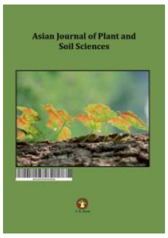

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Effect of Different Nitrogen Fertilizer Levels on Growth and Yield of Bombay Red Onion (*Allium cepa* L.) Variety in the Southern Zone of Tigray, Ethiopia

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Authors' contributions

This work was carried out in collaboration among all authors. Author AS conceived and designed the study, collected and analyzed the data, and wrote the manuscript. Author GH provided guidance on the research concept, data interpretation, and critically reviewed the manuscript. Author BM provided guidance on data interpretation and reviewed the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The primary objective of this study was to assess the impact of nitrogen fertilizer rates on the growth, yield, and yield components of Bombay red onion variety. The study was carried out using a randomized complete block design. The study was carried out at Alamata Agricultural Research Center in Kara Adishabo in 2019, testing various Nitrogen fertilizer rates (0, 23, 46, 69, and 92 kg

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N/ha) with three replications. Results indicated that the different rates of Nitrogen fertilizer significantly wavered most of the growth, yield and yield components of the onion where the highest leaf number (14.67) was obtained from 92 Kg N/ha while the lowest mean number of leaves per plant (4.33) was recorded at nill Kg N/ha while the highest marketable bulb yield was obtained in treatments that received 92 Kg N/ha (38.30 t/ha) and 69 Kg N/ha (40.01 t/ha) which was not statistically different while the lowest one was obtained in treatments that received nill Kg N/ha (17.93 t/ha) and 23 Kg N/ha (19.42 t/ha). Applying 69 kg of nitrogen per hectare in the study area can result in achieving the highest yield of Bombay red onion variety.

Keywords: Growth; onion; nitrogen; marketable bulb yield.

1. INTRODUCTION

“Onions exhibit notable diversity across the eastern Mediterranean countries, ranging from Turkmenistan and Tajikistan to Pakistan and India. These areas are recognized as important reservoirs of genetic variation and are thought to be the birthplace of onions” [1]. Raw sliced onions are known for their antibiotic properties, which can aid in reducing bacterial, protozoal, or helminthic contamination in salads [2].

Onions hold a key economic position in Ethiopia, as the country possesses considerable capacity for year-round production to satisfy local and international market needs. The extensive cultivation of onions in diverse areas serves as a crucial revenue stream for numerous farmers, fostering the commercialization of rural economies and creating multiple off-farm job prospects. [3]. In Ethiopia, during the 2018/2019 cropping season, onion cultivation encompassed an area of 1,299.06 hectares with an average yield of 633 tons per hectare. Likewise, in Tigray, the cultivated areas and yields were reported as 1,299.06 hectares with an average yield of 633 tons per hectare [4].

Onions, with their shallow and linear root system, rely heavily on nutrient uptake, especially for immobile nutrients. Consequently, they thrive and frequently exhibit positive responses to the application of fertilizers [5]. Efficient agronomic practices undeniably play a key role in boosting crop yield. A critical step in improving onion productivity is identifying the ideal fertilizer rates for different agro-ecological zones. Nitrogen, a key fertilizer component, significantly influences plant growth and development by promoting vegetative growth and enhancing leaf coloration with a deep green hue. Nitrogen, essential for proteins, enzymes, vitamins, and key photosynthetic molecules such as chlorophyll, stands out as a crucial nutrient vital for plant growth and development. Implementing suitable agronomic techniques, like fertilization, plays a significant role in enhancing crop yields, including those of onions. The ideal fertilizer needs differ based on crop types, environmental factors, and soil fertility levels in the region [6].

In southern Tigray, farmers cultivate a substantial amount of onions. The low onion yield in the region is linked to inadequate fertilizer application by farmers. Some apply excessive nitrogen fertilizers in an effort to boost yields, while others use insufficient amounts, resulting in reduced onion production. Every plant species has a specific optimal nutrient range and a minimum threshold requirement. When nutrient levels fall below this minimum, plants exhibit signs of deficiency. Conversely, excessive nutrient absorption can lead to toxicity and hinder growth. Hence, the precise application of fertilizers and correct nutrient placement are crucial for optimal plant development [7]. According to [8] report, issuing a standardized recommendation for onion cultivation that is applicable across diverse agro-ecological zones in the country poses a challenge. Therefore, it is essential to apply the optimal amount of fertilizer in specific environments to achieve a good onion yield. Addressing this issue involves implementing optimal nitrogen fertilizer rates in the study area. The primary objective of this study was to assess the impact of nitrogen fertilizer rates on the growth, yield, and yield components of onions.

