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Original Research

Evaluation of onion (*Allium cepa L.*) varieties for adaptability, yield performance, and Leaf spot disease

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Abstract

Onion (Allium cepa L.) is a globally significant crop and a staple vegetable, essential in culinary practices across households. Its year-round demand remains consistently high due to its indispensable role in daily cooking and food preparation. In Ethiopia, the demand for onions is rising at a rate that significantly outpaces production, creating a growing imbalance between supply and demand. This imbalance has driven a threefold increase in onion price inflation over the last ten years. The study aimed to evaluate varieties that can grow and produce optimal yield and resistance to leaf spot disease, improving farmers' welfare and reducing dependence on red onion imports. Six onion varieties, including local materials, were subjected to evaluation are Adama red, Nanthus, Bombe red, Nafis, Nasik red, and local variety was sown on seed bed by using a randomized complete block design (RCBD) with three replications. The data were analyzed using SAS (statistical analysis system) software version 9.0. Mean separation between genotypes was performed with Fisher's least significant difference (LSD) test at a 5% significance level. The evaluated variables included growth traits and yield parameters of onion crops. The result showed that a highly significant (P < 0.05) difference among onion varieties was obtained for total bulb yield. The highest total bulb yield was obtained from Adama red (40.13 t ha^{-1}) followed by Bombey red (39.166 t ha^{-1}). with better resistance to leaf spot disease. Among six varieties screened for leaf spot disease, Bombey red showed resistance reactions, while Nasik red is susceptible. Based on these findings, the enhanced onion cultivars are recommended for cultivation in the study region and comparable agro-ecological zones, particularly under both off-season cultivation and multi-year agricultural cycles.

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INTRODUCTION

Onion *(Allium cepa L.*) is globally significant crop, has been cultivated for millennia, with evidence of its use as a bulb vegetable dating to approximately 4000BCE (Best, 2000). Recognized as one of the earliest cultivated bulb crop s, it remains a stable in agricultural practice to this day. Over 85% of Ethiopia's population lives in rural areas and relies on agricultural production as their primary livelihood. Despite this wide spread dependence on farming, agricultural productivity remains constrained by the limited adoption of improved technologies, lack of improved varieties, risks associated with weather conditions, pests and diseases, etc. Furthermore, as the population continues to grow, the amount of land available for household is shrinking, resulting in insufficient agricultural output to meet the consumption needs of families (Bezabih and Hadera, 2007). Over the last three decades, the Ethiopian agriculture yet unable to produce sufficient quantities to feed the country's rapidly growing population (Belay and Degnet, 2004). To ensure food security and safety, the country should improve the agricultural sector in sustainable ways. The Ethiopian rural development policy and strategy has emphasized on diversification and specializations of production systems, to secure households food security.

Horticultural crops, particularly vegetables, are vital to enhancing house hold level food security in most irrigated areas. Those crops are characterized by high yielder per unit area with two or three production per year. Vegetable crops encompass a wider number of crops including hot peppers, sweet pepper, onions, cabbage, tomato, kale, broccoli, chilli peppers, green beans (Emana et al.,2015; Chewaka, 2018). Implementing efficient irrigation systems can boost year-round production of selected vegetable crops, thereby substantially increasing profitability. Horticultural crops are usually income producing as compared to cereal or pulses crops. Fruit and vegetable cultivation gains a comparative advantage in regions where arable land is limited, labor is plentiful, and market access is readily available (Lumpkin et al., 2005).

Horticultural crop cultivation creates significant opportunities for poverty reduction, due to its higher labor demands compared to staple food crop production, fostering greater income generation. Fruit and vegetable cultivation offers a viable solution for regions with high labor –to-land ratios, as horticultural production is inherently labor-intensive. Depending on the crop, it demands 2-5 times more labor per hectare compared to cereal cultivation, creating substantial employment opportunities. Expanding horticultural crop production drives commercial growth in rural economies and generate significant employment opportunities (Lumpkin et al., 2005).

