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(RESEARCH ARTICLE)

The effect of types of bed and inter-row spacing on yield and quality of onion at Fogera district of South Gondar zone, Ethiopia

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Abstract

Farmers in South Gondar zone were using broadcast transplanting in flatbeds with border ridges to produce onion in the dry season. On the other hand, the research recommendation is to transplant onion seedling in furrow and ridge with double row plantings of 40 cm x 20 cm inter row spacing. This study was therefore initiated to demonstrate to farmers different planting techniques and eventually to observe yield and quality advantages of onion production using furrow and ridge in double rows and flatbed planting methods with various inter row spacing. Thirteen treatments including furrow and ridge planting techniques in double rows (standard check) and flatbeds planting with broadcasting (farmers' traditional practice) were compared in RCBD with three replications. The result revealed that number of leaves, plant neck diameter, bulb length, bulb diameter; marketable bulb yield, unmarketable bulb yield and total bulb yield were significantly affected by planting techniques. Furrow and ridge planting technique in double rows (standard check) with inter row spacing of 40 cm x 20 cm gave the highest bulb yield (25.88 t/ha), followed by 30 cm x 20 cm (24.32 t/ha) as compared to broadcast transplanting in flatbeds with boarder ridges (farmers' traditional practice) (18.42 t/ha). It is therefore confirmed that high bulb yield and superior quality was produced from furrow and ridge method in double rows with inter row spacing of 40 cm x 20 cm. Further advice to farmers and large scale demonstration of this practice is thus essential to persuade farmers to enhance shifting from traditional to research recommended planting practice.

Keywords: Bulb yield; Border ridge; Flood; furrow; Flatbed; Inter row; Ridge spacing

1 Introduction

Onion (Allium cepa L.) is a high value vegetable crop whose scale is used in various industries around the world, including Ethiopia (Getu and Ibrahim, 2018). It is mainly grown in the dry season using irrigation and ranks first in terms of production and productivity of vegetable crops in Ethiopia (Etana et al., 2019). In Ethiopia, total production and yield of onion in 2022 was approximately 3,377,425.30 quintal and 89.71 quintal per hectare (CSA, 2022). South Gondar zone of Amhara region especially Fogera, Libokemkem and Dera districts are renowned by onion production during the irrigation (dry) season. Source of irrigation water in South Gondar zone include major rivers namely Gumara and Rib groundwater; and irrigation canal (Melese et al., 2018). Especially in the Fogera region, onion is an important vegetable crop that uses groundwater, rivers and streams (Yihunie, 2022).

The use of poor agronomic practice is an important factor affecting crop yield and quality through competition for nutrients, light, and moisture with adjacent spaces (Alemu et al., 2022).

Production and productivity has still been challenged by limited access to improved technologies. Furthermore, contradictory to research recommendation of onion planting in ridge and furrow techniques with specified inter and

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intra-row spacing, many farmers in Fogera, Dera and Libokmkem districts are using flatbed with broadcast planting method. Farmers guess that planting in a flatbed gives high yield, harbors less insect and requires less frequency of water application. This experiment was initiated to work with active participation of the farmers aiming to identify which planting technique is best for onion growth performance with ultimate high yield, superior quality and profitability.

2 Material and methods

2.1 Description of the study area

The study was conducted at Fogera National Rice Research and Training Center main research station and at farmers' fields in Fogera district during the 2023 irrigation season. Ground water from all sites was used for irrigation, using engine water pump to push out from Borehole (deep well). Based on the treatment objective, furrow and flood irrigation methods were used in all fields. The soil type in all areas is sandy loamy with a pH of almost 5.48. Average temperature in the site is between 12°C and 28°C. The sites are located in Fogera District, South Gondar, and Amara Region, Ethiopia.

