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Evaluation of Yield and Yield Related Attributes of Potato (solanum tuberosum L.) Varieties in East Gojjam Zone, Ethiopia

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Abstract
In Ethiopia, a number of improved potato varieties have been released by different research centers; with much emphasis for productivity, while it has been given less or no emphasis to adaptability to different agro ecologies and resistance against late blight resistance. Therefore, field experiments at Debre Markos university and Abazash nursery site and laboratory experiments at Debre Markos university were conducted to evaluate yield, yield component and tuber qualities of five released varieties (Belete, Bubu, Gudenie, Gera and Jalenie) and one local cultivar (Demmie) for two consecutive years. The experiment was laid out as a Randomized Complete Block Design with three replications. quality attributes were studied in laboratory using standard procedure. The results revealed that the highest significant different has been recorded for most of traits. On the basis of overall means, the highest total yield (51.2t/ha), marketable tuber yield (46.69t/ha), average tuber weight (99.85gm), large sized tuber number (48.71%), large sized tuber weight (77.52%), were observed for Belete variety. The highest marketable tuber number (87.62%) and unmarketable tuber weight (4.08t/ha) were observed for gera variety. The highest unmarketable tuber number (45.5%), small tuber number (56.03%), small sized tuber weight (28.291%) were observed for farmers' local cultivar Demmie. The highest medium sized tuber number (37.173%) and medium sized tuber weight (42.197%) were observed for bubu varieties. Jalene are highly affected by late blight disease. In conclusion, the result of the study reviled that the variety and growing environment has a great influence on yield and yield components and quality of potato This study suggested that the importance of testing varietiesacross location to recommend varieties for specific end uses.
Keywords: Irish potato, Varieties, Location, Yield and Yield Attributes

Introduction

Potato (*Solanum tuberosum* L.) is one of the major world's agricultural crops. The worldwide production of potato exceeded 324 million tons/year. This figure was exceeding only by wheat, maize and rice (FAOstat, 2012)

Potato was first introduced to Ethiopia in 1858 (Pankhurst, 1964). Since its introduction, potato has been considered as a strategic crop aiming at enhancing food security and economic benefits to the country. Ethiopia has suitable edaphic and climatic conditions for the production of high quality ware and seed potatoes. Ethiopia has the potential to grow potato in 70% of the 10 million ha of arable land of the country (FAO, 2008). However, the total area under potato production is estimated 48,113 ha with total annual production of 384,046 metric tons (FAOstat, 2009).

Potato is grown in four major areas in Ethiopia: the central, the eastern, the north- western and the southern regions. Together, these areas cover approximately 83% of the potato farmers (CSA, 2008/2009). The Northern part mainly covers the Amhara regional state highlands of Ethiopia, especially the east Gojjam zone. Compared to the other parts of the country potato production, this area is characterized by highest production potential with a minimum production result.

Potato has been identified as a cheap source of human diet since it produces more food value per unit time in terms of supplying carbohydrates, quality protein (lysine), minerals, nutrient salts and several vitamins from group B and large amount of vitamin C (Horton, 1987). Although potato is grown for food, animal feed, industrial uses and for seed tuber production; the main use is still as direct food, but an increasing proportion is processed into snack food. Potato is mainly important for subsistence farmers, but it may also be a cash crop (Striuik and Wiersema, 1999).

In Ethiopia, Potato is commonly consumed in the form of boiled and cooked meals in different traditional dishes or 'wet' and 'Dinich betelba'. Recently, consuming potato chips, crisps, and roasted potato are becoming common practices especially in cities like Addis Ababa, Bairdar, Debre Markos, etc. In urban areas, it is also usually consumed mixed with other vegetables as salad (Bezabih and Mengistu, 2011). Large scale potato processing is under the process of establishment in Ethiopia. In large cities like Addis Ababa, it is common to see hotels, restaurants and cafes prepare homemade French fries and Chips from potato. Urban consumers when out for recreation go along French fries and Chips for snacks. Street vendors also prepare French fries and Chips that supply to consumers at dusk. What is limiting potato consumption in Ethiopia is that very little is known to make different dishes from potato (Bezabih and Mengistu, 2011). As a result, most household consumption is limited to using potato stew and boiled. The economic importance of potato manufacturing industries yet not attained; and quality potato varieties for processing were not identified.

