academicresearchJournals

Vol. 6(5), pp. 266-275, June 2018
DOI: 10.14662/ARJASR2018.023

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

Academic Research Journal of Agricultural Science and Research

Full Length Research

Response of Potato Varieties for Extended Harvesting at Kulumsa, Southeast Ethiopia

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Accepted 7 June 2018

An experiment was carried out to identify potato varieties that are suitable for extended harvesting with better tuber yield, quality and reduced losses. Four improved (Belete, Gudene, Dagem and Gera) and one local variety were evaluated under five extended harvesting periods (harvest at maturity as control, 30, 60, 90 and 120 days after 1st harvest) arranged in a 5x5 factorial combinations using a randomized complete block design (RCBD) with three replications. Data were collected from five net rows per plot, each represented the different harvesting period. Data were subjected to analysis of variance (ANOVA) and means were compared using Least Significant Difference (LSD) test at 5% probability level. Simple correlation analysis was undertaken to determine the degree of association of characters. ANOVA showed that the main effects i.e. variety and harvesting periods highly significantly (P<0.01) affected days to 50% flowering, days to physiological maturity, total and marketable tuber yield; whereas variety by harvesting period interaction effects were significant (P<0.05) for unmarketable tuber yield, tuber specific gravity, tuber dry matter and starch content. A maximum of 87.09% and a minimum of 21.57% unmarketable yield was obtained from local and Gudene varieties from 5th (120 days) and 1st harvesting periods respectively. The results suggest that farmers around Kulumsa who do not have modern potato store can extend potato harvesting on clay loam soil with soil moisture content of 15.22 to16.12%, up to 120 days after physiological maturity using variety Gudene and up to 90 days using variety Dagem without compromising for marketable tuber yield and quality. However, the present results imply that further studies need to be conducted to compare the effect of extended harvesting practice with that of modern ware potato storage with regard to yield, quality loss and economic benefit.

Keywords: *Solanum tuberosum*; Harvesting periods and yield

Cite this article as: Birsh TA, Mengistu FG, Nebiyu A, Mohammed A (2018). Response of Potato Varieties for Extended Harvesting at Kulumsa, Southeast Ethiopia. Acad. Res. J. Agri. Sci. Res. 6(5): 266-275

INTRODUCTION

Ethiopia is endowed with suitable climatic and edaphic conditions for high quality ware and seed potato production. About 70% of the available agricultural land is located at an altitude of 1800-2500 m. a.s.l and receives an annual rainfall of more than 600 mm, which is suitable for potato production (Solomon, 1987). Potato is widely grown in Amhara, Oromia, Tigray and Southern Nations Nationalities and Peoples Regional State which together constitute approximately 99.5% of the potato farmers in the country (CSA, 2013). However, the national average yield is 8 -10 t ha^{-1}, which is very low compared to the world's average of 17 t ha^{-1} and to other potato producing countries of the world, such as the Netherlands (46 t ha^{-1}), Germany (45 t ha^{-1}), South Africa (34 t ha^{-1}), Egypt (26 t ha^{-1}) and Zimbabwe (16 t ha^{-1}) (FAOSTAT, 2011).

Potato is dominantly produced in all Arsi highland areas particularly in Tiyo district - Kulumsa PA from crop land of 43.6% (FAO, 2008). In addition to the 'Belg' season, farmers in the area produce potatoes in the rainy season because of the increasing demand of the crop, and to maximize the productivity of the land per unit area due to the subsequent decrease of the average farm land size. The potato varieties grown in the area include Holand and Gojam (local), and Tolcha and Jalene (improved), which are old and low yielding due to susceptibility to late blight disease. Hence, the productivity of the crop under farmer's management ranges from 8 to 15 t ha-1 (Arsi Zone ARDO, 2007) which is very low as compared to that of the research management (>20 t ha-1). The leading problems associated with the very low yield are lack of improved varieties and use of inferior quality seed tubers of unknown origin, high disease incidence (mainly late blight), insect damage such as Potato Tuber Moth (PTM), lack of proper crop management practices, inappropriate storage structure, poor seed system and poor research-extension linkage (Gebremedhin *et al.,* 2008). Moreover, lack of storage facilities for seed and ware potatoes and traditional storage system used by many farmers contribute to severe losses of potatoes in the storage. About 30-50% of the annual production is lost after harvest because of poor farm- and village-level storage system (Buys and Nortje, 1997).