2.2 Research Materials and Designs

A total of thirteen treatments with different planting bed and spacing were considered in this study. Nine treatments are combinations of planting on both sides of a ridge (double row) in a ridge and furrow planting technique with furrow width of 40, 35 and 30 cm and inter- row spacing (spacing between two rows in a ridge) of 15, 20 and 25 cm (40 cm x 15 cm, 40 x 20, 40 x 25, 35 x 15, 35 x 20, 35 x 25, 30 x15, 30 x 20 and 30 x 25). Four treatments include flatbed planting with border ridges with inter-row spacing of 20, 25, 30 cm and broadcast transplanting techniques. Except for the broadcast transplanting of traditional (farmers') transplanting technique where the spacing used was approximately 4 -7 cm between plants, 7 cm was used for intra - row spacing of the rest treatments. A simple complete block design (RCBD) with three replications was used. The size of the plot was 3.9 m x 2 m and Bombay Red variety was used as the testing material as shown in Table 1.

Table 1 Treatment arrangements of transplanting in double rows in a ridge and furrow method and a single inter row and broadcasting in a flatbed with border ridge techniques

Different transplanting techniques	
Furrow width (double rows) by inter row spacing in a ridge pattern	**Inter row spacing in a flatbed with border ridge and broadcast transplanting pattern**
T1. 40 X 20 cm	T10. 20 cm
T2. 30 X 20 cm	T11. 25 cm
T3. 35 X 25 cm	T12. 30 cm
T4. 35 X 20 cm	T13. Broadcast
T5. 30 X 25 cm	
T6. 40 X 25 cm	
T7. 40 X 15 cm	
T8. 30 X 15 cm	
T9. 35 X 15 cm	

Note: double row plant spacing in a ridge (15, 20 and 25 cm), furrow width between ridges (30, 35 and 40 cm) and row to row spacing in a bed (20, 25 and 30 cm), T = treatments and cm = centimeter

2.3 Experimental procedures

Seedlings were raised at horticulture research nursery site of Fogera National Rice Research and Training Center. Seed beds of 1 m width with 5 m length were thoroughly prepared, and the seed was sown at a 15 cm inter row spacing using hand drilling. Onion seed used for a 1 m x 5 m bed was 60 gram and 121 kilogram NPS was also applied. Beds were immediately mulched with eucalyptus leaves and water was applied every afternoon up to seedlings fully germinated with in eight days. Mulches were then removed from the bed and applied as roofs by constructing a frame 1 m height roof over the bed. This mulch as a roof was further completely removed after seven days when seedlings attained good

vigor to withstand exposure to full sunlight. After removal of the roof, water was applied every morning until hardening off begun after 55 days from sowing.

50 gram of urea for a 1 x 5 m bed was applied during hoeing after 15 days from sowing. At 60 days from sowing, the seedlings were ready and transplanted into the main field. The experimental area was well prepared and ploughed three times. NPS (nitrogen = 19 %, phosphorous = 38 %, and sulphur = 7 %) at the rate of 242 kilogram per hectare was applied at transplanting time, whereas Urea (46 % N at the rate of 100 kilogram per hectare was applied twice. The first half of urea was applied 15-20 days after transplanting, and the rest was applied 40 days after transplanting. The experimental field was well managed before and immediately after transplanting and irrigated weekly up to the period of physiological maturity where plants attain full growth and leaves start changing color from green to yellow period of the onion. All other agronomic practices except treatment differences were managed uniformly and timely for all experimental units based on the national recommendation.

2.4 Data collection and analysis

2.4.1 Morphological traits

- Plant height (cm): ten randomly selected plants were pre-tagged and their height measured using a measuring tape starting from the soil surface to the tips of its leaves during the bulb development stage.
- Leaf number (count): ten randomly selected plants were pre-tagged and counted for their total number of leaves during bulb development stage.
- Plant neck diameter (mm): Ten plants were pre-tagged and measured for their plant neck diameter from the bottom part of pseudo stem using a caliper.

2.4.2 Bulb yield and yield components

- Bulb diameter (mm): ten randomly selected bulbs measured for the diameters from the middle part of the bulb using a caliper.
- Bulb length (mm): ten randomly selected bulbs measured for its bulb length from the base of the bulb to its tips using a caliper.
- Marketable bulb yield (t/ha): Weight recorded for disease-free, healthy bulbs of marketable size from the total net plot areas using a sensitive balance and converted to tons per hectare.
- Unmarketable bulb yield (t/ha): undersized and rotten bulbs, and bulbs with physiological disorders like thick-necked, split, and bolters from the total net plot areas were measured using a sensitive balance and converted to tons per hectare.
- Total bulb yield (t/ha): The sum of marketable and unmarketable bulbs from the total net plot areas measured using sensitive balance and converted to tons per hectare.

