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Influence of plant spacing on yield and yield components of improved onion varieties in Mersa District, North Wollo, Ethiopia

Alefe Tesfahun^{1*}, Sultan Mohammed² and Yohannes Gedamu³

¹Department of Horticulture, College of Agriculture, Injibara University, P.O. Box 40, Injibara, Ethiopia

²Department of Biology, College of Natural Science, Woldia University, P.O. Box 400, Woldia, Ethiopia

³Bio and Emerging Technology Institute - BETin, Addis Ababa Ethiopia

*Corresponding author: alefetesfahun@gmail.com (A. Tesfahun)

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ABSTRACT

This study evaluated the effects of plant spacing and variety on growth and yield of onion in Mersa District, North Wollo, Ethiopia. Treatments consisted of a factorial combination of three improved varieties and six planting spacing arranged in a randomized complete block design with three replications. Analysis of variance revealed that the interaction of spacing and variety significantly affected most growth and yield parameters. The highest marketable bulb yield (44.57 t/ha) was obtained from the Nafis variety at 10 cm × 5 cm spacing. Maximum yields of Adama and Bombay Red were recorded at 20 cm × 3 cm spacing. The widest spacing produced the lowest yields across all varieties. Results indicate that optimal spacing is variety-specific; closer spacing favored higher productivity, particularly for Bombay Red and Adama, while Nafis performed well across moderate to close spacings. These findings provide practical recommendations to improve onion productivity under similar agro-ecological conditions.

Introduction

Onion (*Allium cepa* L.) is one of the most important vegetable and spice crops, belonging to the family Alliaceae (Gupta *et al.*, 2025). It is a widely cultivated herbaceous biennial crop believed to have originated in Central Asia, particularly in regions between Turkmenistan and Afghanistan, where its wild relatives still occur. Recent genomic evidence further supports its domestication in the mountainous regions of Iran and surrounding areas, where early selection focused on bulb size and storage quality (Han *et al.*, 2024). Onion was introduced into Ethiopia via Sudan and has since been widely distributed across different

parts of the country. It is an indispensable component of Ethiopian cuisine, resulting in consistently high demand throughout the year.

Despite its importance, onion productivity in Ethiopia remains lower than the African and global averages (FAOSTAT, 2024). This low productivity is partly attributed to suboptimal agronomic practices, particularly the use of inappropriate plant spacing and poorly adapted varieties for specific agro-ecological conditions. Plant density is a critical factor influencing onion yield and bulb characteristics. For instance, Negash *et al.* (2022) reported that higher plant density (approximately 100 plants/m²,

equivalent to 5 cm spacing) significantly increased total bulb yield, although it reduced individual bulb size. Similarly, Yemane *et al.* (2021) observed improved growth and yield of Adama Red and Bombay Red varieties at plant densities of 47.6 and 33 plants/ m², respectively, in the Aksum area.

The national recommendation for onion production in Ethiopia suggests a spacing of 40 cm between double rows, 20 cm between rows, and 10 cm between plants within rows (EIAR, 2017). However, such blanket recommendations often fail to consider variations in soil fertility and local growing conditions (Yemane *et al.*, 2021). As a result, farmers frequently adjust plant spacing to optimize yield, as increasing plant population density can enhance total yield per unit area (Assaye *et al.*, 2020). Nonetheless, achieving a balance between bulb size preferred by consumers and efficient land use remains a key challenge (Gebrekorkos *et al.*, 2017).

The use of suitable, well-adapted varieties in combination with appropriate agronomic practices is essential for maximizing onion productivity. In the Mersa district of North Wollo, Ethiopia, farmers employ varying planting spacings, often without clear guidance on optimal configurations for different varieties. The lack of location-specific recommendations contributes to reduced yields and inconsistent bulb quality. Therefore, this study was conducted to determine the optimum plant spacing for maximizing marketable bulb yield of three improved onion varieties under the agro-ecological conditions of Mersa district, North Wollo, Ethiopia.

Material and Methods

The experiment was conducted under irrigated conditions during the 2020–2021 cropping season at Mersa District, North Wollo, Ethiopia, located about 491 km northeast of Addis Ababa and 30 km south of Woldia town (11°39'00"–11°41'00" N, 39°38'30"–39°40'30" E; 1625 m amsl). The area receives an average annual rainfall of 875 mm with a bimodal distribution and a temperature range of 15–28.5°C. The soil is predominantly clay loam, classified as Vertisol, with slightly acidic to slightly alkaline reaction. The treatments comprised a factorial combination of three onion (*Allium cepa* L.) varieties (Adama Red, Bombay Red, and Nafis) and six planting spacings (20 × 7, 10 × 7, 20 × 5, 10 × 5, 20 × 3, and 10 × 3 cm), laid out in a randomized complete block design with three replications. The experiment included 54 plots (1.0 × 1.5 m each) with 1.0 m and 1.5 m spacing between plots and blocks, respectively, covering a total area of 270 m²; furrow spacing was maintained at 40 cm. Seeds were sown on 22

November 2020 on raised nursery beds (1 × 5 m) with 10 cm row spacing, and 45-day-old seedlings (3–4 leaves) were transplanted on 08 January 2021 after proper hardening.

