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Yield and Storage Performance of Onion (*Allium cepa* L.) Genotypes under *in situ* and ex-situ Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. Author GD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author FK managed the data collection and analyses of the study. Author MM managed the literature searches and article review. All authors read and approved the final manuscript.

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ABSTRACT

Onion (*Allium cepa* L.) varieties grown in Uganda are anticipated to have different yield and storage potential. To determine the yield and storage performance of onion varieties, a field experiment was conducted at Namulonge in Uganda. The experiment constituted six onion varieties as treatments arranged in a completely randomized block design (RCBD) replicated thrice. During the cropping seasons, total and economic yield data was collected and analyzed. The total and economic yield of onions were found to be significantly (P= .05) influenced by varietal effects. Among the onion varieties, Bombay red East Africa provided the highest (4690 kg ha^{-1}) yield while the control (local cultivar) yielded (770 kg ha^{-1}) least. The highest economic yield (2867 kg ha^{-1}) was realized from red creole variety while the lowest yield (687 kg ha^{-1}) was obtained from the control. The economic yield of onions was also influenced by cropping seasons with the highest yield (2693 kg ha^{-1}) obtained during 2017B. Although the control yielded least it had the longest shelf life because after 112 days of storage it had the lowest sprouting and rotting percentage (50%). These results are useful in guiding onion farmers in selecting varieties with high yield and storage potential.

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1. INTRODUCTION

Onion (*Allium cepa* L.) is one of the important vegetable crops grown globally, which belongs to the family Liliaceae. It is subdivided into three groups: *Allium cepa*, *Allium aggregat*ion, *Allium prolilum*, which are all diploids [1]. The crop is a biennial herb which originated from Central Asia with centers of diversity in Afghanistan, Iran and Pakistan. The crop is currently cultivated worldwide with other secondary centers of diversity identified over time [2]. Onion is ranked 4^{th} among the most consumed vegetables after tomato, cabbage and watermelon with a global annual production of 2 million tonnes [3].

Onions are grown primarily for their use as food, adding flavors to food and taste [4]. The crop is also used for processing such as pickling, freezing, dehydration and oil extraction. Young and healthy green onion leaves with their white bases are eaten raw in salads. In addition to consumption, onions are produced for medicinal purposes such as prevention and treatment of blood and heart diseases [5]. The crop is also a rich source of Vitamin C and E [6] and in Uganda, onions contribute to household income especially in highland areas where they are grown purposely for sale [7]. In India, onion is being grown in an area of 0.83 million hectares with production of 13.57 million tonnes and the productivity is 16.30 ton ha^{-1} which is low. Maharashtra is the leading onion producing state followed by Karnataka, Gujarat etc [8].

In spite of its importance, onion production remains as low input and output crop with a national average yield of 5 ton ha^{-1} [8]. However, the yield of the crop is far below the world average (19.7 ton ha^{-1}) despite its being year-round production [8]. The low onion yield in Uganda is partly attributed to farmers' exchange of planting materials (bulbs), they rarely purchase improved and well-adapted genotypes. Furthermore, due to limited research on commercial production of onion, farmers rarely use improved production practices [9]. Common pests such as thrips decrease yield in the absence of timely pesticide application or resistant onion genotypes [10]. Similarly, the ineffective post- harvest handling and storage practices used by farmers also contribute to about 25% losses [9,10]. An ethnobotanical survey tells of the Fennoscandian multiplying onions as being a crop with reliable harvest, excellent storage ability, and good taste. Increased cultivation of this material on both household and commercial-scale should be possible [11,12].

In peri-urban areas of central Uganda, onion is becoming a major spice and vegetable produced by farmers in wetland areas. Consequently, strong help for smallholder producers to achieve potential yields to boost their income and secure their livelihood by providing high yielding and adapted onion genotype is critical. However, the present challenge in most onion growing areas is lack of well-adapted onion genotypes. As a result, varietal information to improve onion yield in production areas is inadequate. Additionally, research has not established a breeding program to develop improved varieties or even evaluated existing onion genotypes imported from outside Uganda to guide growers in selecting best yielding onion varieties to use. Evaluation of onion genotypes for their yield performance is considered as one approach to use in obtaining high yielding and adapted onion genotype. Therefore, this research aimed at identifying the best performing onion genotype with good storage under field and room conditions.