2.5 Statistical analysis

An analysis of variances (ANOVA) was performed on all recorded data using SAS 9.4 software. The mean separation was computed by LSD at a 5% probability level.

3 Results and discussion

The result of analysis of variance revealed significant variations among treatments in yield and yield related attributes. Presumably due to differences in local weather patterns and edaphic factors, highly significant difference was also observed among locations and this had an impact on each parameter's performance. All locations showed similar trends in the overall treatment effects. There was no visible change in the treatment performances by location (Table 2).

Table 2 Analysis of variance for eight quantitative yield and yield related traits of onion

Source of variations	Mean squares								
	DF	PH	LN	PND	BL	BD	MBY	UMBY	TBY
TRT	12	8.63*	2.33***	3.17**	13.40*	18.33**	87.11***	0.5***	84.22***
REP	2	23.32*	0.66ns	1.25ns	48.57**	16.10ns	46.39**	0.25ns	41.30**
LOC	2	229.5***	54.27***	7.46**	252.3***	694.2***	145.3***	0.88**	147.44***
TRTXLOC	24	9.80ns	0.82ns	0.98ns	4.46ns	5.54ns	9.70ns	0.08ns	10.17ns
Error	76	5.43	0.73	1.01	7.28	7.12	8.79	0.15	8.37

Note: TRT = treatments; PH = plant height; LN = leaf number; ND = plant neck diameter; BL = bulb length; BD = bulb diameter; MBY = marketable bulb yield; UMBY = UN marketable bulb yield; TBY = total bulb yield; REP = replication; LOC = locations; ns = non significance; * = significance at ($p \leq 0.05$); ** = highly significance at ($p \leq 0.01$) and *** = very high significance at ($p \leq 0.001$).

The results of the present study and related discussion were summarized under the following key parameters:

3.1 Plant height (cm)

Ridge a furrow planting in double row spacing of 40 cm x 25 cm with furrow irrigation techniques were found to have the highest plant heights (46.39 cm), whereas those with broad cast transplanting pattern in flatbeds with border ridges receiving flood irrigation were found to have the shortest plant heights (43.3 cm). It's possible that the largest plant height results from the plants in the wider plant row spacing having more access to surrounding micro-climatic and edaphic resources like light, nutrients, and water. This is in consistent with Tesfalegn's (2015) finding that intra-row spacing has a major impact on onion plant height.

3.2 Leaf number (count)

leaf number varied significantly between treatments in ridge and furrow planting in double row spacing. High numbers of leaves (10.18) were counted from ridge and furrow planting in double row spacing of 35 cm x 25 cm receiving furrow irrigation, while less number of leaves (9.18) was observed from broadcast transplanting method in flatbeds with border ridges using flood irrigation techniques.

3.3 Plant neck diameter (mm)

The diameter of the plant neck varied considerably between treatments. Ridge and furrow planting in double rows with spacing of 40 cm x 20 cm with furrow irrigation produced a thicker plant neck diameter (10.73 mm), while the thinner plant neck diameter (8.40 mm) were observed from broadcast transplanting in flatbeds with border ridges using flood irrigation system.

3.4 Bulb Length (mm)

Bulb length differed substantially between treatments. The largest bulb lengths (47.7 mm and 47.33 mm) were measured at 25 cm and 30 cm row spacing in flatbed plantings with border ridges, respectively, using flood irrigation system. While the shortest bulb lengths (43.79 and 43.81 mm) were measured in ridge and furrow planting in double rows spacing of 30 cm x 25 cm and 30 cm x 20 cm, respectively, using furrow irrigation techniques.

3.5 Equatorial bulb diameter (mm)

bulb diameter varied considerably between treatments. Ridge and furrow planting in double rows with spacing of 40 cm x 20 cm using furrow irrigation system produced a thicker bulb diameter (57.74 mm), while the thinner bulb diameter (47.15 mm) were observed from broadcast transplanting in flatbeds with border ridges using flood irrigation system. Wider row spacing leading to increased bulb diameter due to increased nutrients and moisture availability and the reduction in bulb diameter may be due to competition in physiological and metabolic processes (Khan et al., 2003).