2. METHODOLOGY

2.1 Description of the Study Area

The research was conducted at the Alamata Agricultural Research Center experimental site, situated in the Southern Zone of Tigray, Raya Azobo Woreda, Ethiopia, specifically in Kara Adishabo in 2019. The area is characterized by a dry semi-arid climate [9]. Geographically, it is positioned between 12°38’50" N and 12°44’36" N latitude and 39°35’10" E and 39°45’10" E longitude. The annual mean minimum, maximum, and average precipitation in the study area are 385.7 mm, 681.1 mm, and 543.6 mm, respectively, with a mean monthly maximum temperature of 29.9 °C and minimum temperatures of 15.9 °C. The Woreda's altitude ranges from 1646 to 1670 m.a.s.l. It encompasses various soil types, including Vertisoils, Nitsoil, Combisols, and Luvisols. Vertisol (black soil with swelling characteristics) is the predominant soil type, covering over 70% of the study area.

2.2 Experimental Treatments, Designs and Procedures

The study involved five nitrogen levels (0, 23, 46, 69, and 92 Kg/ha of N) arranged in a Randomized Complete Block Design with three replications. The blocks and plots were spaced at 1.5 m and 1 m intervals, respectively, with a plot area of 2 m x 3 m. The furrow spacing was maintained at 40 cm, with double rows spaced 20 cm apart within each furrow, and individual plants spaced 5 cm apart. The Bombay Red onion variety seedlings were cultivated on well-prepared nursery beds using recommended practices. This variety is well-suited and widely grown in the study area. Prior to transplanting, the experimental field was ploughed, pulverized, and leveled. Seedlings were transplanted when they reached a height of 12-15 cm or at the 3-4 true leaf stage, carefully uprooted from the nursery bed. Only healthy, vigorous, and uniform seedlings were transplanted, with any gaps filled within a week after transplanting. All plots received a uniform application of Triple superphosphate (46% P_2O_5) at a rate of 92 kg P_2O_5 as a source of phosphorus. Additionally, half rates of urea (46% N) were applied during transplanting, while the remaining half rates of urea (46% N) were applied after 30 days of transplanting. Soil moisture was maintained at field capacity during planting, and furrow irrigation was used for water application in each plot. An initial four-day irrigation interval was maintained for the first four weeks, which was then extended to five to seven-day intervals until 15 days before harvest, at which point irrigation was completely stopped [10].

2.3 Soil Sampling

Before planting, soil samples were gathered from ten random locations diagonally at six-meter intervals using an auger to a depth of 0-30 cm at the experimental site. The collected samples were merged into a single composite sample. These composite soil samples were air-dried, well-blended, and ground to pass through a 2 mm sieve size before laboratory analysis.

2.4 Data Collection

Before planting, the soil's physical and chemical properties such as soil texture, pH, electrical conductivity (EC), cation exchange capacity (CEC), exchangeable potassium and sodium, total nitrogen, total organic carbon, and total available phosphorus were evaluated and documented. Growth parameters (leaf length (cm), days to maturity, plant height (cm), and bolting percentage), yield and yield components (bulb diameter (cm), marketable bulb yield (t/ha), unmarketable bulb yield (t/ha), and harvest index) of onions were collected from the eight central double rows (out of ten rows) (Fig 1.). Ten pre-tagged plants were randomly chosen in each plot for data collection.

Fig. 1. Data collecting methods on leaf number, leaf length and bulb diameter

2.5 Data Analysis

The soil samples collected were combined into one composite sample. These bulked soil samples were air-dried, thoroughly mixed, and ground to pass through a 2 mm sieve before laboratory analysis. Subsequently, the samples were appropriately labeled, packaged, and sent to Mekelle Soil Laboratory for analysis of major physical and chemical properties. As for the crop data, all data were presented as means and statistically analyzed using R software version 3.5.3. The mean values of treatments were compared for significant differences using the least significant difference (LSD) method, calculated from the data where differences among means were tested. Separate analyses were conducted for each dataset at a significance level (P = .05), with the analysis of variance indicating significant treatment variations.