2. MATERIALS AND METHODS

The experiment was conducted at National Crops Resources Research Institute (NaCRRI), Namulonge during 2017A and 2017B. Namulonge lies at an altitude of 1150 metres above sea level (m.a.s.l). For the years the experiment was conducted, the site experienced a bimodal rainfall pattern averaging to 1196 mm with mean daily temperatures of 28.5ºC and 13.0ºC as the maximum and minimum, respectively Table 1. The experiment field was dominated by red sandy clay loam soils of pH 4.9 – 5.0.

2.1 Plant Materials

Seeds of five onion varieties were purchased from three leading vegetable seed supplier companies in Uganda namely; East African Seed (U) Limited, Simlaw Seeds Co (U) LTD and Victoria Seeds limited. The genotypes included; Red Creole, from Victoria seeds limited, Red creole C-5, Texas grano, Bombay red from East African seed (U) limited and Bombay red from Simlaw seeds Co (U), including one local cultivar (control) as a check from Horticulture and oil palm program at Namulonge. The selection of

Table 1. Mean annual rainfall and temperature at Namulonge during seasons 2017A and 2017B

Season 2017A				Season 2017B			
Months	Rainfall (mm)	Temperature (°C)		Months	Rainfall (mm)	Temperature (°C)	
		Min	Max			Min	Max
March	93.3	16.3	29.6	September	200.7	17.7	27.5
April	160.3	17.4	28.9	October	83.8	18.5	28.4
May	64.3	17.2	27.7	November	206.4	17.9	28.0
June	12.9	16.8	28.9	December	12.9	17.0	30.0

the five onion genotype was based on their high yielding and preference by farmers in major onion growing areas in Uganda.

2.2 Seedling Production

Onion seedlings were produced in a nursery bed by initially sowing seeds of the five onion genotypes in a mixture of forest soil, sand and manure in a ratio of 3:1:1. Seedlings emerged 10 days after planting and regular watering was done accompanied with the spraying of cypemethrin at rate of 2 ml L^{-1} to control cutworms and other insect pests. The seedlings were maintained in the nursery bed for 20 days with regular watering before being transplanted into the main field.

2.3 Field Experiment

The experiment was laid out in randomized complete block design (RCBD) with three replications, with the onion genotypes as treatments. Onion seedlings were transplanted into plots of 1.5 m long and 1 m wide and spaced at 15 cm between rows and 10 cm between plants. Nitrogen, phosphorus potassium (NPK) fertilizer mixture (17:17:17) was applied at a rate of 90 kg ha^{-1} to the soil two times at equal rates (the first portion was applied two weeks after transplanting and the second was top-dressed at 6 weeks after transplanting). Three weeding regimes using a hand hoe were done to control weeds and cypermethrin was applied at a rate of 5 ml L^{-1} to control insect pest especially thrips during the growth cycle.

2.4 Data Collection and Analysis

The data collected included a number of days to maturity from transplant, number of bulbs, total yield (taken as the weight of bulb with leaves), economic bulb weight (taken as the weight of bulb without leaves), and yield (t/ha). Twenty-two randomly selected bulbs harvested from each plot were used for the storage treatments. Bulbs were packed in knitted vegetable bags and stored at room temperature (± 25°C). All rotten and sprouted bulbs were removed from the bags and recorded two weeks after storing. This process continued up to the twelfth week at an interval of two weeks. The number of rotten and sprout bulbs were subtracted from the total number of bulbs at harvest and the difference was calculated as per cent loss. Storage of bulbs was terminated as soon as all the bulbs in the bag were no-longer consumable (visual appearance) and marketable. The data were subjected to analysis of variance (ANOVA) for a randomized complete block design using GenStat software version 11 [13] and results were expressed average values.