Storage of potatoes is very important because fresh potatoes are available only for a few months in a year. In Ethiopia, potatoes are stored for ware and seed. Farmers in Arsi use different traditional potato storage systems such as underground storage, floor storage, raised beds and in sacks depending on the intended use (ware or seed). A successful potato production in the tropic depends on the storage conditions of the mother tubers and on temperatures after planting. The lack of proper storage facilities is one of the main factors that farmers face in Ethiopia particularly in the highlands of Arsi which forces them to sell their produce during harvesting where prices at the market are very low. So a change in the market situation may also bring the need to look for other storage methods. Both seed and ware potato storage is a serious challenge to most farmers, leading to storage losses of up to 50% and sometimes even higher (Borgle *et al*., 1980). In the absence of storage technologies and bulkiness of the product, farmers in the highlands of Arsi store their tubers in ground (leave it un-harvested and extend the harvesting period). This storage system is mostly preferred for ware potato due to high dry matter content (Berga, 1982). Hence, these methods protect the product reasonably well but need slight improvements. The extended harvesting storage performance and loss, however, was noted to vary depending on the type of potato varieties. Moreover information on the evaluation of potato varieties for extended harvesting under highlands of Arsi-Kulumsa conditions is rare. In order to alleviate potato storage problems, it is important to evaluate the currently released improved potato varieties for extended harvesting. In view of this, the present study was conducted to determine the extent of delayed harvesting for selected potato varieties with maximum yield and quality of tubers and to assess the yield loss (in relation to un-marketability) from extended harvesting.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Kulumsa Agricultural Research Center (KARC) from March to January 2013/2014 cropping season. KARC is located in Oromia regional state, Arsi zone at Kulumsa, 160 km Southeast of Addis Ababa; 8 kms to the north of Asella town; 8^0 N latitude and 39^0 E, longitude with an average altitude of 2241 meters above sea level (FAO, 2007). The rainfall pattern in the area is bi-modal and almost all part of the area receives high rainfall during the main rainy season with long wet period. The main rainy season begins in June and extends to September. The short rainy season, under normal condition, starts in February and extends to April. The mean annual rainfall at KARC is 823 mm whereas the mean maximum and minimum temperatures are 22.9°C and 10.3°C, respectively.

Treatments and Experimental Design

The experiment was laid out using a Randomized Complete Block Design (RCBD) with a factorial arrangement in three replications. The experiment was conducted with a plot size of 5mx5m in which seed tubers of each variety were planted at a depth of 10cm with 75cm (inter-row) and 30cm (intra-row) spacing. The experiment was conducted with the following treatment of five potato varieties such as Belete, Gudene, Dagim, Gera and local and five extended harvesting periods; such as: harvest at maturity as control depending on the maturity time of each variety, 30, 60, 90 and 120 days after 1st harvest. At crop maturity of the first harvest, dehaulming was done 7 days before harvesting to set tubers' skin so as to minimize bruising and skinning. The tubers were then harvested based on different maturity stages of the varieties according to the extended harvesting treatments. The other management was applied as the recommended practice of potato production.

Data Collection

The first harvest was done when plants are matured and ready for harvest (normal harvesting) i.e., when haulms are dry. The rest treatments continued accordingly. For each treatment combination, the necessary agronomic, yield and quality data were collected. Data collected were days to 50% flowering, days to physiological maturity, total tuber yield (t ha^{-1}), marketable tuber yield (t ha^{-1}), unmarketable tuber yield (t ha^{-1}), tuber specific gravity (gcm^{-3}), tuber dry matter content (%), and starch content (%).