3. RESULTS AND DISCUSSION

3.1 Soil Physico-Chemical Properties of the Experiment

The soil analysis results (Table 1) prior to planting revealed the following results. optimum pH for onion production ranges between 6 and 8 [3]. Hence, the experimental site was conducive to onion production. The particle size proportion was sand 45%, silt 35% and clay 20%. So, based on [11] the textural soil classification the soil of the experimental site was categorized as loamy soil type. The soil organic carbon, organic matter, and total nitrogen of the experimental site were 1.39, 1.79 and 0.114 % respectively. Hence, based on the [11], rating the soil organic carbon of the experimental site was low. According to [11] ratings, the soil organic matter of the site was low similarly the total nitrogen of the experimental field was low. This indicates that the study site needs the application of an external source of nitrogen for growing onions.

3.2 Growth Parameters

3.2.1 Leaf length

"The longer leaf length (36.83cm) was obtained from 92 Kg N/ha while the shorter (18.33cm) was recorded at nill Kg N/ha (Table 2). This is due to nitrogen is a constituent of many fundamental cell components and plays a vital role in cell division and elongation in plants. It improves the vegetative growth of the onion which leads to an increase in leaf length through the increased photosynthetic area. The positive effect of N on leaf length may be due to its role in chlorophyll, enzymes, and protein synthesis" [13]. The results of this study agree with those of [14] who reported that the length of onion leaves increased with increased nitrogen rates.

3.2.2 Fresh total biomass yield

Fresh total biomass yield of onion plants increased across the increasing rate of nitrogen fertilizer. Thus, the highest fresh total biomass yield (97.77 g/plant) was obtained from 92 kg N/ha and the lowest was recorded from nil Kg N/ha (32.33 g/plant) (Table 2). "This is due to the increased N rates which might have stimulating effect on vegetative and root growth development as well as uptake of other nutrients which leads to higher fresh biomass production" [15,16]. Reported also "increasing nitrogen levels from zero to 120 kg/ha resulted in significant increase in this parameter".

3.2.3 Dry total biomass yield

The highest dry total biomass yield (17.20 g/plant) was obtained from 92 Kg N/ha while the lowest dry total biomass yield (2.90 g/plant) was obtained from nil Kg N/ha (Table 2). "This is due to the increased N rates which might have stimulating effect on vegetative and root growth development as well as uptake of other nutrients which leads to higher dry total biomass production" [15]. The result of the study is in line with the finding of [16] who stated that higher dry total biomass yield was obtained at higher nitrogen rates.

3.2.4 Leaf number per plant

The highest leaf number (14.67) was obtained from 92 Kg N/ha while the lowest mean number of leaves per plant (4.33) was recorded at nill Kg N/ha (Table 2). The study findings revealed that nitrogen is a vital component for onion development by facilitating the formation of protoplasm and proteins, which stimulate cell division and meristematic functions [17]. The result of the study is in line with the finding of [18] who found that application of 120 kg ha-1 nitrogen significantly increased the number of onion leaves per plant.

3.2.5 Bolting percentage

Onion plants that were grown at a nill Kg N/ha produces highest bolting percentage (40.4) and those grown at 92 and 69 Kg N/ha produces the lowest bolting percentage (Table 2). The rise in bolting percentage observed with lower nitrogen application rates could be attributed to the limited nitrogen availability for plant growth, resulting in decreased vegetative growth and premature flowering [19]. The result of the study agrees with [16] who stated that nitrogen fertilization significantly reduced bolting in onion.

3.3 Yield Related Parameters

3.3.1 Bulb diameter

The maximum bulb diameter was recorded in response to the application of 92 Kg N/ha and 62 Kg N/ha (5.80 cm and 5.63 cm respectively which are not statistical different) while the minimum one was recorded from 0 Kg N/ha (1.03 cm) (Fig 2). Therefore, nitrogen application promoted plant growth, increased photosynthesis, and facilitated the translocation of photosynthates to storage organs or bulbs, resulting in larger bulb size [20]. This present study aligns with the results reported by Singh [16] who stated that the application of different doses of nitrogen significantly influenced the bulb diameter of onion.

