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Research Article

Determination of Optimum Plant Density on Yield and Yield Components of Onion (*Allium Cepa* L.) in Bena – Tsemay Woreda, Southern Ethiopia

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Abstract
A field experiment was carried out for two successive cropping seasons from 2021 to 2022 cropping season at Enchete, Benatsemay woreda, South Omo zone, Southern Ethiopia, to determine optimum plant population on yield and yield components of onion. The experiment involved a factorial combination of three inter-rows spacing (30, 40 and 50 cm) and three intra-rows spacing (5, 10 and 15 cm). The experiment was conducted using a randomized complete block design with three replications. The analysis of data of revealed a non-significant difference due to main and interaction effects on plant height, leaf number per plant and bulb diameter. On the other hand, the significant two-way interaction effects were observed on unmarketable bulb yield, marketable bulb yield and total bulb yield. Based on the result of this study, among nine treatments use of 5 cm intra- row spacing and 30 cm inter-row spacing is superior in onion bulb yield (27.63 t ha^{-1}). Therefore, use of 5 cm intra- row spacing and 30 cm inter-row spacing can be recommended for onion producing farmers at Bena-Tsemay Woreda.

Keywords: *Optimum plant density, inter and intra-row spacing, onion bulb yield*.

1. Introduction

Onion is one of the important vegetable crops in Ethiopia for home consumption, income source of farmers, and contributes to the national economy as export products (Getachew and Asfaw, 2000). As a result, onion is produced throughout the country both under irrigation and rain fed condition in different agro-ecologies. During the main rainy season of 2014/2015, the total production of onion in the country was about 230,745.2 t of bulbs produced on 22,771.88 ha of land.

The onion bulb demand is increasing time to time both for local consumption and for export that leads to the expansion of small and commercial producers (Lemma and Shimelis, 2003). Due to the increase in irrigable land with suitable agro-ecology for the crop, the country is expected to benefit from bulb production. However, the average productivity of onion in Ethiopia is 10.1 t ha^{-1} (CSA, 2015). This is very low yield compared to the world average of 19.3 t ha^{-1} (FAOSTAT, 2013). The low yield level could be due to low soil fertility, salinity effect and inappropriate cultural practice (MARC, 2004). Geremew *et al*. (2010) suggested the control of plant spacing is one of the cultural practices to control bulb size, shape and yield. Total bulb yield can be increased as population density increases (Kantona *et al*., 2003).

The largest production of onion is not supported with improved production practices like spacing to improve its productivity and bulb quality. To avoid nutrient competition sufficient spacing between plants and rows is vital to get maximum yield in given land. Appropriate spacing enables the farmer to keep appropriate plant population avoid over and less population in a given plot of land which has negative effect on yield and quality (EARO, 2004). Seedlings are widely transplanted with the spacing of 40 × 20 × 10 cm between furrow, row and plants, respectively in Ethiopia. Recently research results confirmed that spacing of 10 cm between plants produced large bulb size. On the other hand, individual consumers do not prefer these large sized bulbs for home consumption (EHDA, 2011). For example, Geremew et al. (2010) recommended intra row spacing of 4 cm for ‘Nasik’ Red and ‘Adama’ Red varieties, and 6 cm for ‘Bombay’ Red variety, in central rift valley areas of Ethiopia.

The use of appropriate agronomic management practices is important to increase the productivity and production of the crop. However, in the country, intra-row spacing of 10 cm and inter-row spacing of 20 cm during transplanting to permanent field is used which was recommended before 20 years (FAO, 1995). But plant spacing as an important economic consideration in the production of onion should have to depend on type of variety (plant architecture, growth habit etc.), agro-ecology, production system etc. Lemma and Shimeles (2003) suggested that to optimize onion productivity, full package of information is required for each growing region of the country.

In South Omo Zone, onion is one of the most important and farmers produced in small scale Most of the demand for onion is met through imports from Zuway and Metehara area which is far to 700 up to 900 km. Farmers are planting differently from the recommended intra and inter row spacing assuming that they could not attain the optimum plant population and optimize yields of onion. Thus, there is need to establish standard intra and inter row spacing to ensure optimum yield performance. Therefore, the objective of this study was to identify the optimum plant population (Inter and Intra-row planting methods) for onion that would enhance growth and productivity.

2. Materials and Methods

2.1 Description of the Study Area

On farm experiment conducted at Enchete kebele, Bena-Tsemay woreda South Omo Zone in 2021/2022 cropping season. The sites are situated 036^{O} 40.259' E longitude and 05^{O} 38.332' N latitude at an altitude of 560 masl. The study area has a mean annual rainfall and temperature ranging from 200-500 mm and 26-32.1°C, respectively.