3. RESULTS AND DISCUSSION

3.1 Total Onion Yield

Statistical analysis showed that total and economic yield of six onion varieties differed significantly (Table 2) but seasons did not significantly affect either the total or economic yield. Among the onion varieties, Bombay red E.A yielded highest (4690 kg ha^{-1}) while the local cultivar (control) gave the least yield (770 kg ha^{-1}). This indicated that the six onion varieties contributed differently to the total yield observed. The variation in total yield among onion varieties was possibly due to bulb size and adaptation to growth conditions. Bombay red E.A is known to have big sized and succulent bulbs as compared to local cultivar with small bulbs [4]. The variation in bulb size clearly explained the difference in yield observed in Bombay red E.A and the local cultivar. Earlier findings by [14] also emphasized the contribution of bulb size in enhancing onion total yield. Even though the local cultivar is well adapted to local edaphic and climatic conditions, its total yield was low due to its low genetic potential. This was in agreement with earlier findings by [15] which indicated that local cultivars may not have characteristics that contribute to high yield if genetic improvement has not been done to them. Nonetheless, seasons did not influence total yield of onion varieties that were tested. This showed that the variation observed in yield was possibly due to genetic makeup of the different varieties rather than the seasonal conditions. These results were in line with findings of [15,16] who reported that various onion cultivars of the same species grown in the same environment give different yields as the performance of a cultivar mostly depend on the interaction of genetic makeup of parental lines from which they are derived.

3.2 Economic Yield

There was significant (P=.05) difference in economic yield among onion varieties (Table 2). The highest economic yield was produced by Red Creole Victoria (3344 kg ha^{-1}) and the lowest by the local cultivar (687 Kg ha^{-1}). The low yield of local cultivar was contributed by the characteristic small-sized and bolter bulbs which are unmarketable and unacceptable by consumers. Previous research by [16] also reported a reduction in economic yield of onion attributed to unmarketable small-sized and bolted bulbs. On the other hand, the red Creole Victoria which registered the highest economic yield had big sized bulbs with limited or no bolters compared to the local cultivar. Bombay red E.A and red Creole C-5 both had equally high economic yield though less than red creole Victoria. Based on the results, it can be concluded that red creole Victoria, Bombay red and Texas grano varieties due to their high economic (marketable) yields can be recommended for commercial production for smallholder farmers in central Uganda.

There was a significant (P=.05) variation in economic yield of six onion varieties observed between the two growing seasons. The highest yield was obtained in season 2017B and the least in 2017A (Table 3). The mean economic yield of 2693 kg ha^{-1} was realized in 2017B compared to 1908 kg ha^{-1} obtained in 2017A. The high economic yield obtained during season 2017B was due to high rainfall received during the growth period of three months in 2017B compared to less rainfall received in 2017A (Table 1). In rain-fed production systems that

Table 2. Total and economic yield results of analysis of variance for six onion varieties

Varieties	Total yield (kg ha^{-1})	Economic yield (kg ha^{-1})
Bombay red E.A	4690a	2805a
Bombay Red Simlaw	2019a	1520b
Red Creole C-5 E.A	4091a	2867a
Red Creole Victoria	4586a	3344a
Texas Grano	3368a	2581a
Local cultivar	770b	687c
Mean	3254	2301
$LSD_{0.05}$	2741	1520

Means which are followed by the same letter in a column do not differ significantly by LSD test at P=.05 but those followed by different numbers are significantly different

Table 3. Analysis of variance for economic yield of onion varieties for two seasons at Namulonge

Varieties	Season 2017A economic yield (kg ha^{-1})	Season 2017B economic yield (kg ha^{-1})
Bombay red E. A	2055a	3556a
Bombay red simlaw	1949ab	1091b
Red creole C-5 E. A	2542a	3193a
Red Creole Victoria	1326b	3858a
Texas grano	2831a	3836a
Local cultivar	748c	626c
Mean	1908	2693

Means which are followed by the same letter in the column do not differ significantly by LSD test at P=.05 but those followed by different numbers are significantly different characterize most of Uganda's farming system, water availability is a critical factor due to its importance in normal onion growth and development. The low rainfall during 2017A reduced the amount of water available for normal development. The little water availed to onions could have affected the physiological processes responsible for bulb formation leading to small sized bulbs [17]. The small-sized bulbs adversely reduced on the economic yield of onions planted in 2017A as small-sized onions are not acceptable in the market [18].