Data analyses

Analysis of variance (ANOVA) normality assumption for each parameter was conducted by Minitab software Version16 (Minitab Inc., 2007) and then data were subjected to ANOVA, using SAS statistical software Version 9.2 (SAS, Institute Inc., 2008). Means of significant differences were compared using Least Significant Difference (LSD) test at 5% probability level (Montgomery, 2005). Simple correlation analysis was undertaken to determine the degree of association of characters, to test their significance difference statistically and to compare characters correlation coefficients against r -values using SAS version 9.2 (Snedecor and Cochran, 1989). The ANOVA model used for analysis was:

$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \epsilon_{ijk}$

Where, yijk = the response measures for the ijkth observations

μ = the overall mean effects

αi = the effects of ith level of variety i = 1-5

βj = the effects of the jth level of harvesting time j = 0-5

(αβ) ij = the interaction effects between variety and harvesting time

ϵijk = the random error compared for the whole factor

k = number of replication

RESULTS AND DISCUSSION

Tuber yield. The interaction effect of variety and extended harvesting time on total yield was not significant (P >0.05). However, the main effects (variety and extended harvesting) independently have shown highly significant (P<0.001) effects on total yield (Table 1). Among the treatments, the highest total yield with mean value of 56.07 t ha^{-1} was gained from Gudene. This result however, is statistically similar with Dagem and Local check (52.39, 50.55 t ha^{-1}), respectively whereas, the lowest total yield (35.66 t ha^{-1}), was obtained from Gera variety and it was also statistically similar with Belete (37.93 t ha^{-1}) (Table 2). The difference in plant yield might be due to high yielding potential or efficiency of the variety. These finding supported by the work of Meyling and Bodlaender (1981) who reported that, inter-varietal differences in tuber yield of potato cultivars were largely due to differences in dry matter production. On the other hand, harvesting time showed a significant difference (P<0.001) in respect of total yield. Highest total yield was recorded at 1st harvest (59.23 t ha^{-1}) and lowest yield (40.23 t ha^{-1}) was obtained at 5th (last) harvest (250 days) (Table 2). Regarding correlation, total tuber yield was highly positively correlated with marketable yield at (r = 0.84***) (Table 3).

Marketable tuber yield (t ha^{-1}) is highly significantly (P<0.001) affected by the main effects (Table 1). However, it was not significantly (P>0.05) affected by the interaction of variety and harvesting time. The highest marketable yield was recorded from Gudene (34.30 t ha^{-1}) whereas the lowest was gained from Belete, Local and Gera respectively(Table 2). Harvesting time also imparted a significant (P<0.001) difference on marketable yields (Table 2). Significantly high marketable yield was observed at first harvest (36.22 t ha^{-1}) and low marketable yield (11.43 t ha^{-1}) was noted at last harvest. As harvesting time delayed, marketable yield also decreased. This is because of rotting, disease, insect pests, greening and sprouting. Moreover, tuber physical damage during harvesting affects the marketability of potato tuber as well as the quality of tuber to use as planting materials. On the contrary, marketable yield was negatively correlated with unmarketable tuber yield (r=-0.85***) (Table 3). This implies that when harvesting time extends, the marketable yield decreased, unmarketable yield increased due to the above mentioned reasons.