Ethiopia possesses significant potential to expand vegetable cultivation across both smallholder farming and large scale commercial operations, creating versatile opportunities for agricultural development. Onion is the most crucial vegetable crop in the country. The 2022/2023 production year report from Ethiopia's central statistical Agency (CSA) documented the output status of root crops-including beetroot, onion, potato, and garlic across private agricultural holding was about 281,000 hectares and 8.76 million quintals respectively. Ethiopian faces a widening gap between escalating onion demand and stagnant domestic production, driving a twofold surge in price inflation over the past decade. Although Ethiopia's climate and soil conditions are ideal for cultivating a wide variety of vegetable crops, including onions, the productivity of this crop remain significantly low. Currently, the total production and productivity of the crop stand at 8 tons per hectare significantly lower than the global average of 34 tons per hectare. This gap is attributed to lack of improved varieties, poor production (lack of improved production technologies) and agronomic practices and insect pest and severe disease (Binalfew et al., 2016; Alemayehu and Alemayehu, 2017).

In West Wollega zone, the onion cultivation remains small scale and low-yielding, confined to limited land areas. In addition, markets in this zone and surrounding zones, found in western and southwestern part of Ethiopia, depend on the onion produces transported from the rift valley areas where there is availability of irrigation facility, accessibility and closeness to agro-industry (Emana et al., 2015). To satisfy the local demand needs to add the production and productivity of onion in the area in quantity and quality by introducing improved varieties thereby increasing income of farmers and minimizing of malnutrition problem. Despite the area's favorable soil and climatic conditions, there has been minimal effort to introduce and assess the adaptability of improved onion verities. . Therefore the objective of the study was to investigate the performance of different varieties of onion & identify the best adapted, high yielding and leaf spot disease resistance onion varieties to the area.

MATERIALS AND METHODS

Description of the Study Site

The study was conducted in the Gimbi district of West Wollega Zone, Western Ethiopia, from May to December 2022, coinciding with the region's main rainy season. The experimental site lies at latitude $36^0$26'N and longitude $8^0$41'E with an elevation of 1,327 meters above sea level .the area experiences an average annual rainfall of 1,477mm, though precipitation patters vary, and daily temperatures typically range between 11.5^{0}C and 22.5^{0}C. Luvi soils dominate the local soil composition.

Experimental materials and design

Six varieties, including local check were evaluated; these varieties are Adama red, Nanthus, Bombe red, Nafis, and Nasik red and local variety. The varieties have been collected from national horticultural research coordinating center, Melkassa Agricultural research Center (MARC) and local market and sown on **seed bed** by using randomized completely block design (RCBD) fashion with three replications. At four leaves stage or pencil thickness seedlings each varieties were transplanted in plot size of 3.2m*3.2m and spacing of 15*10cm was followed. Each plot comprised eight rows, each measuring 3.2 meters in length. To minimize edge effects, data were collected exclusively from the middle six rows, excluding the two outermost border rows and plants at the ends of each row. Row spacing was 40 cm and plant spacing was 20 com.

Data collected

Days to maturity: The number of days from seedling transplanting until greater than 80% of plants within a plot exhibited leaf yellowing or reached physiological maturity.

Plant height (cm): Plant height was measured from the soil surface to the uppermost growth points of the above ground plant part. Plant length was recorded from central –row plants in each plot at the final harvest stage.

Average stand count at harvest (SCAH): Yield and related data were collected from plants in each of the three experimental replications, and values were averaged for analysis.

Average leaf length (cm): Leaf length (in centimeters) was measured for ten representative plants using a measuring tape, and the average leaf length was calculated.

Bulbs diameter (cm): The diameters of marketable bulbs from the same representative trees were measured using calipers, and the average diameter was calculated and utilized.

Marketable bulbs yield (t ha^{-1})**:** This describes the yield of healthy, marketable bulbs within a weight range of 20 g to 160 g. According to Lemma and Shimeles (2003), bulbs weighing less than 20 g were classified as undersized and unsuitable for sale, while those over 160 g were categorized as oversized. The yield parameter was calculated based on data collected from net plot measurements during the final harvest and reported in tonnes per hectare.

Total bulb yield (t ha^{-1})**:** The total bulb yield was determined by weighing all harvested bulbs from the net plot, including both marketable and unmarketable yields. The combined weight was recorded in kilograms per plot and subsequently converted to tonnes per hectare (t ha^{-1}).