Quality is a complex of many characters so that a simple definition may be misleading. The complexity is

increasing as potato is processed in different forms and ways (Stevenson *et al.,* 1964). One of the factors affecting the quality of processed product of potato is the physicochemical characteristics from which it is made. For instance, not all the potato varieties will produce high quality potato chips (Miranda & Aguilera, 2006; Bennett, 2001). Studies have shown significance differences in chip quality as a result of varying chemical composition of the potato tubers (Kumar *et al*, 2004; Kita, 2002). The physical and chemical characteristics of the potato tubers vary from one variety to another and within the same variety depending on growing conditions (e.g. soil temperature and soil moisture), harvesting and handling conditions (Kumar *et al*., 2004). Therefore, the choice of variety and its growing environment is probably the most critical decision with respect to matching tuber quality with intended market.

Only local varieties called Demie with no application of improved technologies such as fertilizer, spacing etc is produced in Debre Markos as well as Sinan districts at the back yard plots (Personal observation). However, farmers are aware of the importance of the crop and looking for high yielding varieties, disease resistance/tolerance, and other technologies that improve the performance of the crop.

In Ethiopia as a whole more than 27 potato varieties with their full package were formally released for production for wider adaptation. Among these in the year 2002 and 2010, Haramaya University, Holeta and Sirinka Agricultural research centre, officially released five potato varieties which are resistant to potato late blight, adaptable to wide range of climatic conditions and altitudes (Ministry of Agriculture and Rural Development, 2006 and 2010). The varieties produce 31.5 to 39.3 t/ha at research field and 28.4 to 29.1 t/ha at farmers' field which is by far higher than the yield obtained from local variety (5-8t/ha) (Ministry of Agriculture and Rural Development, 2008). Thus it was paramount important to introduce, evaluate and recommend varieties and other potato technologies. This helps to identify varieties for good quality and to generate information that could be utilized as a yardstick in variety development for processing. Therefore, this study was conducted with the following objective.

- **Objectives**
  - Evaluating the agronomic performance of improved potato varieties at Debre Markos and Sinan Wereda of East Gojjam Zone

Materials and Methods

Description of the Experimental Site

The experiment was conducted in two highlands districts of East Gojjam zone, namely; Debre Markos, Debre Markos University research field and Sinan, Abazash Kebele nursery site under rain fed condition during the year 2014. Debre Markos located is *between 10°17'00" to 10°21'30" N Latitudes and 37°42'00" to 37°45'30" E* longitudes and its elevation ranges in altitude from 2350-2500 meters above sea level. The mean annual rainfall is 1380 mm. The minimum and maximum temperatures are 15 ^{0}C and 22^{0}C, respectively. Abazash nursery site is geographically located between 10°17′00″ to 10°21′30″ N Latitudes and 37°42′00″ to 37°45′30″ E longitudes and its elevation ranges in altitude from 3373 meters above sea level. The mean annual rainfall is 1380 mm. The minimum and maximum temperatures are 15^{0}C and 22^{0}C, respectively.

Mean air temperature, monthly rainfall, soil temperature, relative humidity, solar radiation and soil moisture at two experimental sites

Experimental sites	Cropping season months	Mean monthly rainfall (mm)	Mean air temperature (^{0}C)		Soil temperature /^{0}C/	RH (%)	Solar radiation	Soil moisture
			Min.	Max.				
Debre Markos	July	165	14.30	15.5	18.10	79.80	201.8	28.12
	August	397	14.35	15.29	17.32	65.14	174.11	25.34
	September	143	14.29	15.45	17.97	77.24	212.3	27.95
	November							
	October	45	14.77	16.05	18.40	67.34	232	51.58
	December	107	14.53	15.75	18.19	73.29	222	36.38
Abazash nursery	July		8.70	9.50		91.4	546.4	
	August		8.80	9.60		88.7	546.2	
	September		8.82	9.70		87.3	546.1	
	October		9.09	10.1		80.1	545.34	
	November							

Source Debre Markos University Choke Watershed project,201

Experimental Material

Five improved potato cultivars, which were released by research centres and Haramaya University at two

different locations, were used (Table 1).

Table 3. Description of potato cultivar used, released year & maintenance Centre.

