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Evaluation on Growth Performance of Improved and Local Potato (*solanum tuberosum* l.) Cultivars Grown in Eastern Ethiopia

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Abstract
Field experiments were conducted at Haramaya and Hirna with the objective of assessing growth performance of local (farmers') and improved potato cultivars. The treatments consisted of five released cultivars (Badhasa, Chala, Chiro, Gabbisa, Zemen) and four local (farmers') potato cultivars (Batte, Daddafa, Jarso, Mashenadima). The experiment was laid out as a Randomized Complete Block Design with three replications. Earliest cultivar to attain days to 50% emergence was Chiro at Hirna and Mashenadima emerged late at Haramaya. The earliest cultivars to reach 50% flowering was Jarso (43.83 days) and Mashenadima late (57.67 days). Chiro matured in (86.17 days) while Daddafa (114 days), indicating that they are early and late maturing, respectively. The tallest plants were recorded at Hirna for Zemen (106.48 cm) while the shortest (39.93 cm) were for Batte at Haramaya. Maximum (6.58) and minimum (2.41) stem numbers per hill were produced by Chala and Mashenadima, respectively.
Keywords: potato (*solanum tuberosum* l.), Growth Performance, Improved, local, Ethiopia

Introduction

Potato is regarded as a high-potential food security crop because of its ability to provide a high yield of high-quality product per unit input with a shorter crop cycle (Adane *et al*., 2010). It is a major part of the diet of half a billion consumers in the developing countries (Mondal, 2003). Potato is an important food and cash crop in Eastern and Central Africa, playing a major role in national food security and nutrition, poverty alleviation and income generation, and; provides employment in the production, processing and marketing sub-sectors (Lung'aho *et al*., 2007).

In Eastern Ethiopia, improving and maintaining potato cultivars with high yield and market values is limited by lack of knowledge on the diversity of the local as well as the improved cultivars. This is because; the local cultivars are not well studied as that of the improved ones, which need studying both cultivars for better documentation.

However, to date, no systematic studies have been done to investigate and document the similarities and differences in agronomic performances among the local and improved potato cultivars grown in the Eastern Ethiopia. Therefore, this study was initiated with the objective of assessing growth performances of major local and improved cultivars of potato grown in Eastern Ethiopia.

Materials and Methods

Description of the study area

The study were carried out at Rare, Horticulture section's research field, Haramaya University and Hirna research site of the University under rainfed condition during the 2011 main growing season. Rare research site is located at 9 ^{o}26' N latitude, 42 ^{o}3' E longitudes at an altitude of 1980 m.a.s.l. The mean annual rainfall is 760 mm (Belay *et al*., 1998). Mean annual temprature16 °C (Mishra *et al*., 2004). The mean relative humidity is 50%, varying from 20 to 81%. The soil of the experimental site is alluvial type with organic carbon content of 1.15%, total Nitrogen content of 0.11%, available Phosphorus content of 18.2 mg kg soil^{-1}, exchangeable Potassium content of 0.65 cmol$_c$ kg soil^{-1}, pH of 8.0 and per cent sand, silt and clay content of 62.92, 19.64 and 17.44, respectively (Simret, 2010).

Hirna sub-station is located at 9 ^{o}12' N latitude, 41 ^{o}4' E longitudes at an altitude of 1870 m. a.s.l. The area receives mean annual rainfall of 990 to 1010 mm with an average temperature of 24 ^{o}C (HURC, 1996). The soil of Hirna is vertisol with organic carbon content of 1.75%, total Nitrogen content of 0.18%, available Phosphorus content of 32 mg kg soil^{-1}, exchangeable Potassium content of 0.68 cmol$_c$ kg soil^{-1}, pH of 7.09 and percent sand, silt and clay contents of 27, 28 and 45, respectively (Nebret, 2011).

Description of Experimental Material
Five potato cultivars, which were released by Haramaya University at different times and four locally available potato cultivars were used for the experiment (Table 1).