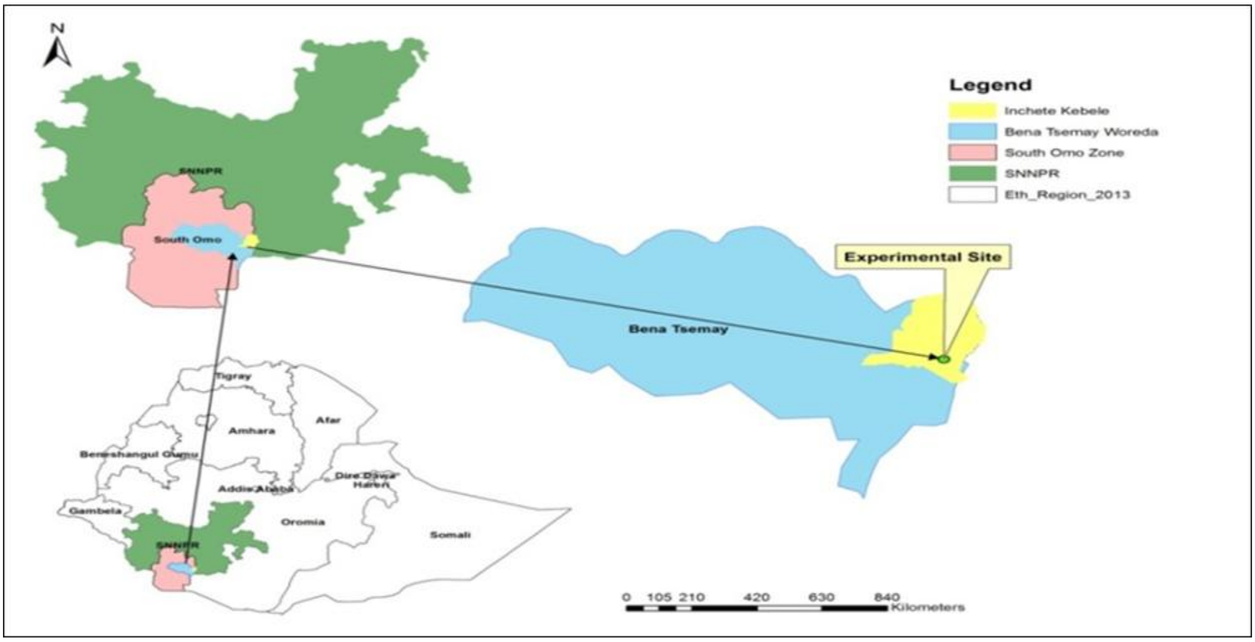

Figure 1: Map of study area

2.2 Experimental Treatments and Procedures

Field experiment conducted using 9 treatments and laid in randomized complete block design in 3 replications. The treatments included three intra row spacing (5, 10 and 15 cm) and three inter row spacing (30, 40, 50 cm) with factorial combination. The experiment design was Randomized Complete Block Design (RCBD) with three replications.

2.3 Observation and measurement

Plant height (cm): was measured using a scale ruler from the ground level to the tip of the terminal leaves of ten randomly selected plants at the time maturity. The average of ten plants was used for statistical analysis.

Leaf number per plant: The total number of leaves per plant was counted from ten randomly selected plants at maturity. The average of ten plants was used for statistical analysis.

Bulb diameter (cm): The mean bulb diameter of ten sample bulbs was measured at the wider portion of matured bulbs at harvest using digital caliper. The average of ten plants was used for statistical analysis.

Marketable bulb yield (t ha^{-1}): This referred to as the weight of healthy and marketable bulbs that range from 20 to 160 g in weight of bulbs from the net plot area at the time of harvesting.

Unmarketable bulb yield (t ha^{-1}): The total weight of unmarketable bulbs that are under sized (< 20 g), diseased, decayed and bulbs from plants with physiological disorder such as thick neck and split were measured from a net plot at final harvest and expressed in t ha^{-1}.

Total bulb yield (t ha^{-1}): The total bulb yield was measured from the total harvest of the net plot as a sum weight of marketable and unmarketable bulb yields that were measured in kg per plot and finally converted into t ha^{-1}

2.4. Statistical Analysis

The collected data were subjected to ANOVA using SAS computer software (SAS Institute, 2000). Significance differences between and among treatments were delineated by LSD (least significance difference).

3. Result and Discussion

3.1 Plant height

The analysis of data of revealed a non-significant difference due to main and interaction effects on plant height (Table 5). The highest plant height (49.16 cm) was recorded in the treatment combination of 40 cm inter-row and 10 cm intra-row spacing (Table 5). On the contrary, the lowest plant height (45.49 cm) was recorded in the treatment combination of 30 cm between row and 15 cm between plant spacing (Table 5).