No	Varieties	Released year	Breeder/Maintainer centre
1	Belete	2010	HARC
2	Bubu	2010	Haramaya University
3	Gudenie	2006	HARC
4	Gera	2003	SARC
5	Jalenie	2002	HARC
6	Demie	-	Local

HARC: Holleta Agricultural Research Centre, SARC:

Experimental Design and Management

The experiment was laid out as a Randomized Complete Block Design (RCBD) and replicated three times. Each plot was 3.60 m x 4.50 m (16.2 m^2) wide consisting of six rows, which accommodated twelve plants per row and thus 72 plants per plot. The spacing between plots and adjacent replication were 1 m and 1.5 m, respectively. There was a total of 669.3 m^2 area for experimental site. The experimental field was cultivated to a depth of 25-30 cm and levelled and ridges were made by hand. Medium sized (39-75 g) Lung'aho et *al*., (2007) and well sprouted tubers were planted at the sides of ridges at the spacing of 75 cm between ridges and 30 cm between tubers. Planting depth was maintained at 5 cm (Mahmood *et al*., 2001).

Experimental Procedures

Land preparation: The experimental fields were cultivated by a oxen to a depth of 25-30cm and levelled; then ridges were made by hand.

Planting: Medium sized (39-75g) Lung'aho *et al*., (2007) and well sprouted tubers were planted at the sides of ridges at the spacing of 75cm between ridges and 30cm between tubers in June 2007 during the main growing season after the rain commenced and when the soil was moist enough to support emergence. The planting depth was maintained at 5cm (Mahmood *et al.,* 2001).

Fertilizer application: Fertilizer was applied as the recommendation, which Phosphorus fertilizer was applied at the rate of 92kg P_2O_5 ha^{-1} in the form of Diammonium Phosphate (200kg ha^{-1}) and the whole rate was applied at planting. Nitrogen fertilizer was applied at the rate of 75kg Nitrogen ha^{-1} in the form of Urea in two splits, half rate after full emergence (two weeks after planting) and half rate at the initiation of tubers (start of flowering).

Harvesting: The haulm was mowed two weeks before harvesting to thicken tuber periderm; as the plants reached physiological maturity, yellowing or senescence observed apparent on the lower leaves, which was helped to avoid bruising and skinning during harvesting and post-harvest handling. For yield estimation, tubers were harvested from four middle rows, leaving the plants growing in the two border rows as well as those growing at both ends of each row to avoid edge effects.

3.4 Data Collection

3.4.1 Yield and tuber physical quality parameters

The following yield and yield related parameters data were collected:

Total tuber yield (t/ha): At harvest the total tuber yield of four row per plot were recorded by adding up the weights of marketable and unmarketable tubers and converted to yield per hectare.

Marketable tuber yield (t/ha): All the marketable tubers which were free from diseases, insect pests and greater than or equal to 20 g in weight were recorded.

Unmarketable tuber yield (t/ha): The tubers that were diseased, insect attacked and small-sized (< 20 g) were recorded as unmarketable tuber yield.

Marketable tuber number (%): The number of tubers which were free from diseases, insect pests and greater than or equal to 20 g in weight were recorded.

Unmarketable tuber number (%): The number of tubers that were diseased, insect attacked and small-sized (< 20 g) were counted as unmarketable tuber yield.

Average tuber weight (g/tuber): The average tuber weight was determined by dividing the total fresh tuber yield to the respective total tubers number.

3.5 Data Analysis

Data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) of the Statistical Analysis System (SAS) statistical package. As suggested by Watts *et al*., (1989), Finally, means comparison was made by using LSD (5% probability level).

Result and Discussion

Data on potato yield and yield components parameters were recorded during the study period. The results of the study are presented and discussed sequentially as follows.

4.1 Effect of Growing Environment and Genotype on Yield and Yield Components

Analysis of variance was conducted for total, marketable and unmarketable tuber yields and the results are presented (Table 2and 3). The Analysis of variance revealed that, average tuber weight marketable tubers yield, marketable tuber number and total tuber yield showed significant (P<0.01) difference among the tested varieties. The other traits; average number of tuber per plant and unmarketable tuber yield showed non-significant variation among the tested varieties (Appendix 1 and 2)

