Yield and yield components of potato (*Solanum tuberosum* L.) cultivars as jnfluenced by seed tuber storage duration at Adet, Northwest Ethiopia

[1]Alemu Worku, [2]Tekalign Tsegaw, [3]Fentahun Mengistu

[1]Adet Agricultural Research Center; [2]Haramaya University; [3]Amhara Region Agricultural Research Institute

(alemuworku32@yahoo.com)

Abstract

A field experiment was conducted at Adet in 2009/2010 to determine the effects of seed tuber storage durations on yield and yield components of improved potato cultivars. Seeds of Potato cultivars, Guassa and Zengena, stored in diffused light store for periods of 2, 3, 4, 5, 6 and 7 months prior to planting. Field experiment was carried out 2 x 6 factorial arrangements in a randomized complete block design with three replications, and cultivar and storage durations were completely randomized within each block. Analysis of variance indicated that statistically significant ($P < 0.05$) variation was observed among the storage durations. Results of this study also indicated that, days to emergence, stem number per hill, days to maturity, tuber number per hill and total tuber yield were found to be the parameters most affected by seed tuber storage duration. Six months stored tubers of both cultivars gave plants which are early to emerge, better leaf area, stem number, biomass, and tuber number and weight, yield, specific gravity and dry matter. The highest total tuber yield was recorded from 6 months old tubers of Guassa (30.30 ton ha^{-1}) and Zengena (27.49 ton ha^{-1}) and the lowest was from 7 months old seed tubers (20.66 ton ha^{-1}). Generally it was found that 32.01% yield advantage was recorded from 6 months compared to 7 month storage. Therefore, it is concluded that both cultivars have attained optimum seed tuber physiological developmental stage at 6 months storage duration at Adet for high crop productivity. Since this experiment was conducted at one location for one season; it is difficult to give final recommendations at this stage. Thus, considering additional storage durations, further study across locations and season can provide more information on the impact of seed tuber age on seed quality and yield potential of the crop.

Introduction

In Ethiopia, potatoes are basically stored for two reasons: ware and seed. Farmers use different traditional potato storage system (underground storage, floor storage, and raised beds and in sacks) depending on the use (ware or seed). Nearly all the major physical, physiological and disease problems that cause quality loss were not effectively regulated in the above mentioned tuber storage methods. Thus, the problem is very critical in affecting seed quality and subsequent performance of the crop in the field (Endale *et al*., 2008). Observations made at Holleta indicated that tubers could be stored as along as 7 months without considerable loss of seed quality. The storage performance, however, was noted to vary depending on cultivar and location (Endale *et al*., 2008).

Entire crop may fail if seed tubers that are not at proper stage of physiological development are planted (Endale *et al*., 2008). Hence, lack of proper storage facilities is one of the main factors forcing farmers in Ethiopia to sell their potatoes on harvesting, even at low prices. Due to the high perishability of potato and poor storage facilities and methods, most farmers cannot store potatoes for a long time. Problems in both seed and ware potato storage are a serious challenge for most farmers leading to storage losses that can reach up to 50% and some times higher (Bergel, 1980). In Ethiopia, farmers store seed potato for 8-9 months which is quite open for disease build up and tuber degeneration. At this stage, seed tubers of the varieties under evaluation have very long and weak sprouts. This means that the genotypes are being evaluated under sub-optimal physiological conditions.

Moreover, still there is no research recommendation at Adet agricultural research center regarding storage durations for improved varieties. In addition, information regarding the effect of seed tuber storage duration on subsequent crop performance of potato under Adet condition is scanty. Therefore, the study was conducted to investigate the effect of seed tuber storage duration on yield and yield components of improved potato cultivars.

Materials and methods

The study area

The experiment was conducted at Adet Agricultural Research Center, Northwestern Ethiopia, during 2009/2010 cropping season. Adet lies between 11^0 16'N latitude and 37^0 29' E longitude at an altitude of 2240 meters above sea level. The mean annual rainfall of the area is 1250 mm and the maximum and minimum temperatures recorded were 26.54 ^{0}C and 11.37 ^{0}C, respectively (Data taken from Adet Meteorological Station). The soil is well drained red brown camisole with an organic matter content of 6.53% and a pH of 5.43.

Experimental materials, treatments and design

A 2 x 6 factorial experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Two cultivars of potato (Guassa and Zengena) and six seed storage durations (2, 3, 4, 5, 6 and 7 months after harvesting) were combined to produce 12 treatments, and each treatment was randomly assigned to the experimental plots in each block. A gross plot size of 3.75 x 3.3 m accommodating five rows and 11 tubers per row and a net plot size of 1.5 x 2.7 m were used for data collection.