3.3.2 Average bulb weight

Onion plants that were grown at 92 Kg N/ha produces highest average bulb weight (113.63 g) while the lowest one was recorded from nill kg N/ha (20.67 g) and 23 Kg N/ha (32.21g) which are not statistically different (Fig 3). Application of nitrogen generally enhances the production of assimilate and dry matter accumulation in plants including onion which is an important element needed for proper growth and development [21]. Similar results were also recorded by Soleymani [22] who reported an increase of onion bulb weight with increased nitrogen rate.

Table 1. Physico-chemical properties of the experimental soil

Soil properties	Unit	Experimental field value	Ratings	Sources
Particle size distribution	%			
Sand	%	45		
Silt	%	35		
Clay	%	20		
Textural class			Loamy soil	[11]
Soil Ph		7.87	Moderately alkaline	[11]
Organic carbon	%	1.39	Low	[11]
Organic matter	%	1.79	Low	[11]
Total Nitrogen	%	0.114	Low	[11]
Total available phosphorus	mg /kg	14.89	Medium	[11]
Cation exchange capacity	Cmol(+)/kg	35.2	High	[11]
Exchangeable Sodium	Cmol(+)/kg	1.83	High	[12]
Exchangeable potassium	Cmol(+)/kg	0.71	Medium	[12]
Electrical conductivity	dS/m	0.29	Medium	[11]

Table 2. Effect of Nitrogen fertilizer rates on leaf length, leaf number per plant and bolting percentage of onion

Nitrogen rates (Kg/ha)	Leaf length (cm)	Leaf number per plant	Bolting percentage (%)	Fresh total biomass Yield (g/plant)	Dry total biomass yield (g/plant)
92	36.83a	14.67a	12.4d	97.77a	17.20a
69	32.13b	9.83b	14.3d	84.00b	12.74b
46	30.66b	8.17c	21.9c	66.70c	10.90bc
23	26.60c	6.83c	30.3b	48.00d	7.50c
0	18.33d	4.33d	40.4a	32.33e	2.90d
CV (%)	2.1	3.2	2.8	2.7	3.9
LSD (5%)	1.59	1.5	7.02	13.33	3.65

3.3.3 Marketable bulb yield

This referred to the weight of healthy free of mechanical, disease and insect pest damages, uniform in color, and marketable bulbs that range from 20 g to 160 g in weight. Bulbs below 20 g in weight were considered too small to be marketed whereas those above 160 g were considered oversized according to [6]. The highest marketable bulb yield was obtained in treatments that received 92 Kg N/ha (38.30 t/ha) and 69 Kg N/ha (40.01 t/ha) which was not statistically different while the lowest one was obtained in treatments that received nill Kg N/ha (17.93 t/ha) and 23 Kg N/ha (19.42 t/ha) (Fig 3). This is because nitrogen increased the absorption of readily available nutrients, promoting growth and thereby improving the allocation of assimilates to the storage organ, the bulb [23]. The result of this study is consistence with the finding of [24] who reported that higher marketable onion yield was obtained by the application of high level (120 Kg N/ha) of nitrogen.

3.3.4 Unmarketable bulb yield

Bulbs that are undersized (< 20 g), oversized (>160g), diseased, decayed, split, damaged, small bulbs, splitter, thick-necked, doubles (misshaped), rotten, off-color and discolor bulbs after curing was measured from a net plot at final harvest and expressed in t/ha are called unmarketable bulb yield [6]. The lowest unmarketable bulb yield of onion was recoded from 92 Kg N /ha (0.48 t/ha) and 62 Kg N/ha (0.20 t/ha) which are not statistically different while the highest unmarketable bulb yield of onion was recorded in nil nitrogen fertilizer application (4.96 t/ha) (Fig 2). This can be attributed primarily to nitrogen deficiency and the suboptimal growth of onion plants, leading to weaker plants that are susceptible to diseases and other biotic and abiotic stresses. Additionally, this condition results in low assimilate production, ultimately leading to smaller bulb weights [25]. The current study aligns with the results reported by Etana [26] which indicated that higher unmarketable bulb yield of onion was recorded from lower or fewer nitrogen rates.