4.1.1 Total, marketable and unmarketable tuber yield

4.1.1.1 Total tuber yield

The varieties exhibited differential yielding ability at two locations. Belete (45.14/ha) grown at Debre Markos and Belete (53.79t/ha) grown at Sinan district, produced highest total tuber yield per hectare. Whereas, Gudenie grown at Debre Markos (27.54t/ha) and Gudenie at Sinan (36.86t/ha), and Gudenie (27.54t/ha) grown at Debre Markos produced statistically lowest total tuber yield (Table 2). The variation in total yield of potato varieties at different location may be due to response of Varieties to growing environmental factors. This suggestion is in agreement with other authors who reported that yield differences among genotypes were attributed both by the inherent yield potential of genotypes and growing environment as well as the interaction of genotype x environment (Elfinesh, 2008; Asmamawu, 2007 & Tekalign, 2003). Singh and Singh (1973) also indicated that yield per unit area is the end product of components of several yield contributing characters which are highly influenced by environment.

When mean total tuber yield across locations was considered, the highest outstanding total yield was recorded to the variety Belete (53.79t/ha) followed by Bubu (45.32t/ha) and Gera (40.19/ha). whereas the lowest yield was registered for Gudenie (27.54t/ha) followed by jalene (34.15t/ha). Considering the two locations, Sinan district site (42.84 t/ha) was producing highest average yields as compared to Debre Markos site (35.67t/ha) (Table 2). Bradshaw *et al*., (2007) reported that unlikely that one of many potential new cultivars will be best in all environments and for all uses; and an assessment of genotype × environment (including end use) interactions answers that which one of many potential new cultivars will be best in target environments and for all uses. As Falconer and Mackay (1996) explained, it is known that selection in one type of environment has consequences for performances in different types of environment, and how these can be quantified.35.67

Table 2. The interaction effect of location and potato varieties on total, marketable and unmarketable tuber yields (t/ha)

Location	Varieties	Tuber yield (t/ha)		
		Marketable	Unmarketable	Total
Debre Markos	Belete	43.99^{a}	1.14^{b}	45.14^{a}
	Bubu	35.31^{b}	1.54^{ab}	36.85^{b}
	Gera	**32.91^{b}**	**1.25^{b}**	34.15^{bc}
	Gudaine	25.79^{c}	1.75^{ab}	27.54^{c}
	Jalenie	32.29^{b}	2.37^{a}	34.67^{b}
Sinan	Belete	52.27^{a}	1.52^{ab}	53.79^{a}
	Bubu	43.98^{ab}	1.34^{ab}	45.32^{ab}
	Gera	**39.45^{b}**	0.74^{b}	40.19^{b}
	Gudaine	35.02^{b}	1.83^{ab}	36.86^{b}
	Jalenie	35.87^{b}	2.20^{a}	38.07^{b}
LSD(0.05)		6.37**	0.97	6.98**
CV (%)		9.94	32.16	10.40

**, Significant at P<0.01, respectively.

CV (%)= Coefficient variation in percent.

Means followed by the same letter with in a column are not significantly different.

4.1.1.2 Marketable tuber yield

Marketable tuber yield is the most important factor that persuades farmers to cultivate a potato variety. According to the study result, marketable tuber yield was influenced by genotype, growing environment and the interaction effect of genotype and growing environment. Belete (52.27t/ha) and Gudenie (25.79t/ha) produced the highest and the lowest marketable tuber yield at Sinan and debre markos, respectively. The combined mean marketable tuber yield of genotypes varied from (48.13t/ha) for Belete to 30.04 t/ha for Gudenie. In addition to Belete, Bubu(43.98t/ha) and Gera (**39.45**t/ha) produced the highest mean marketable tuber yield across locations. Gudenie and Jalenie (33.67t/ha) recorded the lowest mean marketable tuber yield in that order. Highest mean

marketable tuber yield of varieties was recorded for Sinan district (52.27t/ha) testing site while it was lowest for Debremarkos (25.79t/ha) (Table 2). Similarly, other researchers also investigated that marketable yield was significantly varied by variety, location and genotypes x environment interaction (Elfinesh, 2008, Pandey *et al*. 2004, Kumar *et al*., 2007).