Unmarketable tuber yield was significantly (P< 0.05) affected by the interaction effect of variety and harvesting time (Table 1). The highest (38.95, 37.24 t ha^{-1}) was obtained at 5th and 4th harvest from Dagem and local check respectively. In relation to highest unmarketable yield, statistically identical result was recorded at 5th and 2nd harvests from local check. The lowest unmarketable tuber yield (15.32, 15.38 t ha^{-1}) was registered at 2nd harvest from Gera and Gudene varieties with statistically similar value of 1st, 3rd, 4th, 5th harvests of Gera and 2nd, 3rd, 4th, 5th harvests of Belete variety in addition to 1st, 2nd, 3rd harvests of Dagem and 3rd harvest of Gudene (Table 4). However, the above mentioned unmarketable yield result could not give a real picture for unmarketable yield in percent mentioned in Table 5.

The reason for the higher percent of unmarketable yield was attributed to the observed problems such as

Table 1. P-values for total, marketable, unmarketable yield and percent of unmarketable yield loss.

Sources of variation	Degree of freedom	Total yield (t ha^{-1})	Marketable yield (t ha^{-1})	Unmarketable yield (t ha^{-1})	Unmarketable yield loss (%)
Variety	4	<.0001***	<.0001***	<.0001***	<.0001***
Harvest time	4	<.0001***	<.0001***	<.0001***	<.0001***
Var*Hart	16	0.5031^{ns}	0.2677^{ns}	0.0216**	<.0001***
Replication	2	0.1334^{ns}	0.2091^{ns}	0.2796^{ns}	0.7267^{ns}
CV (%)	-	16.86	21.16	19.01	7.18

*ns, *, ** and ***= Indicates the p-value is non-significant, significant, highly significant and very highly significant difference at P≤ 0.05 and P ≤ 0.01 respectively,*

Table 2. Mean effect of potato varieties and extended harvesting time on total and marketable tuber yield.

Varieties	Total yield (t ha^{-1})	Marketable Yield (t ha^{-1})
Local	50.55^{a}	19.33^{c}
Gudene	56.07^{a}	34.30^{a}
Belete	37.93^{b}	16.65^{c}
Dagem	52.39^{a}	26.67^{b}
Gera	35.66^{b}	17.89^{c}
LSD (5%)	5.76	3.57
Extended harvesting time		
1st harvest- When plant mature	59.23^{a}	36.22^{a}
2nd harvest- 30 days after 1st harvest	46.55^{b}	28.27^{b}
3rd harvest-60 days after 1st harvest	44.82^{bc}	23.06^{c}
4th harvest-90 days after 1st harvest	41.76^{bc}	15.84^{d}
5th harvest-120 days after 1st harvest	40.23^{c}	11.43^{e}
LSD (5%)	5.76	3.57
CV (%)	16.86	21.16

Means followed by different letters differ significantly (P < 0.05)

bruising, greening, sprouting, rotting, insect damage, shrinkage and undersized tubers. Out of which sprouting at last harvest time was the most important reason for unmarketablity. This result is in line with the work of Berga (1982), who reported that, the marketable yield was found to decrease by about 60% at 210 days as opposed to 120 days and the major contributor for loss of yield was potato tuber moth (PTM) and also Burton and Hartmans (1992) strengthened the idea by reporting that storage losses mainly caused by respiration, evaporation of water from tubers, and spread of disease. On the other hand, Hayma (2003), reported that, much of the theory of the storage of agricultural products depends on the relative humidity of the air, and the moisture content of the products. This is due to the fact that well-developed periderm helps to minimize water loss and resist entrance of disease causing pathogens in to the tuber during storage life of potato tuber.

Quality parameters. Tuber dry matter contents and specific gravity of potato are predictors of the tubers' end use quality. The interaction effect of variety with