Number and weight of unmarketable bulbs (t ha^{-1}): The unmarketable bulb yield was calculated by measuring the combined weight of undersized bulbs (< 20 g), diseased or decayed bulbs, and bulbs from plants exhibiting physiological disorders. These measurement were taken from the net plot at final harvest and converted to tonnes per hectare (t ha^{-1}).

The study for screening the resistance varieties was conducted at the experimental site described above. Disease intensity was assessed using a 0-5 rating scale Sharma, (1986)

Table 1: Leaf spot disease scale measurement adopted to determine disease reaction of onion varieties.

S.no	Disease severity	Category	Reaction
1	<5	0	Immune
2	5-10	1	Resistance
3	11-20	2	Moderately resistance
4	21-40	3	Moderatly susceptible
5	41-60	4	susceptible
6	>60	5	Highly susceptible

Data analysis: The collected data was subjected to statistical analysis software (SAS) version. 9.0. The mean separation test was done using least significant difference (LSD).

RESULTS AND DISCUSSION

Analysis of variance (ANOVA) revealed highly significant differences ($p<0.01$) among tested varieties for establishment percentages, days to

80% maturity, and total yield. Similarly, all variables exhibited highly significant variations across the majority of the data. However, establishment percentages showed significance at the p<0.05 level of probability.

Days to maturity

Analysis of variance showed that days to 80% maturity were significantly (at P<0.001) varied among the onion varieties. Variety Adama red and Bombe red showed the longest and shortest days to 80% maturity (172 days) and (152 days) respectively, while varieties Nanthus, Nafis, and Nasik red required non- significantly less number as compared to the local varieties (163.3). The observed differences in maturity dates among improved onion cultivars may be linked to their phylogenetic divergence. Studies by Yemane *et.al*. (2014) and Gebremedhin *et al.* (2018) observed statistically significant variations in maturity dates across onion cultivars, highlighting the influence of genetic differences on phonological development.

The early maturity observed in these varieties may result from the accelerated translocation of photosynthesis from leaves to bulb, which enhances bulb growth rate, thereby promoting precocious maturation, early bulb initiation, and ultimately earlier harvest (Pardeshi and Waskar,2012). The extended time to maturity observed in these cultivars could be attributed to their reduced photosynthetic efficiency, which prolongs the vegetative growth phase before bulb development (Pardeshi and Waskar, 2012). The findings of this study aligned with earlier research demonstrating genetic variation in maturity timelines among onion genotypes. Sharma (1986) observed significant differences in days to maturity across cultivars, a pattern corroborated by Mahanthesh *et al*. (2008) and Kabura (2008), who attributed such variations to genotypic adaptability under diverse growing conditions.

Plant height

Analysis of variance (ANOVA) revealed a highly significant effect (p <0.01) of onion variety at plant height 36 and 43 days after planting. LSD test showed that variation among onion varieties. Higher plant heights were recorded from Local (89.9 cm) and Nasik red (88.7cm). Similarly, Fikre *et al*. (2021) also reported that Naik red has a higher plant height than other varieties.

Where as to some extent lower values were obtained from Nanthus (72.8 cm) and Bombay red (80.5 cm). Report by Haile-Selassie *et al*. (2016) showed that higher plant height was recorded from Nafis (57.4 cm) and Nafis red (66.26 cm). The observed disparity likely arises from the local cultivar's agroecological compatibility, where prevailing growing conditions align with its physiological requirements, in contrast to non-local varieties that may require adjusted cultivation practices to thrive in the same environment. This difference might be due to climatic conditions during the growing seasons. Indah (2016) highlights that improved onion varieties are typically bred for adaptability to local conditions, high yield potential, early maturation, resistance to biotic stressors, and the capacity to produce market-preferred bulb quality while thriving under diverse agro-ecological conditions.

Average stand count at harvest (SCAH)

The analysis revealed a significant variation in the final stand count at harvest among the evaluated onion varieties. The highest number of plants per plot was recorded for the local variety, with an average stand count of 89.67, followed by Nasik Red and Nafis, which exhibited average stand counts of 87.80 and 86.50, respectively. In contrast, the variety Nanthus showed the lowest plant count per plot, with an average of 72.83 (Table 2).