3.3 Sprouting Percentage

The sprouting was measured in percent growth of onion stored for a period of 112 days. The sprouting behavior of different onion varieties tested are indicated in Fig. 1. The percent sprouting varied significantly (P=0.05) among onion varieties during the storage period. The bulbs remained dormant for 42 days, after which sprouting started up to 112 days. The delay in the sprouting of stored onion varieties was attributed to the fact that onion bulbs are naturally dormant at maturity and the length of this dormancy depends on conditions under which the bulbs are stored [18]. However since in this study storage condition for all varieties were the same (at room temperature) the variation in dormancy was probably due to varietal difference rather than storage conditions. Earlier work by [19] reported that onions were dormant for 75 days at room temperature before sprouting was observed. This was contrary to our findings were onion varieties were dormant for only 42 days in storage. Red creole Victoria had the highest sprouting percentage and in fact by the 112th day 100% of its bulbs had sprouted. The local cultivar had the lowest percent sprout among onion varieties tested of which 50% had sprouted by 112th day. The variation in percent sprout among onion varieties tested was probably due to the fact that sprouting is a normal physiological change in stored bulbs that develops reproductive shoots; however, this change depends on storage conditions and cultivars [17]. The dependence of sprouting on onion cultivars possibly explained the variation in sprout percent observed among onion varieties in this study. Bombay red E.A, Bombay red similaw and Texas grano equally had relatively low sprout percent at 112th day as compared red creole E.A whose percent sprout was higher. Irrespective of the source the percent sprout for red creole varieties was high at 112th day as compared to Bombay red varieties or Texas grano. The positive correlation among Creole varieties or Bombay varieties irrespective of their sources was possibly due to genetic relatedness resulting from sharing of similar parentage during their development which led to sharing of similar trait such as sprouting ability.

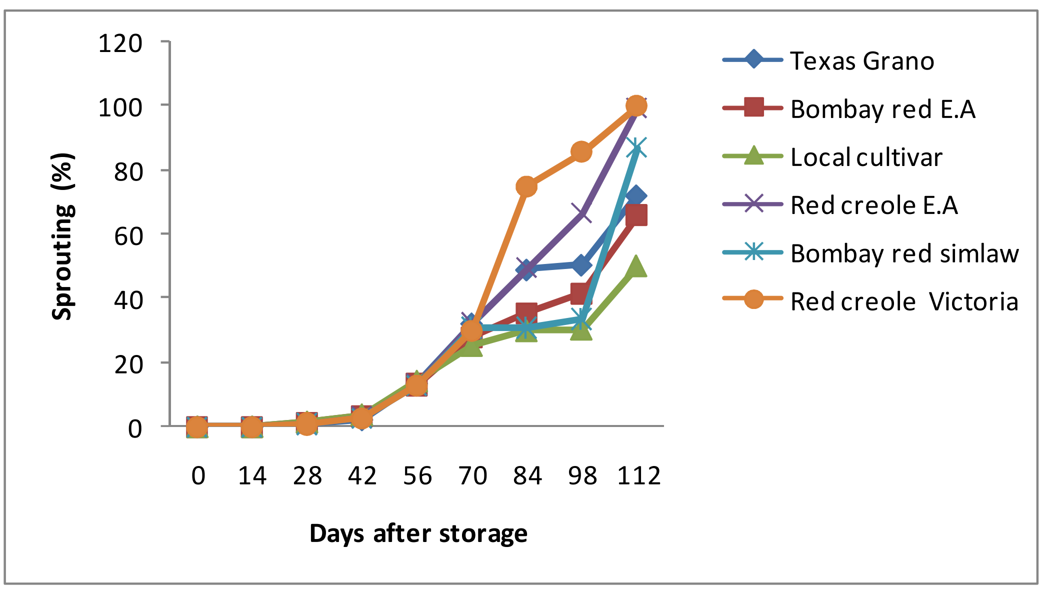

Fig. 1. Sprouting percentage of six onion varieties under room condition at Namulonge in 2017