Table 3. Simple correlation of growth, yield and quality parameters

	DTF	DTM	TYE	MYE	UMYE	UMYP	SG	DM	ST
DTF	1								
DTM	0.97***	1							
TYE	-0.37^{ns}	-0.353^{ns}	1						
MTYE	-0.68**	-0.66**	0.84***	1					
UMYE	0.29^{ns}	0.28^{ns}	0.63*	0.09**	1				
UMYP	0.77***	0.75***	-0.42^{ns}	-0.85***	0.43^{ns}	1			
SG	-0.39^{ns}	-0.27^{ns}	-0.28^{ns}	-0.12**	-0.34^{ns}	-0.08**	1		
DM	-0.42^{ns}	-0.27^{ns}	0.09**	0.15^{ns}	-0.02**	-0.16^{ns}	0.35^{ns}	1	
ST	-0.39^{ns}	-0.27^{ns}	-0.28^{ns}	-0.12**	-0.34^{ns}	-0.08*	1.00**	0.35*	1

DF= days to 50% flowering, DM=days to physiological maturity, TYE = Total yield t ha-1, MYE= Marketable yield t ha-1, UMYE- - UN marketable yield (t ha-1), UMYP UN marketable yield (%), TSG = Tuber specific gravity (gcm3), TDMC=Tuber dry matter content (%), SC=starch content (%)
*Ns, *, ** and *** = Indicates that correlation is non-significant, significant, highly and very highly significant difference at P<0.05=0.67 and P<0.01=0.80 respectively for df = n-2, where n is the sample size.*

Table 4. Interaction effect of potato varieties and extended harvesting time on unmarketable tuber yield.

Varieties	Unmarketable yield (t ha-1) Per harvesting time				
	1st harvest	2nd harvest	3rd harvest	4th harvest	5th harvest
Local	25.28^{dc}	24.65^{dc}	33.44^{ab}	37.24^{a}	35.49^{ab}
Belete	25.33^{dc}	16.94^{ef}	19.01^{def}	22.71^{cdef}	22.40^{cdef}
Gera	20.32^{def}	15.32^{f}	16.19^{ef}	18.60^{def}	18.44^{def}
Dagem	22.61^{cdef}	19.09^{def}	21.57^{cdef}	28.12^{bc}	38.95^{a}
Gudene	23.21^{cde}	15.38^{f}	18.58^{def}	22.94^{cde}	28.74^{bc}
Mean					
LSD (5%)	7.41				
CV (%)	19.13				

1. *Means followed by different letters differ significantly (P < 0.05)*
2. *Description of harvesting time - 1st harvest- When plant mature, 2nd harvest- 30 days after 1st harvest, 3rd harvest-60 days after 1st harvest, 4th harvest-90 days after 1st harvest, 5th harvest-120 days after 1st harvest*

harvesting time showed a statistically significant (P < 0.001) effect on tuber specific gravity, tuber dry matter and starch content among the treatments (Table 6).

Tuber specific gravity. The highest (1.26 gcm^{-3}) was obtained at the 3rd harvest from Belete variety and this result was statistically similar with Belete at the 4th

Table 5. Interaction effect of potato varieties and extended harvesting time on unmarketable tuber yield percentage.

Varieties	Unmarketable yield (%) Per harvesting time				
	1st harvest	2nd harvest	3rd harvest	4th harvest	5th harvest
Local	35.30[hij]	45.88[e]	62.38[c]	76.97[b]	87.09[a]
Belete	37.85[ghi]	45.95[e]	55.44[d]	63.28[c]	74.80[b]
Gera	32.30[ij]	39.06[fgh]	45.70[e]	62.10[c]	75.10[b]
Dagem	22.61[k]	36.81[hi]	42.83[efg]	66.44[c]	73.55[b]
Gudene	21.57[k]	30.24[j]	37.02[ghi]	44.28[ef]	54.59[d]
Mean	50.77				
LSD (5%)	5.89				
CV (%)	7.18				

3. *Means followed by different letters differ significantly (P < 0.05)*
4. *Description of harvesting time - 1st harvest- When plant mature, 2nd harvest- 30 days after 1st harvest, 3rd harvest-60 days after 1st harvest, 4th harvest-90 days after 1st harvest, 5th harvest-120 days after 1st harvest.*

Table 6. P- values for tubers specific gravity, tuber dry matter content and starch content