4.1.1.3 Unmarketable tuber yield

Jalene (2.37t/ha) grown at Debremarko and Gudenie (1.75t/ha) grown at debremarkos. Gera (0.74t/ha) grown at Sinan site and Belete (1.14 t/ha) grown at debremarkos site, produced lowest unmarketable tuber yield (Table 2). Mean unmarketable tuber yield calculated from the two locations revealed that Jalene and Jalenie recorded the highest, while Gera and Belete registered the lowest. Varieties were producing highest mean unmarketable yield at Debre markos (2.37t/ha) site where as it was lowest at Sinan site (0.67t/ha) (Table 2). The variation in non-marketable yield of the genotypes may be due to adaptability, crop maturity, and inherent ability of potato genotypes in producing unmarketable tubers per plant. The result for non-marketable yield of potato varieties in present work is in line with the finding of Elfinesh (2008), who reported that the interaction effect of growing environment and genotype significantly influence unmarketable tuber yield.

4.1.2 Potato tuber number

In this study, the effect of varieties on tuber number were studied. The effect of variety significantly (P<0.01) influenced marketable and unmarketable tuber number in percent (Appendix Table 2).

4.1.2.1 Marketable and unmarketable tuber number in percent

Marketable tuber number in percent: The higher marketable tuber number in percent was produced by Gera (96.7%), followed by Gudenie (87.9%) both grown at Sinan site, Bubu (72.8%) and Gera (38.8%) both grown at Debremarkos produced lowest marketable tuber number in percent. The difference in tuber number might be due to varietal character and growing environmental factors.

Number of marketable tubers in percent calculated for varieties across locations revealed that Belete(81.9%) followed by Gudenie(80.1%) recorded the highest mean marketable tuber number, while Jalene (76.9%), followed by Bubu (77.2%) registered the lowest mean percent of marketable tuber number. Varieties were producing highest mean marketable number at Sinan (81.9%) site where as it was lowest at Debre markos (76.9%) (Table 3).

Table 3 The effect of varieties on marketable and unmarketable tuber number in percent

Treatments		Mean Tuber number per hill	
Locations	**Varieties**	**Marketable**	Unmarketable
Debre Markos	Belete	79.7a	20.3b
	Bubu	72.2a	27.8b
	Gera	38.8b	61.2a
	Gudaine	78.63a	21.4b
	Jalenie	75.0a	25.0b
Abash nursery	Belete	84.1a	15.9c
	Bubu	85.6a	14.4ab
	Gera	96.7c	3.3d
	Gudaine	87.9ab	12.1b
	Jalenie	80.6bc	19.4ab
LSD(0.05)		9.5	8
CV (%)		12	14

*, & ** = Significant at P<0.05 and P<0.01, respectively.
CV (%) = Coefficient variation in percent.
Means followed by the same letter with in a column are not significantly different.

Unmarketable tuber number in percent: Tubers of Gera (61.2%) grown at Debremarkos and Jalene (25%) both grown at Debremarkos produced highest unmarketable tuber number in percent. Gera (3.3%) followed by Gudene (12.1%) both grown at Sinan district recorded lowest unmarketable tuber number in percent (Table 3).

When the mean percent of unmarketable tubers number considered, Gera (32%) followed by Jalene (22.1%) registered the highest mean percent unmarketable tubers in number, whereas Belete (17.5%) followed by Gudenie(20%) recorded the lowest mean percent unmarketable tubers in number. varieties were producing highest mean unmarketable number at Debrmarkos site where as it was lowest at Sinan district (Table 5).

Number of tubers is the main traits and carried into account as one of the most important traits and also as one of the yield components in the potato. The trait by the side of tuber weight consist two crucial components of yield component and none of the other traits have been effective as much as this in yield. The number of tubers per plot will depend mainly on number of stems per plot, total number of stolons and stolons which tuberize. Both genetic and environmental factors play a vital role in stolon development and tuberization process (Subarta & Upadhya, 1997).

5. SUMMARY AND CONCLUSION

The development of varieties with desirable characteristics and a wide adaptability is important component to all segments of processing industry. In Ethiopia, a number of improved potato varieties have been developed by different research institutions and widely grown in different growing environment. However, in developing the varieties less or no emphasis was given to adaptability trial of released varieties in relation to high yielding and processing quality. Besides, potato is commonly consumed in Ethiopia the form of boiled and cooked meals in different traditional dishes such as "wot' except recently, chips, crisps, and roasted potato are in practices. Therefore, the present study was conducted to evaluate yield and yield components potato varieties in two locations of east gojjam zone during the main growing season of 2014.

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