Average leaf length

The analysis of variance showed a highly significant ($P < 0.05$) variation among onion varieties on leaf length. Both Local and Nasik showed the highest leaf length (89.66 & 87.8 cm, respectively, while the lowest leaf length was recorded from Nanthus (72.8cm). The variation in leaf length observed among cultivars may be attributed to differences in their genetic composition. In agreement with the current result, Gebremedhn *et al*. (2018) reported that Nasik showed the highest leaf length, and Jilani *et al*. (2010) also reported the differences among cultivars in leaf length.

Table 2: The mean performance of onion varieties for days to maturity, plant height, average stand count at harvest and leaf length

S/N	Varieties	DM	PH(cm)	SCAH	LL(cm)
1	Nantus	162.3^{b}	72.833d	115.3a	72.83d
2	Adama red	172^{a}	80.933 c	87.3b	80.93c
3	Bombe red	152^{c}	80.50c	73c	80c
4	Nafis	166^{b}	86.5b	72c	86.5b
5	nasik red	161.33^{b}	87.83ab	76c	87.8ab
6	Local	163.33^{b}	89.66a	82.33bc	89.66a
Mean		**162.8**	**162.8**	**83.04**	**84.33**
CV%		**1.8**	**1.8**	**1.7604**	**6.9**
LSD(5%)		**5.304**	**5.304**	**2.6596**	**10.54**

Means with in the same column followed by identical letters are not statistically different at the 5 % significance level: DM=Days to maturity; PH=plant height; SCAH=Average stand count at harvest; LL= leaf length

Bulb diameter/size

As far as bulb size is concerned, significant differences were observed among varieties where the largest bulb size was recorded from Adama red (6.7 cm) and Nanthus (6.37 cm) varieties, which were statistically not different, followed by Nafis (5.33 cm) and Bombey red (4.7 cm) varieties. The smallest bulb size was recorded from local (4.6 cm) and Nasik(4.27 cm) varieties.

Marketable and unmarketable bulbs yield

The highest marketable bulb yield was recorded from variety Bombey red (60.66 t ha^{-1}) followed by Nasik red (59.43 t ha^{-1}), Nafis (59 t ha^{-1}), Nanthus(51.7 t ha^{-1}) and Adama red (44.8 t ha^{-1}) while the minimum marketable yield was recorded from local variety (41 t ha^{-1}). The observed variation in bulb yield among onion cultivars could stem from inherent genetic divergence within their germplasm. Consistent with the current findings of Yemane *et al*. (2014) reported that the melkam variety produced a higher marketable bulb yield (34.36 t ha^{-1}), while the Adama red variety yielded significantly lower (28.45 t ha^{-1}). Similarly, Dessie *et al* (2020) observed reduced marketable bulb yields in the Adama red variety, further corroborating its lower productivity compared to other cultivars.

A Significant variation was observed in unmarketable fruit weight, with the highest values recorded for the Adama red variety, 4.067 t ha^{-1} followed by local and Nanthus, which had statistically similar letter with values of 3.48 t ha^{-1} and 3.316 t $ha^{-1,}$ respectively, and the least was achieved with variety Nasik 1.86 t ha^{-1}. This might be due to the genetic variation among onion varieties. Additionally, Geremew *et al.* (2010) reported that the Bombay red variety exhibited the highest unmarketable bulb yield (8.98t ha^{-1}) and while the Adama red yielded the lowest (0.36 t ha^{-1}). This difference might be due to climatic conditions and other environmental factors.

Total bulb yield

The analysis of variance exhibited a highly significant (P < 0.05) effect of variety on total bulb yield. The maximum total bulb yield was recorded from Adama red (40.13 t ha^{-1}), followed by Bombey red (39.16 t ha^{-1}), while Nasik (31.19 t ha^{-1}) and Nanthus (34.2 t ha^{-1}) had non-significantly different total bulb yields from the local variety, which is about 30.33 t ha^{-1}. The higher total bulb yield was recorded from Adama red (40.133 t ha^{-1}), and the lower total bulb yield was obtained from variety local variety (30.33 t ha^{-1}) (Table 2). This result contrasts with Geremew *et al.* (2010) report on such a way that the minimum marketable and total bulb yield was recorded from Adama Red (15.82 and 19.22 t ha^{-1}, respectively). This difference may come from the location of the study area

Table,3:The mean performance of onion varieties for bulb diameter, marketable yield, unmarketable yield and total bulb yield