Table 1: Effects of inter and intra row spacing on plant height and leaf number per plant in 2021 cropping season

Treatments		Plant height	Leaf number per plant
Intra row spacing (cm)	30	34.11	11.23
	40	33.69	10.60
	50	34.44	10.30
	LCD (5%)	**NS**	**NS**
Inter row spacing (cm)	5	33.98	10.80
	10	35.11	10.57
	15	33.16	10.30
	LCD (5%)	**NS**	**NS**
	CV (%)	11.85	12.90

Table 2: Interaction effect of inter and intra row spacing on Bulb diameter, unmarketable bulb yield, marketable bulb yield and total bulb yield in 2021 cropping season

Treatments	BD (cm)	UMBY (t ha^{-1})	MBY (t ha^{-1})	TBY (t ha^{-1})
30*5	4.10^{ab}	4.90^{a}	16.70^{a}	21.70^{a}
30*10	4.47^{a}	3.63^{abcd}	8.86^{bc}	13.86^{bc}
30*15	4.13^{ab}	2.10^{cde}	6.26^{bcd}	11.27^{bcd}
40*5	3.90^{ab}	4.40^{abc}	9.76^{b}	14.76^{b}
40*10	4.03^{ab}	1.76^{de}	4.97^{cd}	9.97^{cd}
40*15	4.13^{ab}	4.60^{ab}	5.30^{cd}	1030^{cd}
50*5	3.23^{b}	2.43^{bcde}	5.63^{cd}	1063^{cd}
50*10	3.37^{b}	1.13^{e}	3.83^{d}	8.83^{d}
50*15	3.63^{ab}	1.20^{de}	2.76^{d}	7.83^{d}
LSD 5%	1.06	2.46	4.912	3.91
CV (%)	4.40	28.84	31.85	18.62

The result of this investigation oppose with the finding of Aliyu et al. (2008), who reported that wider rather than narrower spacing produced taller onion plants, showing that narrower spacing leads to stiffer competition among plants for growth factors, causing reduced growth. In contrary Hamma et al. (2013) also showed that plant heights of garlic plants increased in response to increasing intra-row spacing.

Table 3: Effects of inter and intra row spacing on plant height, leaf number per plant and bulb diameter in 2022 cropping season

Treatments		Plant height	Leaf number per plant	Bulb diameter cm
Intra row spacing (cm)	30	56.87	12.13	4.91
	40	64.62	12.60	4.78
	50	58.16	12.09	6.35
	LCD (5%)	NS	NS	NS
Inter row spacing (cm)	5	60.13	13.06	5.25
	10	61.18	12.57	5.40
	15	58.30	12.30	5.35
	LCD (5%)	NS	NS	NS
	CV (%)	15.56	12.16	9.83

Table 4: Interaction effect of inter and intra row spacing on unmarketable bulb yield, marketable bulb yield and total bulb yield in 2022 cropping season

Treatments	UMBY (t ha^{-1})	MBY (t ha^{-1})	TBY (t ha^{-1})
30*5	4.90^{a}	28.67^{a}	33.57^{a}
30*10	4.30^{ab}	26.12^{ab}	30.50^{b}
30*15	2.10^{cde}	24.10^{b}	26.2^{c}
40*5	3.40^{abc}	27.63^{a}	31.03^{b}
40*10	1.76^{de}	18.30^{cd}	20.07^{d}
40*15	2.93^{bcd}	17.40^{cd}	20.33^{d}
50*5	2.43^{cde}	19.30^{c}	21.73^{d}
50*10	1.13^{e}	12.13^{e}	13.27^{f}
50*15	1.20^{e}	16.63^{d}	17.83^{e}
LSD 5%	1.51	2.59	2.14
CV (%)	32.57	17.07	15.19

Mean values within column followed the same letters are not significantly different ($P < 0.05$), UMBY=Unmarketable bulb yield, MBY=Marketable bulb yield and TBY=Total bulb yield.

3.2 Leaf Number Per Plant

The analysis of data of revealed a non-significant difference due to main and interaction effects on leaf number per plant (Table 5). The highest mean leaf number per plant (12.3) was obtained from 30*5 cm inter and intra row spacing, while the lowest mean unmarketable bulb yield (11.09) was obtained from the wider inter and intra row spacing 50*15 cm. The result of this investigation oppose with the finding of Sikder *et al.* (2010), who reported that higher leaf numbers per plant of onion were recorded in response to wider plant spacing.