3.6 Marketable bulb yield (t/ha)

Analysis of variance showed that there was a significant difference in yield between flatbed planting with broad cast method and ridge and furrow planting in double rows transplanting, having the highest yield of 25.88 ton/ha^{-1} from the spacing of 40 cm x 20 cm, followed by 24.32 ton/ha^{-1} from 30 cm x 20 cm, while the lowest yield was recorded from flatbed row transplanting with 30 cm spacing (15.29 tons/ha^{-1}), followed by ridge and furrow planting in double rows with spacing of 35 cm x15 cm (15.97 tons/ha^{-1}). Therefore, the previous research recommendation in the country

considered for validation in this study gave the highest marketable bulb yield advantage as compared to the farmer's broadcast transplanting method in flat beds with border ridges. Ridge and furrow planting in double rows with spacing of 35 cm x 15 cm and flatbed with broadcast transplanting gave the lowest yield as compared to the standard research recommendation planting method in ridge and furrow with spacing of 40 cm x 20 cm. Similarly, Kantona et al. (2003) concluded that, planting densities significantly affected the onion bulb yield which achieved the optimum plant spacing.

3.7 Non-market bulb yield (t/ha)

Analysis of variance showed that there was a significant difference in non-market bulb yield between furrow and ridge planting in double rows and flatbed row transplanting, which had a significant impact on farmers' bed planting practices. It is observed that onion bulb yield was highly affected by row spacing with irrigation techniques. The highest non marketable yield was obtained from broadcast transplanting in flatbeds as compared to the standard check (double rows planting in furrow and ridge with spacing of 40 cm x 20 cm). This is for the reason that broadcast transplanting in flatbeds and ridge and furrow in double row (15 cm x 35 cm) transplanting produced high rotten and small sized bulbs which was unwanted (unmarketable) in the local market. This finding was in line with the result of other researchers (Yemane et al., 2013; Habtamu et al., 2016) who concluded that plant density has an impact on unmarketable bulb size as consequences of high plant nutrient and light competition between plants.

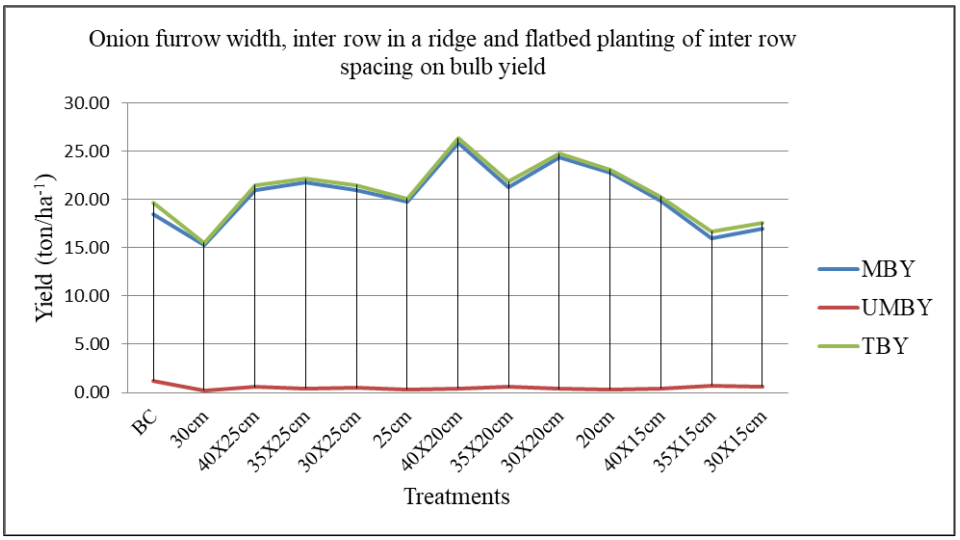
3.8 Total bulb yield (t/ha)

Analysis of variance showed that there were significant difference between farmers' planting methods and the research recommended transplanting method of 20 cm x 40 cm gave the highest bulb yield per hectare (26.32) as compared to flatbed broadcast transplanting method (19.63 t/ha).