Sources of variation	Degree of freedom	Tuber Specific gravity (g/cm^3)	Tuber dry matter content (%)	Starch content (%)
Variety	4	<.0001***	<.0001***	<.0001***
Harvest time	4	<.0001***	<.0001***	<.0001***
Var*Hart	16	<.0001***	<.0001***	<.0001***
Replication	2	0.1901[ns]	0.8153[ns]	0.1899[ns]
CV (%)	-	0.84	8.41	5.88

*ns, *, ** and ***= Indicates the p-value is non-significant, significant, highly significant and very highly significant difference at P≤ 0.05 and P ≤ 0.01 respectively*

harvest (1.25 gcm^{-3}). The lowest tuber specific gravity (1.16 gcm^{-3}), on the other hand, was obtained at the 1st harvest of the Local check (Table 7). This result was statistically similar with the value obtained at the 1st harvest of Belete, Dagem and Gera with related mean value of 1.17gcm^{-3} for all 2nd harvests of Local check, Belete, Dagem and Gera with comparable value of 1.17 gcm^{-3}, at 3rd harvest of Gera (1.17 gcm^{-3}), 4th harvest of Local check and Gera with equivalent value of 1.17 gcm^{-3} and 5th harvest of Local check, Belete, Dagem and Gera at comparable mean value of 1.17gcm^{-3}. The reason for the observed variation in specific gravity among varieties through different harvesting time could be due to their genetic difference, physiological maturity, and storage condition. Regarding maximum quality of tubers and their storability, Asmamaw (2007) reported that, cultivars with high specific gravity and dry matter content can be stored for longer period at ambient temperature without significant quality deterioration. Freitas *et al*. (2012) also reported a significant decreasing trend in the specific gravity and dry matter contents of the potato tubers stored for 180 days. Moreover, Alemu *et al.* (2013) observed that there is an increase in tuber specific gravity and dry matter content at six month storage duration and then declined. However, this also depends on variety. Generally potato tubers with dry matter contents greater than 20% and specific gravity of greater than 1.08 gcm^{-3} are the most preferred for processing of tuber into different potato products, while less than 1.070 gcm^{-3} are generally unacceptable for processing (Jackson and Berga, 2003; Lefort *et al*., 2003; Abebe *et al*., 2013). In addition to these, Rommens *et al*.(2010) stated that tubers with high dry matter and specific gravity generally give higher yields of French fries or chips of low oil

Table 7. Interaction effect of potato varieties and extended harvesting time on tubers' specific gravity

Varieties	Tuber Specific gravity (gcm^3) per harvesting time				
	1st harvest	2nd harvest	3rd harvest	4th harvest	5th harvest
Local	1.16^{f}	1.165^{f}	1.18^{bcd}	1.17^{cdef}	1.16^{ef}
Gudene	1.19^{b}	1.18^{bc}	1.176^{bcde}	1.18^{bcd}	1.176^{bcde}
Belete	1.17^{cdef}	1.17^{cdef}	1.26^{a}	1.25^{a}	1.17^{cdef}
Dagem	1.17^{cdef}	1.17^{cdef}	1.176^{bcde}	1.176^{bcde}	1.17^{cdef}
Gera	1.17^{cdef}	1.17^{cdef}	1.17^{cdef}	1.17^{cdef}	1.17^{def}
Mean	1.18				
LSD (5%)	0.017				
CV (%)	0.84				

1. *Means followed by different letters differ significantly (P < 0.05)*
2. *Description of harvesting time - 1st harvest - When plant mature, 2nd harvest - 30 days after 1st harvest, 3rd harvest - 60 days after 1st harvest, 4th harvest-90 days after 1st harvest, 5thharvest-120 days after 1st harvest*

Table 8. Interaction effect of potato varieties and extended harvesting time on tubers' dry matter content.