3.3 Bulb Diameter

The analysis of data of revealed a non-significant difference due to main and interaction effects on bulb diameter (Table 5). The highest mean bulb diameter (4.90 cm) was obtained from 50*15 cm inter and intra row spacing, while the lowest mean bulb diameter (4.40 cm) was obtained from 40*5 cm inter and intra row spacing.

Table 5: Effects of inter and intra row spacing on plant height, leaf number per plant and bulb diameter of combined mean results

Treatments		Plant height	Leaf number per plant	Bulb diameter cm
Inter row spacing (cm)	30	45.49	12.3	4.59
	40	49.16	11.60	4.4
	50	46.3	11.09	4.9
	LCD (5%)	NS	NS	NS
Intra row spacing (cm)	5	47.06	12.06	4.5
	10	48.14	11.57	4.7
	15	45.74	11.30	4.7
	LCD (5%)	NS	NS	NS
	CV (%)	17.6	12.35	10.29

3.4 Unmarketable Bulb Yield

The analysis of data revealed significant difference due to interaction effects on unmarketable bulb yield (Table 6). The highest mean unmarketable bulb yield (4.90 t ha^{-1}) was obtained from 30*5 cm inter and intra row spacing, while the lowest mean unmarketable bulb yield (1.20 t ha^{-1}) was obtained from the wider inter and intra row spacing 50*15 cm. The present result is in agreement with the finding of Yemane *et al*. (2013) who mentioned that narrow intra-row spacing increased unmarketable bulb yield of onion.

Table 6: Interaction effect of inter and intra row spacing on unmarketable bulb yield, marketable bulb yield and total bulb yield of combined mean results

Treatments	UMBY (t ha^{-1})	MBY (t ha^{-1})	TBY (t ha^{-1})
30*5	4.90^{a}	22.70^{a}	27.63^{a}
30*10	4.30^{a}	17.50^{bc}	22.20^{b}
30*15	2.10^{bc}	15.15^{c}	18.73^{c}
40*5	3.90^{ab}	18.70^{b}	22.90^{b}
40*10	1.76^{c}	11.63^{de}	15.03^{de}
40*15	3.77^{ab}	11.35^{de}	15.33^{d}
50*5	2.43^{bc}	12.47^{d}	16.20^{d}
50*10	1.13^{c}	7.98^{f}	11.07^{f}
50*15	1.20^{c}	9.70^{ef}	12.83^{ef}
LSD 5%	1.82	2.47	2.25
CV (%)	27.20	10.10	17.24

3.5 Marketable Bulb Yield

The analysis of data revealed significant difference due to interaction effects on marketable bulb yield (Table 6). The highest mean marketable bulb yield (22.70 t ha^{-1}) was obtained from 30*5 cm inter and intra row spacing, while the lowest mean marketable bulb yield (7.98 t ha^{-1}) was obtained from the wider inter and intra row spacing 50*10 cm. Similar observations were reported by Latif *et al*. (2010), Sikder *et al.* (2010) and Dorcas *et al*. (2012) who reported that maximum marketable bulb yields of onion were obtained at lower intra-row spacing.

Thus, the marketable bulb yield of onion per unit area does not completely depend up on the performance of individual plants but also related with the total number of plants per unit area and yield contributing parameters (Latif *et al*., 2010 and Aliyu *et al*., 2008).

3.6 Total Bulb Yield

The analysis of data revealed significant difference due to interaction effects on marketable bulb yield (Table 6). The highest mean marketable bulb yield (27.63 t ha^{-1}) was obtained from 30*5 cm inter and intra row spacing, while the lowest mean marketable bulb yield 11.07 t ha^{-1}) was obtained from the wider inter and intra row spacing 50*10 cm.

4. Conclusion and recommendation

From the interaction effects of inter row by intra row spacing, it was apparent that inter row spacing of 30 cm and 5 cm intra row spacing produced the highest mean values of unmarketable bulb yield, marketable bulb yield and total bulb yield. Application of 30 cm and 5 cm inter and intra row spacing gave the highest unmarketable bulb yield, marketable bulb yield and total bulb yield 4.90, 22.70 and 27.63 t ha^{-1}, respectively. On the other hand, the analysis of data revealed a non-significant difference due to main and interaction effects on plant height, leaf number per plant and bulb diameter.

Based on the present finding, the maximum onion bulb yield (27.63 t ha^{-1}) was obtained from 30 cm and 5 cm inter and intra row spacing. Therefore, use of 30 cm inter row spacing with 5 cm intra row spacing can be recommended for potato producing farmers at Bena-Tsemay woreda. However, it would be too early to reach at a conclusive recommendation since the current study was carried out only in one location. Hence, further studies replicated across locations are needed to recommend agronomical optimum onion bulb yield.

Field Photos

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