3.3.5 Harvest index

Onion plants that were grown at 92 Kg N/ha produces highest harvest index (70.10) while the lowest one was recorded from nill Kg N/ha (49.15) and 23 Kg N/ha (51.80) which are not statistically different (Fig 3). The observed enhancement in harvest index could be attributed to an expanded photosynthetic area in response to nitrogen fertilization, which improved assimilate production and allocation to the bulbs [27]. The study by Abdissa [19] on onion supports this result.

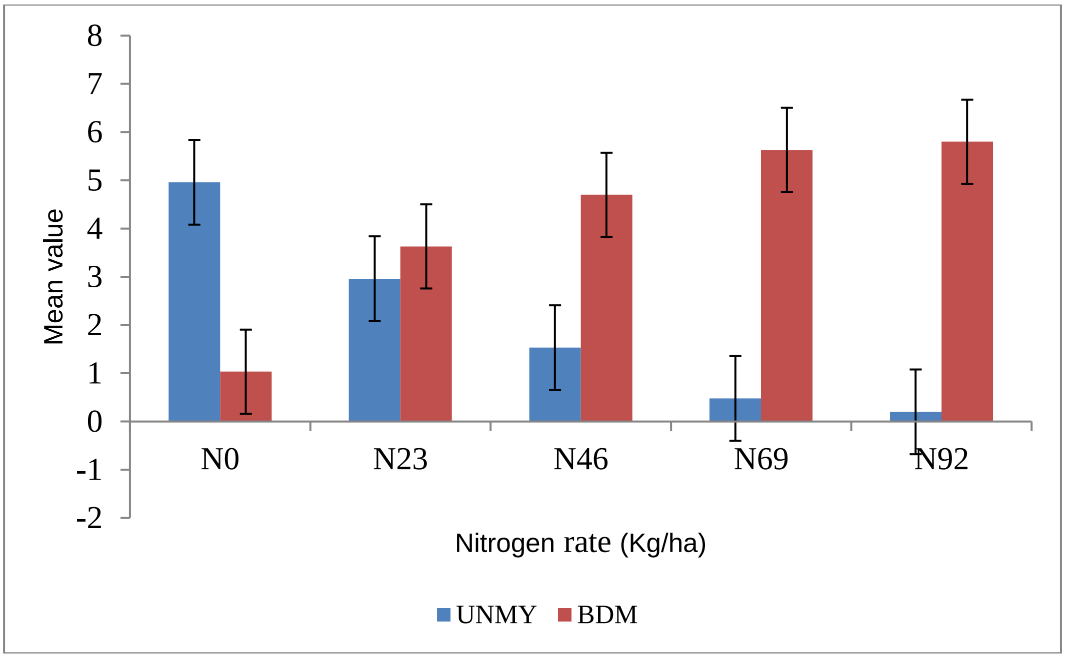

Fig. 2. Effect of Nitrogen fertilizer rates on bulb diameter and unmarketable bulb yield of onion
Abbreviation Key: - UNMY= Unmarketable bulb yield, BDM= Bulb diameter