Varieties	Tuber dry matter content (%) per harvesting time				
	1st harvest	2nd harvest	3rd harvest	4th harvest	5th harvest
Local	23.64^{fghi}	21.24^{hijk}	17.62^{l}	28.71^{d}	17.55^{l}
Gudene	27.19^{de}	24.38^{efgh}	21.72^{ghijk}	21.82^{ghijk}	21.72^{ghijk}
Belete	37.68^{b}	33.64^{c}	19.66^{kl}	20.35^{ijkl}	20.90^{ijkl}
Dagem	43.22^{a}	38.47^{b}	21.45^{ghijk}	25.92^{def}	20.13^{jkl}
Gera	25.50^{def}	23.26^{fghij}	20.34^{ijkl}	24.66^{efg}	19.38^{kl}
Mean	24.81				
LSD (5%)	3.37				
CV (%)	8.41				

1. *Means followed by different letters differ significantly (P < 0.05)*
2. *Description of harvesting time - 1st harvest- When plant mature, 2nd harvest- 30 days after 1st harvest, 3rd harvest-60 days after 1st harvest, 4th harvest-90 days after 1st harvest, 5thharvest-120 days after 1st harvest*

absorption (less calorie impact benefit to health) and better texture and are more economical to process. On the other hand, tuber specific gravity was also significantly and positively correlated with starch content (r = 1.00**) (Table 3).

Tuber dry matter content. Varieties with extended harvesting time resulted in highly significant (P<0.001) effect on tuber dry matter content (Table 6). Significantly the highest tuber dry matter content (43.22%) was obtained from Dagem variety at the 1st harvest while the lowest (17.55%) was obtained from Local check at the 5th harvest. The smallest value is statistically similar with 3rd harvest of Local check, Belete, and Gera with mean value of 17.62, 19.66, and 20.34% respectively, 4th harvest of Belete (20.35%), 5th harvest of Belete, Dagem and Gera (20.90, 20.13, 19.38% respectively) (Table 8). The variation in tuber dry matter content could be due to the inherent genetic variation among the cultivars, maturity and growth pattern, climate and poor to medium soil fertility status of the experimental site. This finding is also in coherence with Gawronska *et al.* (1990) who stated that tuber dry matter could vary due to cultivars difference in terms of the rate of photosynthesis production and distribution. Furthermore, the study conducted at Holetta Agricultural Research Center in Ethiopia by Gebremedhin *et al.* (2008) showed that, potatoes produced in the off-season had higher tuber dry matter content and tuber specific gravity than from the main season potato for most of the varieties. Moreover, stored potatoes from main and off-season production had acceptable dry matter and tuber specific gravity for processing. Potatoes with a tuber dry matter content of 20-24% are an ideal of making French fries. While those with a dry matter of up to 24% are also promising for preparing crisps (Kabira and Berga, 2003).

Starch content. The interaction effect of varieties and extended harvesting time showed highly significant (P<0.001) effect on starch content (Table 6). The maximum starch content (48.99%) was recorded from Belete variety at the 3rd harvest which makes it highly preferred for processing. This result is statistically significant with the value registered for variety Belete (47.00%) at the 4th harvest. The minimum starch content was, however, registered from the Local check (29.75%) at the 1st harvest. This value is also statistically comparable with that of Belete, Dagem and Gera (32.40, 32.40, 31.74 % respectively) at their 1st harvest, the 2nd harvest of Local, Gudene, Belete, Dagem and Gera (29.76, 34.39, 32.40, 32.40 % respectively), the 3rd harvest from Gera (31.74%), the 4th harvest of Local and Gera (32.40, 31.74% respectively) and the 5th harvest from varieties Local, Belete, Dagem and Gera (30.41, 32.40, 32.40, and 31.08% respectively) (Table 8).

Tuber's starch content was influenced by extended harvesting, particularly Belete variety. The contributing factor for the variation in starch content among varieties with harvesting time could be cultivar difference. These findings are also supported by the work of Olsen and Brandt(2003) who reported that starch yield was significantly reduced after three months of storage, due to weight loss and reduction in the starch content in the tubers. The maximum losses occurred during the first month of storage.