Trial management and crop culture

Tubers from each cultivar were stored in a Diffuse Light Store (DLS) at maximum and minimum temperatures ranging from 29.98 ^{0}C to 8.04 ^{0}C for two to seven months storage durations. Uniform in size and healthy seed tubers from each variety and age group were planted in the first week of December 2009 at the spacing of 75 cm between rows and 30cm between plants. Phosphorus was applied as Diammonium Phosphate (DAP) at the rate of 69 kg P_2O_5 ha^{-1} and Nitrogen was side dressed at the rate of 81 kg N ha^{-1} in the form of urea. To maintain adequate moisture in the soil, plots were irrigated weekly. Other cultural practices like weeding, hoeing and cultivation were carried out as required. The vines were killed two weeks before harvesting for proper skin set and wound healing.

Data Collection

Days to emergence was recorded when 50 percent of the plants per plot were emerged and emergence percentage per plot was also recorded after emergence. Days to flowering was recorded as the number of days from emergence to 50 per cent of flowering. Plant height was measured as the distance from the base of the stem to the tip of five randomly selected matured plants per plot of the central rows. Leaf area was estimated using a portable leaf area meter (Model CI-202-Area Meter CID.Inc., USA) on five selected hills per plot after 50 percent flowering. Six weeks after flowering, while the vines were green but had practically ceased growth (CIP,1983), five randomly selected hills per plot were harvested and dried in oven at 72 ^{0}C to a constant mass to determine aboveground (stem, branches and leaves) and underground (root, stolon and tuber) dry biomass. Days to physiological maturity were recorded when the haulms of 50% of the plants in each plot turned yellowish.

The actual number of main stems per hill was recorded from five sampled hills per plot at physiological maturity. Marketable and total tuber yields were recorded from two central rows of plants excluding two plants from each end of the two rows. Average tuber weight was determined from 10 tubers sampled per plot at harvest. Tuber specific gravity was determined using weight-in-air and weight-in-water method (Murphy and Goven, 1959) from five kilogram tubers. For tuber dry matter content, 100 g of tubers from 10 sampled tubers was chopped and oven dried at a temperature of 72 ^{0}C to a constant mass.

Data analysis

The field data collected was subjected to analysis of variance SAS statistical software Version 9.00 (SAS institute, 2000). Means of significant differences were compared using Least Significant Difference (LSD) test at 5% probability level.

Results and discussions

Sprout number and sprout length

Data recorded during tuber storage indicated that sprout number was highly influenced by seed tuber storage durations and cultivar (Figure 1). Maximum number of sprouts (4.0) was recorded from Guasa stored for 5 months while minimum number of sprouts (1.2 on averages) was from 3 and 4 months old Guassa and Zengena tubers, respectively. Zengena did not produce sprouts until 3 months of storage indicating its long dormancy period as compared to Guassa. Caldiz (1991) reported that number of sprouts and their behavior was highly affected by seed tuber storage age at planting. The number of sprouts per seed tuber has an implication on number of main stems produced in the field (Morris, 1969). Goodwin *et al.* (1969) found that the number of main stems in the field was proportional to the number of sprouts at planting. The length of sprout increased with increasing storage durations considered as indicated in Figure 2. The longest sprout was recorded from 7 months stored tubers. This is in conformity with Kawakami (1952) who found that the rapidity of sprout length growth increased with seed tuber age during storage though too long and weak sprouts are not desirable as they could be damaged during handling and transport.

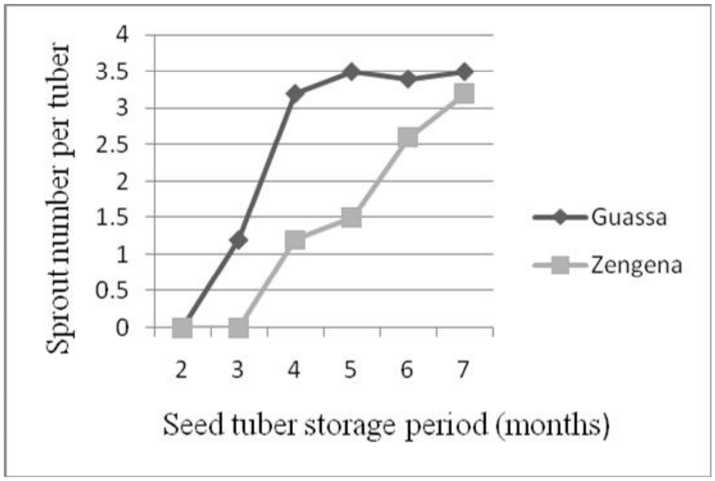

Figure 3. Number of sprouts versus storage period.

