudo-stem diameter, biological fresh yield weight (BFMY) and dry-matter content of Leek in Southern Ethiopia

Treatment	Pseudo-stem diameter	Pseudo-stem length	Fresh Matter (g plant^{-1})	Dry matter (%)
Carentan	38.18	5.92b	72.70^{d}c	10.96
Dawn	29.62	6.96b	82.9^{ab}	11.27
Lancelot	26.84	9.96a	93.80^{a}	11.15
LSD(0.05)	11.34	14.04	26.60	NS
Intra row spacing and intra-spacing(cm)				
5x20	28.38	5.78	88.10	11.91
10x30	27.59	5.72	78.60	10.83
15x40	25.58	6.38	70.40	11.21
LSD(0.05)	02.80	NS	11.01	NS
CV (%)	13.3	16.2	35.4	17.3

Means followed by the same letter within a column are not significant different at 5% level of significance; NS= not significant, LSD = Least Significant Difference and CV = Coefficient of variance

f) Fresh matter Yield

Analysis of variance showed that the biological fresh matter yield of Leek significantly (P<0.05) affected due to the main effects variety, intra and inter row spacing. The highest biological Fresh matter yield was recorded in Lancelot variety with 20 cm inter row spacing while the lowest yield (72.70) was recorded in 40 cm inter-rows (Table 5). This might be due to genetic potential of the crop and plant density variation. Similarly, Getachew et al. (2013) reported that different varieties with vary inter row spacing gave different fresh matter weight in shallot crop.

g) Marketable and Unmarketable pseudo stem

The interaction effects of varieties and inter-intra row spacing did not show significant effect on the number of unmarketable pseudo-stems of leek. On the other hand, the number of marketable pseudo-stems was highly significantly affected (P<0.01) by the intra row spacing. The highest number of stems plant^{-1} was recorded for variety 'Dawn Giant' (27.59) followed by variety 'Lancelot' (24.88) while the lowest number of stems plant^{-1} was recorded for variety Carentan Giant (17.12) (Table 6). As the inter-row spacing increases from 20 to 40 cm, the number of pseudo stem (shaft) per plant increases. Significant variation was existed between 20 cm and the other inter-row spacing but similar significance level were found between 30 and 40 cm inter-row spacing. Average number of pseudo stem plant^{-1} was increased by 10.72 and 12.51% as the inter-row spacing was increased from 20 to 30 cm and 20 to 40 cm, respectively (Table 6). Higher number of pseudo stem plant^{-1} in 40 cm apart inter-rows might be due to low competition of plants in the field which facilitated more aeration, greater light interception and more photosynthetic activity per individual plant. Number of pseudo stem (shaft) per plant is a key factor for determining the yield performance in *allium* plants. The productive capacity of leek plant is ultimately considered by the number of pods plant^{-1}.

Higher average number of pseudo stem plant^{-1} (24.06 stems) was noted in 15 cm intra-row spacing and the lower number of pods plant^{-1} (22.34 stems) was recorded in plots with 10 cm intra-row spacing (Table 6). The wider intra-row spacing produced the higher number of stems plant^{-1} because of sufficient space and plants utilized more water, light, air and nutrients as a result, more photosynthetic activity, which eventually resulted in higher number of pods plant^{-1}. The reduction in number of stems plant^{-1} (7.15 %) in narrower intra-row spacing might be due to higher number of plant per unit area where competition for nutrients, light, space and moisture was very tense as compared with the wider intra-row spacing. Similarly, Baker (1998) reported that in the narrow intra row spacing of leek crop were decrease in marketable stem at wider spacing.

h) Total Biological Yield

Variety 'Dawn (454.82 kg ha^{-1}) and 'Lancelot' (427.93 kg ha^{-1}) had the highest biological yield whereas variety Carentan Giant had the lowest biological yield (147.90 kg ha^{-1}) (Table 6). However, all varieties showed statistically non-significant differences. The productivity of a crop is largely determined by the biological yield. Production of large amount of biomass is among one of the attributes of seed yield. The decrease in biological yield due to low branching habit and low number of pods per plant of variety Carentan Giant might be compensated by the increased in other parameters such as plant height, seed weight and stem thickness.