The field was prepared by ploughing and harrowing, and uniform, healthy seedlings were transplanted as per treatment, with gap filling within one week. Fertilizer was applied at 200 kg ha⁻¹ NPSB at transplanting and 100 kg ha⁻¹ urea in two splits (half at transplanting and half six weeks later). The crop was irrigated using furrow irrigation at 4–5 day intervals during establishment and 5–7 day intervals thereafter, and irrigation was stopped 15 days before harvest. Harvesting was done at about 70% neck fall, followed by field curing for four days. Data were recorded on plant and plot bases; five plants per plot were sampled for plant-based parameters, while phenological data were recorded on a whole-plot basis, excluding border rows. Data were tested for normality and subjected to analysis of variance using SAS (version 9.3), and treatment means were compared using LSD at 5% probability level; Pearson's correlation analysis was also performed.

Results and Discussion

The interaction effects of plant spacing and variety on phenological, growth, and yield parameters of onion are presented in Table 1. Bolting percentage was significantly (P<0.01) influenced by both main effects and their interaction (P<0.05). The highest bolting (22.00%) was recorded in Adama Red at the closest spacing (10 × 3 cm), followed by Nafis (20.97%), whereas the lowest value (9.67%) was observed in Nafis at the widest spacing (20 × 7 cm). In general, bolting increased with closer spacing, likely due to increased competition for nutrients and moisture, leading to stress-induced reproductive development (Assaye *et al.*, 2020).

Bulb diameter and bulb length were significantly (P<0.01) affected by spacing, variety, and their interaction. The largest bulb diameter (7.77 cm) and length (6.43 cm) were recorded in Nafis at 20 × 7 cm spacing, while the smallest diameter (3.83 cm) and shorter bulbs were observed in Adama Red under closer spacing (10 × 3 cm). Wider spacing favored bulb enlargement due to reduced competition and better resource availability, whereas closer spacing restricted bulb growth. Similarly, bulb neck thickness, bulb weight, and bulb dry weight showed significant variation among treatments. The highest neck thickness (1.60 cm), bulb weight (152.37 g), and dry weight (30.97 g) were obtained from Nafis at 20 × 7 cm spacing, while the lowest values were recorded under closer spacing, particularly in

Bombay Red and Adama Red. This trend indicates that lower plant density enhances vegetative growth and assimilate accumulation, resulting in larger bulbs (Muhammad *et al.*, 2017; Yemane *et al.*, 2021).

Table 1. The interaction effects of planting space and variety on different parameters of onion