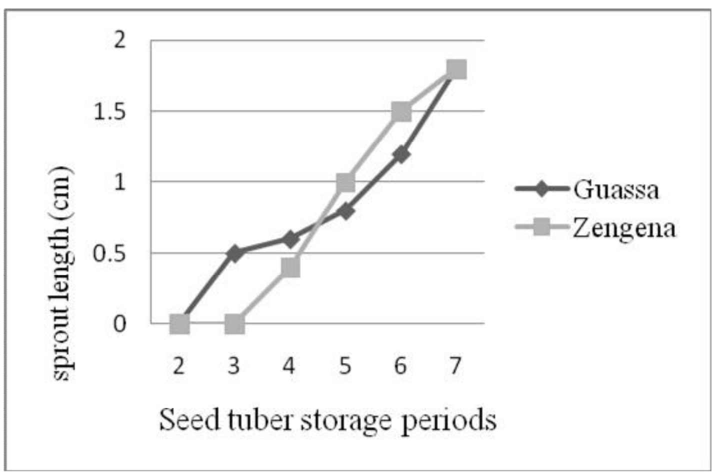

Figure 4. Length of sprouts per tuber versus storage periods.

Storage losses

Storage losses of up to 26.8% of Guassa and 29.4% of Zengena were recorded in 7 months storage period. Similarly, Tesfaye and Yigzaw (2007) reported that seed tuber losses could reach up to 50% during 7- 8 months storage at Adet depending on a variety.

Days to Emergence and Emergence Percent

The analysis of variance indicated that days to emergence was significantly (P<0.05) influenced by the interaction effect of cultivar and seed tuber storage durations (Table 1). Tubers of both varieties that were stored for 6 or 7 months emerged earlier than those tubers of the same varieties stored for 2 months (Table 1). Vander Zaag and Van Loon (1987) reported that plants growing from seed tubers of different physiological age performed differently. According to Struik and Wiersema (1999) the length of time from planting to emergence depends on storage age of seed tubers.

Percentage of emergence was significantly (P<0.05) influenced by the interaction effect of cultivar and tuber storage period (Table 1). However, in the case of Zengena, 7 months old seed tubers showed significantly lower emergence percentage (72.77%) as compared to that of the other storage durations (Table 1). The low rate of plant establishment from old seed tubers is more explained by weak sprouts and low starch reserves for sprouts to develop in stems because of advanced seed tuber ages though moisture and depth of planting are also causes for low rates (Struik and Wieresema, 1999).

Table 1. Days to emergence and emergence percentage of potato as affected by the interaction effect of cultivar and seed tuber storage duration at Adet.

Treatments		Days to Emergence	Emergence (%)
Variety	Storage duration (months)		
Guassa	7	14.00g	84.88a
	6	14.00g	89.09a
	5	20.00f	92.73a
	4	22.67e	90.91a
	3	30.67c	85.46a
	2	36.00b	92.73a
Zengena	7	15.00g	72.77b
	6	14.67g	93.94a
	5	25.67d	87.31a
	4	25.67d	92.12a
	3	32.00c	87.27a
	2	45.00a	91.51a
Mean		24.61	88.39
Cultivar x Storage (5 %)		2.4	10.38
CV (%)		5.85	6.94

* significantly different at 0.05 probability level; Means followed by the same letter within a column are not significantly different at 0.05 probability level.

In favor of the current finding, Vander Zaag (1973) reported that physiologically old seed tubers shorten the time between emergence and senescence. Moreover, Eremeev and Joudu (2007) reported that plants coming from physiologically older seed tubers obvious signs of senescence started to appear earlier. Wurr (1982) also found that storage of potato seed tubers for long periods of time significantly shortens days to physiological maturity of the progeny crop.

Plant height

The analysis of variance indicated that plant height was significantly ($P<0.05$) influenced by cultivar (Table 3). Cultivar Zengena gave better plant height than that of Guassa. Differences in plant height due to seed tuber ages were not significant. However, as previously reported by Kumar and Knowles (1993), a 6 month storage period was optimal in terms of growth vigor and canopy structure. Reports also indicted that planting physiologically older seed tubers results in smaller plants with more stems and promotes earlier tuberization and senescence (Ewing, 1997). This is may be due to the same harvesting time that halts growth of tubers stored for short period.