As the inter-row spacing increases, the biological yield also increases and hence, the highest biological yield 863.23 kg ha^{-1}) was recorded in 20 cm inter-row spacing followed by 30 cm with a yield of 167.55 kg ha^{-1} while the lowest biological yield (899.88 kg ha^{-1}) was obtained from 40 cm inter-row spacing (Table 6). Inter-row spacing having 20 cm was significantly affected and 30 and 40 cm inter-row spacing but non-significance effect was recorded between 30 and 40 inter-row spacing. The biological yield was increased by 24.94 and 18.01% when inter-row spacing was changed from 40 to 20 cm and 30 to 20 cm, respectively. This finding was in agreement with Gan et al. (2003) reported that increasing yield of onion at high density. Bahr (2007) also reported that high plant density (30 plants m^{-2}) gave higher seed yield as compared to low plant density (26 plants m^{-2}) in Leek crop.

i) Pseudo-stem yield

The main effects of variety did not influence the pseudo-stem yield of Leek varieties. However, the highest stem yield of 1026.68 kg ha^{-1} had occurred for variety 'Lancelot' followed by variety 'Dawn Giant' (911.50 kg ha^{-1}) while the lowest stem yield was obtained for variety Carentan Giant (CG),(821.77 kg ha^{-1}) (Table 6). The decreased in pseudo stem yield due to short shaft habit and stunt of pseudo stem per plant for variety Carentan Giant variety might be compensated by other parameters such as stem weight. Pseudo-stem yield and its transformation into economic yield is the ultimate outcome of various physiological and morphological events occurring in the plant system. Pseudo-stem yield varies with in varieties is as a result of interplay of its genetic makeup. The interaction effects of all treatment combinations for this parameter were also non-significant. In line with this result, Brittain (1988[c]) found that narrow inter-row spacing (30 cm) gave the highest seed yield as compared to wider spacing of 45 and 60 cm on Leek varieties.

Table 6: Main effects of varieties, intra and inter row spacing on the number of Marketable pseudo stem, number of unmarketable pseudo stem (NUMARPS), biological yield (TBY and Pseudo-stem yield (PSY) at Boloso Bombe, Southern Ethiopia

Treatments	NM	NUMPS	TBY (kg/ha)	TY (kg/ha)
Variety				
Carentan Giant	17.12c	1.06	137.90	821.77
'Dawn Giant'	27.59a	1.07	454.82	911.50
Lancelot	24.88b	1.09	427.93	1026.68
LSD (5%)	1.58	Ns	Ns	Ns
Inter-row spacing (cm)				
20	21.33b	1.06	863.23a	2340.33a
30	23.89a	1.08	167.55b	1800.45b
40	24.38a	1.07	899.88b	1619.16b
LSD (5%)	1.58	Ns	98.51	250.89
Intra-row spacing (cm)				
10	22.34b	1.06	3599.85a	2081.65a
15	24.06a	1.08	3020.58b	1758.32b
LSD (5%)	1.29	Ns	325.38	204.85
C.V (%)	10.06	9.20	17.77	19.29

Means followed by the same letter within a column are not significant different at 5% level of significance; NS= not significant, LSD = Least Significant Difference and CV = Coefficient of variance

The main effects of inter and intra row spacing caused a highly significant effect ($p < 0.01$) on the total yield of Leek varieties. The highest average total yield (2340.33 kg ha^{-1}) was recorded in 20cm inter row spacing followed by 30cm inter rows with average total yield value of 1800.45 kg ha^{-1} while the lowest yield (1619.16 kg ha^{-1}) was recorded in 40 cm inter rows (Table 6). But there was no statistically significant difference between 30 and 40 cm inter row spacing. The total yield was decreased by 23.07 and 30.81 % when inter row spacing was increased from 20 to 30 cm and 20 to 40 cm inter row spacing, respectively (Table 6). The higher pseudo stem yield (2081.65 kg ha^{-1}) was recorded in 10 cm intra row spacing and lower yield of 1758.32 kg ha^{-1} was recorded in plots with 15 cm intra row spacing. When intra row spacing was increased from 10 to 15 cm, the yield was decreased by 15.53 %.

IV. Conclusion

Generally, this study revealed that Leek varieties total yield increased in individual basis due to the favor of spacing did not compensate the increase in total pseudo stem yield due to the favor of population per unit area basis at Farawoch site of Boloso Bombe Woreda, in Wolaita Zone, Southern Ethiopia. The analyzed data indicated that days to 90% physiological maturity, leaf length, leaf width, leave number per plant, plant height, dry matter weight, biological yield and total pseudo stem yield were significantly affected by the main effect of variety, inter- and intra-row spacing. As the inter and intra row spacing increases the days to 90% physiological maturity and leaf number per plant increases whereas biological and pseudo stem yield decreases. Likewise, variety 'Dawn Giant' at 15 cm intra row spacing gave the highest number of leaf width while variety Carentan Giant at 10 cm intra row spacing gave the lowest. Variety 'Dawn (454.82 kg ha^{-1}) and 'Lancelot' (427.93 kg ha^{-1}) had the highest biological yield whereas variety Carentan Giant had the lowest biological yield (147.90 kg ha^{-1}). From this finding, it could be concluded that Leek varieties (Carentan Giant, Lancelot' and 'Dawn Giant') could be planted at optimum spacing of 20 cm x 10 cm at Boloso Bombe area to attain maximum yield. However, this study conducted in one season and one location, further study across location and season is suggestible for remarkable recommendation.

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