N/S	Variety name	BD(cm)	MY	UMY	TBY
1	Nantus	6.37a	51.7c	3.316b	34.2c
2	Adama red	6.7a	44.86d	4.066a	40.13a
3	Bombe red	4.7bc	60.66a	1.9c	39.166ab
4	Nafis	5.33b	59b	2c	37.956b
5	Nasik red	4.27c	59.43ab	1.856c	31.193d
6	Local	4.6c	41e	3.486b	30.33d
Mean		**5.33**	**52.8**	**2.77**	**35.5**
CV(%)		**7.12**	**1.7**	**5.75**	**3.097**
LSD(5%)		**0.6852**	**1.569**	**0.2899**	**2.0001**

BD=Bulb diameter,MY=Marketable yield, UMY=Unmarketable yield, TBY=Total bulb yield

Resistance to pest and diseases

The evaluation study of six onion varieties conducted in 2023 under natural epiphytotic conditions revealed that leaf spot disease infected all tested varieties. However, disease severity varied significantly across varieties, demonstrating distinct levels of susceptibility to the pathogen.

Table 4: Disease reaction of onion varieties for leaf spot under field conditions at Gimbi area

No	Varieties	PDI	Scale	Scale reaction
1	Bombe red	8.6	1	Resistant
2	Adama red	10.34	2	Moderately resistant
3	Nanthus	20.8	3	Moderately susceptible
4	Nafis	28.99	3	Moderately susceptible
5	Nasik red	46.6	4	susceptible
6	Local	24.65	3	Moderately susceptible

PDI: Percentage of disease incidence.

The disease severity of leaf spot among the varieties ranged between 8.6 to 46.6 percent (Table 4). The result of the data indicated that the majority of the varieties evaluated were moderately susceptible to the disease. The low productivity of onion crops can primarily be attributed to two factors: the limited availability of regionally adapted varieties tailored to diverse agro-climatic conditions and growing environments, coupled with widespread susceptibility to pests and diseases. Fungal pathogens, such as those causing leaf spots, are among the most critical agricultural threats. Not only do they damage crops, but their infections can also weaken plant defenses and create pathways for secondary viral infections, amplifying overall crop vulnerability. Among the genotype screened, Bombey red (8.6%) recorded the minimum per cent of leaf spot damage, while Nasik red variety (46.6%) recorded the maximum per cent of disease damage.

Therefore, cultivating disease-tolerant varieties represents one of the most straightforward and practical approaches to managing pests and diseases, reducing reliance on chemical interventions while aligning with sustainable agricultural practices. Manna (2014) documented that a growing number of farmers in the Gojjam zone have shifted from onion to shallot cultivation, primarily driven by severe disease outbreaks (like Botrytis or leaf spot) and persistent agronomic challenges affecting onion productivity.

In onion production, leaf spot ranks as the most destructive disease, severely compromising both crop yield and produce quality. This pathogen-driven constraint not only diminishes harvest volume but also degrades marketability, contributing to significant economic losses for farmers. From the studied genotypes, Bombey red (8.6%) recorded the minimum leaf spot disease, followed by Adama red (10.34%) and local variety (24.65%) compared to other varieties. Leaf spot disease is widespread across nearly all major onion-growing regions in the country, posing a persistent threat to crop health and productivity. Similarly, Shoba (2017) emphasized that leaf spot disease severely compromises onion production, leading to significant reductions in both yield and quality of the harvested bulb.

CONCLUSION AND RECOMMENDATIONS

Bombe red and Adama red demonstrated superior adaptability and high-yielding potential varieties with resistant and moderately resistant leaf spot disease reaction, respectively, in the study area. The selection of onion varieties should prioritize region-specific adaptability, yield stability, and resistance characteristics. While improved varieties like Adama Red and Bomb Red show high potential (40.13 t ha^{-1} and Bombey red 39.166 t ha$^{-1,}$ respectively), local cultivars remain vital for low-input systems. Policy makers and agricultural extensions must promote context-specific recommendations to enhance productivity and economic returns for smallholder farmers. Integrated studies on disease resistance, pest management, and nutrient optimizations are needed to address gaps in current evaluations.

Conflict of Interest

The authors confirm that there are no competing interests or conflicts of interest to disclose.

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