Leaf area

The results showed significant ($P<0.05$) variation with respect to total leaf area per plant between cultivars and among the seed tuber storage durations (Table 3). Cultivar Guassa produced more leaf areas (3411.90 cm^2) per plant as compared to that of Zengena (2058.80 cm^2) (Table 2). The highest average leaf area per hill (3393.60 cm^2) was recorded from 6 months old seed tubers of both cultivars (Table 3). However, 7 months old seed tubers have produced lower leaf area (2921.2 cm^2). Similarly, growth characterization study of Mikitzel and Knowles (1990) showed that the production of more leaves in older seed tuber occurred at the expense of dry matter accumulation per leaf and resulted in greatly reduced leaf area per shoot and leaf. Similar report by Wieresema (1989) indicated that older seed tubers have longer sprouts and earlier emergence, canopy development and tuber initiation but may also show a lower leaf area or ground cover.

Table 2. Plant height, leaf area per plant, days to flowering and physiological maturity of potato as affected by the main effect of cultivar and seed tuber storage durations

Main effect	Plant height (cm)	Leaf area (cm^2)	Days to flowering	Days to physiological maturity
Variety				
Guassa	49.39b	3411.9a	61.55	109.89a
Zengena	61.90a	2058.8b	61.44	105.89b
LSD (5%)	3.9	492	ns	2.1
Storage duration				
7 months old	53.25	2921.2b	53.00d	97.50d
6 months old	58.57	3393.6a	53.67d	98.83d
5 months old	58.43	2218.3b	61.00c	106.83c
4 months old	52.78	2669.5b	63.00c	109.10c
3 months old	55.52	2587.4b	65.33b	113.33b
2 months old	55.33	2626.2b	73.00a	121.33a
LSD (5%)	ns	852.4	2.05	3.58
CV (%)	10.13	26.03	2.79	2.77

Ns,* non-significant and significantly different at P<0.05, respectively; Means followed by the same letter are not significantly different at P<0.05.

Main stem number hill^{-1}

Statistically significant (P<0.05) differences were observed between cultivars and among different seed tuber storage durations with respect to number of main stems hill^{-1} (Table 3). Guassa produced significantly higher number of stem hill^{-1} than Zengena. Seed tubers stored for six months resulted in significantly higher number of main stems per hill followed by seven months old tubers (Table 3). Seed tubers stored for 2, 3 and 4 months gave the lowest and comparable number of stems per hill (Table 3). In favor of this result, Kawakami (1952) reported that the difference in the number of main stems of different cultivars is due to the basic correlation between the age of seed tubers and the number of tubers those sprouted.

Biomass yield

A significant variation ($P<0.05$) in above ground and underground dry biomass was observed between cultivars and among seed tuber ages (Table 3). Guassa produced higher aboveground and underground dry biomass than Zengena (Table 3). Mikitzel and Knowles (1990) indicated that plants from old seed tubers displayed reduced shoot, root and leaf dry weights and these effects reflect altered dry matter partitioning and contributed to an overall change in plant morphology with advanced tuber age.

Table 3. Stem number per hill, aboveground dry biomass and underground dry biomass yield of potato as affected by cultivar and seed tuber storage duration.

Main effect	Stem number $hill^{-1}$	Aboveground dry biomass (g $hill^{-1}$)	Underground dry biomass (g $hill^{-1}$)
Variety			
Guassa	3.17a	64.95a	12.85a
Zengena	1.99b	58.02b	11.82b
LSD (5%)	0.40	2.44	0.97
Storage duration			
7 months old	3.50b	65.55b	11.47b
6 months old	4.40a	77.47a	16.64a
5 months old	2.27c	66.28b	12.06b
4 months old	1.95cd	56.90c	11.39b
3 months old	1.98cd	54.38c	11.21b
2 months old	1.40d	48.35d	11.23b
LSD (5%)	0.70	4.22	1.69
CV (%)	22.64	5.74	11.44

Ns,*: non-significant and significant at 0.05 probability level, respectively; Means of the same main effect within a column followed by the same letter are not significantly different at 0.05 probability level.

Tuber number hill^{-1}

Variety and seed tuber storage duration significantly ($P<0.05$) affected seed tuber number hill^{-1} (Table 4). Guassa produced significantly higher number of tubers per hill than Zengena (Table 4). The number of tubers increased with the increase in seed tuber age and the highest mean tuber number was observed for 6 months old seed tuber while the lowest was from 2 months old seed tuber (Table 4).