Table 3 Mean performance of eight quantitative yield and yield related traits of onion

Treatments	PH (cm)	LN (count)	PND (mm)	BL (mm)	BD (mm)	MBY (t/ha)	UMBY (t/ha)	TBY (t/ha)
DRTP								
20X40 cm	45.97ab	10.42abc	10.30ab	45.73abc	52.74a	25.879a	0.47bc	26.322a
20X30 cm	44.23abc	10.64ab	9.88abc	43.81c	49.38bcd	24.319ab	0.39bc	24.711ab
25X35 cm	45.22abc	10.87a	10.14abc	44.87bc	50.92abc	21.732bcd	0.41bc	22.144bcd
20X35 cm	44.53abc	10.61ab	10.06abc	44.02c	49.87bc	21.245cd	0.59bc	21.839cd
25X30 cm	43.62c	9.78cd	9.42bc	43.79c	49.72bc	20.999cde	0.46bc	21.458cd
25X40 cm	46.39a	10.92a	10.73a	44.76c	50.44abc	20.929cde	0.56bc	21.485cd
15X40 cm	45.21abc	10.84ab	10.24ab	45.48abc	51.49ab	19.865de	0.44bc	20.303de
15X30 cm	44.38abc	10.04bc	10.04abc	44.63c	49.65bcd	16.967fgh	0.63bc	17.596ef
15X35 cm	43.89bc	10.33abc	10.12abc	45.03bc	50.6abc	15.966gh	0.76b	16.679f
BRFBIRBTP								
20 cm	43.46c	10.3abc	9.24cd	45.87abc	48.79cd	22.744bc	0.42bc	23.083bc
BC	43.30c	9.18d	8.40d	44.70c	47.15d	18.424efg	1.20a	19.627de
25 cm	43.57c	9.78cd	9.55bc	47.70a	51.74ab	19.743def	0.36c	20.085de
30 cm	44.87abc	10.22abc	10.20ab	47.33ab	51.03abc	15.285h	0.25c	15.497f
CV	5.24	8.30	10.18	5.97	5.31	14.60	70.49	13.89
LSD (5%)	2.60	0.80	0.94	2.53	2.50	2.78	0.50	2.72
SGN.	*	***	**	*	**	***	**	***

Means with the same letter(s) in the same column are not significant difference; * = significance at 5% probability level; ** = highly significant at 1% probability level; *** = very high at 0.1% probability level; ns = non-significant; DRTP = double row transplanting pattern; BRFBIRBTP = border ridge flatbed inter row and broad cast transplanting pattern; PH = plant height; LN = leaf number; ND = plant neck diameter; BL = bulb diameter; MBY = marketable bulb yield; UMBY = unmarketable bulb yield; TBY = total bulb yield; CV = coefficient of variation; LSD = least significance difference; SGN = significance; BC = broadcast; mm = millimeter; t/ha = ton per hectare and cm = centimeter



Keys: MBY = marketable bulb yield; UMBY = unmarketable bulb yield and TBY = total bulb yield.

Figure 1 Bulb yield trends affected by types of bed and inter-row spacing with ridge furrow and flood bed irrigation techniques

Plant population density significantly influenced for total bulb production and marketable bulb yield. This result indicating that a positive correlation between optimum plant density and marketable bulb yield. The quality and yield of onion plants were also significantly influenced by the irrigation systems of flat beds with border ridges and furrows (figure 1).

Abbreviations

ANOVA: analysis of variance
CSA: central statistical agency
LSD: least significance difference
RCBD: randomized complete block design
SAS: statistical analysis software

4 Conclusion

Furrow and ridge method in double rows transplanting with spacing of 40 cm x 20 cm and 30 cm x 20 cm using furrow irrigation techniques resulted in the highest marketable bulb yield as compared to broadcast transplanting in flat beds with border ridges using flood irrigation systems. Farmers are therefore once again advised to use furrow and ridge techniques in double rows transplanting using furrow irrigation systems, since it is confirmed in this study that high yield and superior quality of onion bulbs is obtained from this practice. Further research may also be required on onion varieties and agronomic management techniques at various soil types and agro-ecologies.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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