Variety	Spacing	Bolting percentage (%)					
		20 × 7 cm	10 × 7 cm	20 × 5 cm	10 × 5 cm	20 × 3 cm	10 × 3 cm
Adama Red		14.43 ^{fg}	15.30 ^{efgh}	19.50 ^{abc}	19.17 ^{abc}	19.28 ^{abc}	22.00 ^a
Bombay Red		12.27 ^{hijk}	11.77 ^{ijk}	13.13 ^{ghij}	15.42 ^{efg}	16.10 ^{defg}	16.83 ^{cdef}
Nafis		9.67 ^k	11.00 ^{jk}	13.50 ^{ghij}	18.23 ^{bcde}	18.83 ^{abc}	20.97 ^{ab}
LSD (5%) : 3.03; CV (%) : 11.12							
		Bulb diameter (cm)					
Adama Red		7.42 ^{ab}	6.83 ^{bcd}	6.66 ^{bcd}	5.77 ^{ef}	4.87 ^g	3.83 ^h
Bombay Red		7.65 ^a	6.87 ^{bcd}	6.45 ^{de}	6.43 ^{de}	5.87 ^{ef}	5.65 ^f
Nafis		7.77 ^a	7.20 ^{abc}	6.76 ^{bcd}	6.45 ^{de}	6.27 ^{def}	4.69 ^g
LSD (5%) : 0.73; CV (%) : 6.56							
		Bulb length (cm)					
Adama Red		5.72 ^{abc}	5.39 ^{cde}	5.67 ^{bcd}	4.97 ^{def}	5.07 ^{cdef}	4.57 ^f
Bombay Red		6.35 ^{ab}	5.10 ^{cdef}	4.93 ^{def}	5.17 ^{cdef}	4.72 ^{ef}	4.60 ^f
Nafis		6.43 ^a	6.36 ^{ab}	5.61 ^{cd}	5.11 ^{cdef}	5.22 ^{cdef}	4.73 ^{ef}
LSD (5%) : 0.74; CV (%) : 7.19							
		Bulb neck thickness (cm)					
Adama Red		1.21 ^{bc}	1.13 ^c	0.92 ^{de}	0.72 ^{fg}	0.72 ^{fg}	0.65 ^{ghi}
Bombay Red		1.30 ^b	1.10 ^c	0.80 ^{ef}	0.68 ^{gh}	0.55 ^{ij}	0.48 ^j
Nafis		1.60 ^a	1.27 ^b	1.28 ^b	1.20 ^{bc}	0.97 ^d	0.59 ^{hij}
LSD (5%) : 0.12; CV (%) : 7.45							
		Bulb weight (g)					
Adama Red		127.80 ^b	112.00 ^{cde}	111.67 ^{de}	86.13 ^{gh}	77.47 ^{hi}	58.83 ^k
Bombay Red		149.33 ^a	124.07 ^{bc}	99.27 ^f	73.87 ^{ij}	67.60 ^{ijk}	63.67 ^{jk}
Nafis		152.37 ^a	128.33 ^b	123.80 ^{bcd}	102.33 ^{ef}	95.47 ^{fg}	72.13 ^{ij}
LSD (5%) : 12.15 ; CV : 7.39							
		Bulb dry weight (g)					
Adama Red		23.75 ^{bc}	21.77 ^{cd}	19.64 ^{def}	16.39 ^{gh}	15.34 ^{hi}	12.42 ^j
Bombay Red		25.67 ^b	20.27 ^{de}	18.36 ^{efg}	17.84 ^{efgh}	12.78 ^{ij}	11.16 ^j
Nafis		30.97 ^a	20.49 ^{de}	19.70 ^{def}	17.26 ^{fgh}	13.34 ^{ij}	13.65 ^{ij}
LSD (5%) : 2.68; CV (%) : 8.97							
		Total bulb yield (t/ ha)					
Adama Red		28.73 ⁱ	33.99 ^{fgh}	32.62 ^{fgh}	34.80 ^{efg}	40.53 ^{abcd}	30.96 ^{gh}
Bombay Red		29.13 ⁱ	36.74 ^{cdef}	40.05 ^{bcde}	43.08 ^{ab}	35.46 ^{defg}	32.22 ^{fgh}
Nafis		30.40 ^{hi}	41.83 ^{abc}	45.84 ^a	42.90 ^{ab}	39.70 ^{bcde}	35.08 ^{defg}
LSD (5%) : 5.46; CV (%) : 9.05							

Means with same letter(s) are not significantly different at 5% level of significance

Total bulb yield was significantly ($P < 0.01$) affected by both main and interaction effects. The highest yield (45.84 t/ ha) was obtained from Nafis at 20 × 5 cm spacing, followed by Bombay Red (43.08 t/ ha) at 10 × 5 cm, whereas the lowest yield (28.73 t/ ha) was recorded in Adama Red at the widest spacing (20 × 7 cm). Yield increased with closer to moderate spacing due to higher plant population per unit area, which

compensated for reduced individual bulb size. Although wider spacing improved individual bulb traits, it resulted in lower yield per unit area. Thus, optimum productivity depends on balancing plant density and individual plant performance, in agreement with earlier findings (Rahel and Khasay, 2018).

Conclusion

Onion productivity in Mersa is significantly influenced by varietal differences and plant spacing, indicating that the blanket recommendation (40 × 20 × 10 cm) is not suitable for all varieties. The highest total bulb yield (45.84 t/ ha) was recorded from Nafis at 20 × 5 cm, while maximum marketable yield was obtained at 10 × 5 cm. Bombay Red also performed best at closer spacing (10 × 5 cm), whereas Adama Red showed improved yield under relatively narrow spacing. Wider spacing enhanced individual bulb size but reduced total yield. Therefore, spacing of 10 × 5 cm to 20 × 5 cm for Nafis and closer spacing (around 10 × 5 cm) for Bombay Red and Adama Red is recommended for higher productivity under similar agro-ecological conditions.

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Conflict of Interest

The authors have no conflict of interest to declare.

Data Sharing

All relevant data are included in the manuscript.

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