Average tuber weight

Statistically significant ($P<0.05$) differences were observed between the cultivars and among seed tuber storage durations with regard to average tuber weight (Table 4). However, the interaction effects of cultivar and seed tuber storage durations were found to be non-significant. Guassa gave higher average tuber weight than that of Zengena (Table 4). Six months stored seed tubers of both cultivars produced large tubers as compared to 7 months stored seed tubers (Table 4). Studies by Knowels *et al* (2003) showed a shift in tuber size distribution in relation to stem number per plant as affected by seed tuber age in storage.

Tuber specific gravity and dry matter content

Tuber specific gravity and dry matter content were not significantly ($P<0.05$) influenced by cultivar and their interaction effect with seed tuber storage durations. However, both parameters were significantly affected by seed tuber storage durations (Table 4). Tubers with the highest specific gravity (1.100 g cm^{-3}) and dry matter content (23%) were obtained from 6 months old seed tubers. This indicated that six months seed tubers are optimal for these cultivars to potatoes suitable for processing at Adet and similar environments.

Marketable and total tuber yield

Variety and seed tuber storage duration significantly ($P<0.05$) affected marketable and total tuber yield per hectare of potato. Variety Guassa consistently produced higher marketable (24.66 ton ha^{-1}), and total tuber yield (27.29 ton ha^{-1}) than Zengena (Table 5).

Table 4. Effect of cultivar and seed tuber storage duration on tuber number hill^{-1}, tuber weight, tuber specific gravity and dry matter at Adet

Main effect	Tuber number hill^{-1}	Average tuber weight (g)	Specific gravity (g cm^{-3})	Dry matter Content (%)
Variety				
Guassa	12.6a	83.84a	1.0850	19.54
Zengena	9.8b	74.21b	1.0867	19.94
LSD (5%)	1.47	9.07	ns	ns
Storage duration				
7 months old	14.0a	76.63b	1.0867b	21.83b
6 months old	14.7a	92.38a	1.1000a	23.00a
5 months old	11.0b	77.05ab	1.0850b	19.33bc
4 months old	10.0bc	78.50ab	1.0850b	18.50c
3 months old	9.2bc	79.67ab	1.0817bc	17.83c
2 months old	7.7c	69.93b	1.0767c	17.67c
LSD (5%)	2.5	15.71	0.008	2.65
CV (%)	19.01	16.60	0.62	11.23

*: significantly different at 0.05 probability level; Means of the same main effect within a column followed by the same letter are not significantly different at 0.05 probability level.

In the present study, the maximum marketable and total tuber yield were obtained from 6 month stored tubers. Meyling and Bodlaender (1981) reported that inter-varietal differences in tuber yield of potato cultivars were largely due to differences in dry matter production. Caldiz *et al.* (1996) also indicated that because of high rate of dry matter accumulation, plants coming from physiologically young seed tubers produce maximum tuber yield. Results of the present study were also supported by Kawakami (1962) who explained that seed tuber aging is physiological degeneration or loss of ability of a seed tuber to produce plants with high yield potential through its effect on tuber yield per plant.

Table 5 Effect of cultivar and seed tuber storage duration on marketable, unmarketable tuber yield and total tuber yield.

Main effect	Marketable yield (ton ha^{-1})	Total yield (ton ha^{-1})
Variety		
Guassa	24.66a	27.29a
Zengena	18.52b	20.55b
LSD (5 %)	2.7	2.7
Storage duration		
7 months old	17.90b	20.66b
6 months old	27.01a	30.30a
5 months old	20.45b	23.08b
4 months old	21.16b	23.01b
3 months old	21.89b	23.75b
2 months old	21.11b	22.72b
LSD (5%)	4.68	4.64
CV (%)	18.11	16.20

Ns,* non significant and significantly different at 0.05 probability level, respectively; Means of the same main effect within a column followed by the same letter are not significantly different at 0.05 probability level.

Conclusions

Results of the study showed that varieties responded differently to seed tuber storage durations for some of the parameters considered. It was observed that storage of seed tubers for 6 months significantly shortened days to emergence, flowering and maturity, increased stem and tuber number as compared to other storage periods. Irrespective of the cultivars, the highest tuber yield (30.3 ton ha^{-1}) was harvested from 6 months old seed tubers whereas lowest (20.66 ton ha^{-1}) was from 7 months old tubers though it was statistically non significant as compared to the remaining storage periods.. It is indicate that compared to 6 months old tubers, 7 months storage period resulted in 32% yield reduction. The highest specific gravity values (1.1000 gcm^{-3}) and tuber dry matter content of (23.67%) was recorded from 6 months stored tubers. As a conclusion, storing seed tubers of Guassa and Zengena and morphologically similar potato cultivars for six months can give optimum potato production for Adet and similar edaphic and climatic conditions.

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