Simple correlation analysis was performed among growth, yield and quality parameters (Table 3) in order to determine the degree of association among characters, to test for their significance and compare characters correlation coefficients against r -values. The results of this analysis revealed the presence of a strong, positive association between DTF and DTM ($r = 0.97$; $P < 0.01$), DTF and UMYP ($r = 0.77$; $P < 0.05$), DTM and UMYP ($r = 0.75$; $P < 0.05$), TTY and MYE ($r = 0.84$; $P < 0.01$), TTY and UMYE ($r = 0.63$; $P < 0.05$), TTY and TDM ($r = 0.09$; $P < 0.01$), MYE and UMYE ($r = 0.09 < 0.01$), TSG and SC ($r = 1.00$; $P < 0.01$), TDM and ST ($r = 0.34$; $P < 0.01$) (Table 3).

CONCLUSION AND RECOMMENDATIONS

Results of the study revealed that five of the varieties responded differently to harvesting periods. It can be noted that delayed and early matured varieties could shorten and extend time of harvesting, respectively and hence could affect the extent of variation in terms of yield and loss among varieties. Besides, time of harvesting also affected marketable tuber yield, which decreased as time of harvesting extended. Irrespective of harvesting time, the maximum and minimum (34.30, 16.65 t ha^{-1} respectively) marketable yield were also noted from Gudene and Belete varieties respectively. The highest (38.95, 37.24 t ha^{-1}) unmarketable yield was obtained at 5th and 4th harvests from local check and Dagem varieties respectively. While the lowest (15.32, 15.38 t ha^{-1}) was gained at 2nd harvest from Gera and Gudene variety. The maximum unmarketable yield percent (87.09 %) was observed from Local check at the 5th harvest (120 days) whereas the lowest (21.57, 22.61%) were registered at 1st harvest from Gudene and Dagem varieties respectively. Likewise, quality attributes such as tuber's specific gravity, dry matter & starch content were affected by variety and harvesting time although the degree to which varieties responded to the harvesting times varies. However, beyond the 3rd harvest (60 days from 1st harvest), the quality of all varieties, except Gudene, began to decline to the extent that tubers became unacceptable for processing.

Finally, the present results suggest that, small-scale growers around Kulumsa area, who do not have modern potato store can extend potato harvesting on clay loam soil with soil moisture content of 15.22 to 16.12 % under dry conditions, up to 120 days after physiological maturity using variety Gudene and up to 90 days using variety Dagem without compromising marketable tuber yield. On quality aspect, extended time of harvesting up to 90 days after normal harvest favors for high tuber specific gravity, dry matter & starch production on Belete variety. Harvesting Dagem variety at physiological maturity gives also excellent dry matter. Cognizant of the fact that the study was conducted only for one season and in a single location as future line of works, it would be wise to have further study by considering diverse agro-ecology, soil types, and different varieties. Moreover, studies should have detailed economic analysis of the practices to see the opportunity cost due to land occupation from extended harvesting. Effect of extended harvesting on yield loss and quality aspect needs to be thoroughly investigated and compared with that of modern ware potato storage.

ACKNOWLEDGEMENT

The authors are deeply indebted to Arsi Zone Water, Mine and Energy office for realizing the study and Kulumsa Agricultural Research Center (KARC) for supporting with the research components (working area, materials and technical support) of the study. We would like to extend our appreciation to all Horticulture Research Department staffs, especially Mr. Zewge Behiru, Mr. Getachew Kebede, Mr. Hailu Yai and Mrs. Asha, for their tremendous assistance throughout the study. We also extend our gratitude to JUCAVM and Department of Horticulture and Plant Science of Jimma University for the continuous assistance and help during the study period to accomplish the work.

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