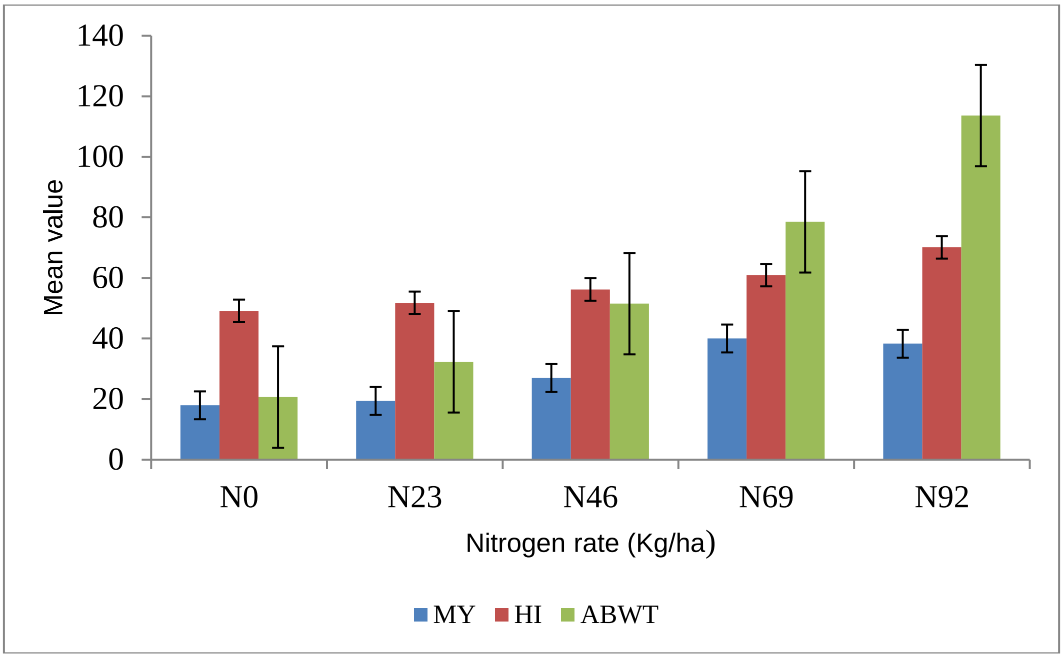

Fig. 3. Effect of Nitrogen fertilizer rates on Marketable bulb yield, Average bulb weight and Harvest index of onion

Abbreviation Key: - MY= Marketable bulb yield, ABWT= Average bulb weight, HI =Harvest index

Table 3. Correlation relationship between different variables of onion

	BP	BDM	HI	LL	LN	MY	UNMY
BP	1						
BDM	-0.94**	1					
HI	-0.78**	0.83**	1				
LL	-0.91**	0.94**	0.86**	1			
LN	-0.85**	0.86**	0.97**	0.89**	1		
MY	-0.86**	0.88**	0.83**	0.81**	0.79**	1	
UNMY	0.88**	-0.94**	-0.85**	-0.94**	-0.79**	-0.85**	1

BP= Bolting percentage, BDM= Bulb diameter, HI= Harvest index, LL= Leaf length, LN= Leaf number, MY= marketable yield and UNMY= Unmarketable bulb yield

3.4 Correlation Analysis

The correlation values showed an apparent association of the parameters with each other and clearly indicated the magnitude and direction of the association and relationships. Hence, it was observed that marketable bulb yield was significantly and positively correlated with bulb diameter (r=0.88**), harvest index (r=0.83**), leaf length (r=0.0.81**) and leaf number (r=0.79**) (Table 3). This indicates that the application of different nitrogen rates for snowballing the vegetative growth, outcomes to the indirect selection of the of nitrogen rates, for enhancing or increasing bulb yield of onion. But, marketable bulb yield was statically and negatively correlated to unmarketable bulb yield (r=-0.85**) and bolting percentage (r=-0.86**). The report by Tekle [27] shows that the marketable bulb yield was highly significantly and positively correlated with leaf number (r=0.53**), leaf length (r=0.47**), bulb diameter (r=0.47**) and harvest index (r=0.84**) while marketable bulb yield was negatively and significantly correlated with an unmarketable (r=-0.56**) bulb yield of onion.

4. CONCLUSION

Ethiopia has significant potential for year-round onion (*Allium cepa* L.) production, which plays a crucial economic role by meeting both domestic and export demands. Farmers in southern Tigray cultivate a substantial amount of Bombay red onion variety, yet face low yields due to either excessive or insufficient fertilizer application. The experimental results showed that the growth, yield, and yield components of Bombay red onion plants were notably influenced by different nitrogen applications. Longer leaf lengths (36.83cm) were achieved with 92 Kg N/ha, while shorter lengths (18.33cm) were observed at zero Kg N/ha. The highest marketable bulb yields were obtained with 92 Kg N/ha (38.30 t/ha) and 69 Kg N/ha (40.01 t/ha), which were statistically similar, while the lowest yields were from zero Kg N/ha (17.93 t/ha) and 23 Kg N/ha (19.42 t/ha) treatments. The marketable bulb yield was significantly and positively correlated with bulb diameter (r=0.88**), harvest index (r=0.83**), leaf length (r=0.0.81**) and leaf number (r=0.79**). Therefore, the application of 69 Kg N/ha is recommended for Bombay red onion variety production in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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