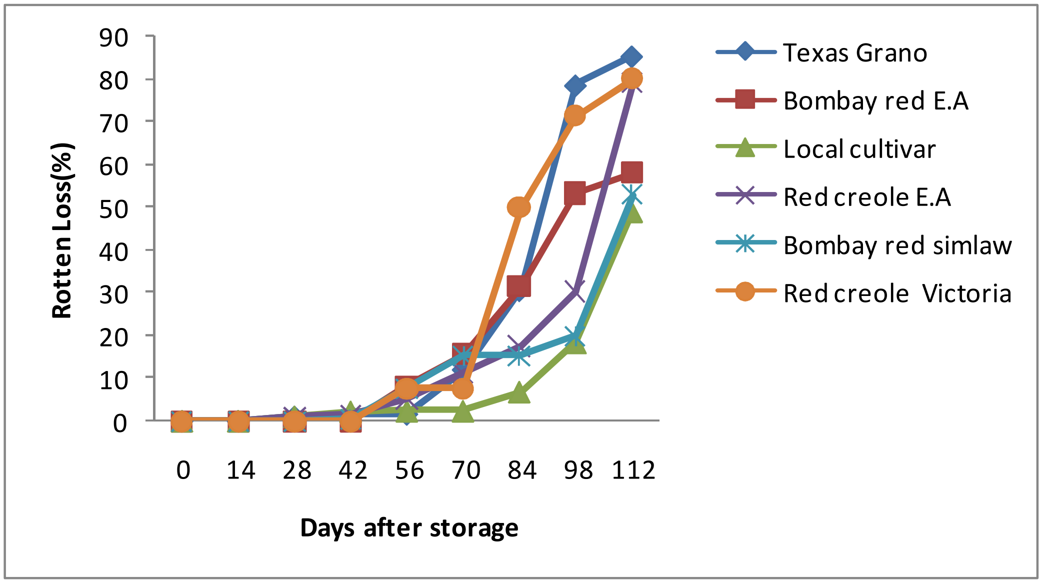

Fig. 2. Rotting percentage of six onion varieties under room condition at Namulonge in 2017

3.4 Rotting Percentage

The onions in storage were observed for signs of rotting for 112 days. Significant variation in percent rot was observed among stored onion varieties with red creole Victoria and red creole E.A having the highest percent (100%) rot at 112th day followed by Bombay red Simlaw red creole E.A (90%) and Texas Grano (60%) (Fig. 2). The local check on the other hand, had the lowest percent rot (below 50%) after 112 days of storage. This result corresponds to the earlier findings of [20] who reported a substantial increase in onion decomposition during storage. The lowest rot loss in the local cultivar (control) may be due to the fact that, this cultivar is adapted to storage conditions in Uganda unlike other varieties which were introduced into the country from elsewhere, where long term storage is mainly done under cold storage conditions. Furthermore, the local cultivar bulbs where less succulent and as a result, they were less attacked by bacteria and fungi during storage.

4. CONCLUSION

Basing on the study results it can be concluded that onion genotypes vary in yield and storage period. Onion genotypes like Bombay red E.A and Red Creole Victoria could be recommended for high total and economic yield while the local cultivar can be best used for longer storage. However, since local cultivar is low yielding, it's good storage qualities need to be transferred to commercial varieties to prolong their shelf life. Nonetheless, a study to determine the of the nutritional quality of the bulbs of Bombay red E.A and red creole Victoria needs to be undertaken to make a better selection of varieties for Ugandan farmers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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