Table 2. Potato cultivars used in the study, year of release and their sources.

Variety	**Year of release**	**Source of planting material**
Chiro	1998	HUPIP
Zemen	2001	HUPIP
Badhasa	2001	HUPIP
Gabbisa	2005	HUPIP
Chala	2005	HUPIP
Source (MoARD, 2010)		
Batte	Local	RHSPC
Mashenadima	Local	RHSPC
Jarso	Local	RHSPC
Daddafa	Local	RHSPC

Key: HUPIP = Haramaya University Potato Improvement Programme
RHSPC = Rare Hora Seed Producers' Cooperative

Treatments and Experimental Design
The treatments are nine consisting of five improved cultivars (Chala, Chiro, Badhasa, Gabbisa and Zemen) and four local cultivars (Batte, Mashenadima, Jarso and Daddafa). 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.

Experimental Procedures
The experimental field was cultivated by a tractor 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). Phosphorus fertilizer at the rate of 92 kg P_2O_5 ha^{-1} in the form of Diammonium Phosphate (200 kg ha^{-1}) was used and the whole rate was applied at planting. 75 kg Nitrogen ha^{-1} was applied 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). Potato plants were treated with Mancozeb 80% WP at the rate of 1.5 kg ha^{-1}diluted at the rate of 40 g per 20 litre water once a week to control late blight disease.

Plant Data Collection and Analysis
Pre harvest observations and measurement were taken from randomly selected plants from each plot for all characters studied. Data were subjected to analysis of variance (ANOVA) using the General Linear Model of the SAS statistical package (SAS, 2007) version 9.1. All significant pairs of treatment means were compared using the Least Significant Difference Test (LSD) at 5% and 1% level of significance.

Results and Discussion
Days to 50% emergence
Analysis of variance of the results revealed that the main effect of cultivar and location significantly ($P < 0.01$) influenced days to 50% emergence. The analysis also revealed that the interaction effect of cultivars and location significantly affected days to 50% emergence at both locations, Mashenadima required the highest number of days to reach 50% emergence, closely followed by Batte and Jarso. In contrast, Gabbisa, Zemen, Badhasa and Chiro required the smallest number of days for 50% emergence (Table 3).

The number of days required to reach 50% emergence by the other cultivars variably lay between the number of days required by Mashenadima (19 days) and Gabbisa, Zemen, Badhasa and Chiro (10 at Hirna and 12 days at Haramaya). Thus, on average, the number of days required by Mashenadima to reach 50% emergence was prolonged by additional number of days amounting near to 90%, compared to the number of days required by

Gabbisa, Zemen, Badhasa and Chiro for 50% emergence. In agreement with this result, Mondal *et al.* (2007) from Bangladesh reported significant differences in days to emergence in 31 potato varieties.

Days to 50% flowering and maturity

Analysis of variance revealed that the main effect of cultivars and location significantly ($P < 0.01$) influenced days to 50% flowering and maturity. However, cultivar and location did not interact to influence significant difference on both parameters. The cultivars that reached 50% flowering significantly earlier than all other cultivars was Jarso, closely followed by Daddafa, Chala and Gabbisa. Batte, Chiro and Zemen, which required intermediate durations of time to reach 50% flowering. This variation might be due to the differences in the soil and climatic conditions between the two locations.

The cultivars named Mashenadima required the longest duration of time to reach 50% flowering, which was later than Jarso, Daddafa, Chala, Gabbisa, Batte, Chiro, Zemen and Badhasa by about 32, 21, 19, 18.9, 13.4, 13.5, 13 and 9%, respectively (Table 2). In case of 50% maturity Daddafa required the longest duration of time by about 31% than early matured cultivar Chiro. This variation might be the differences of the two genotypes in their genetic make-up of the cultivars. Related to this, Yibekal (1998) also observed a significance difference in days to 50% flowering and maturity between cultivars. On the average, all cultivars flowered and attained maturity significantly earlier at Hirna than at Haramaya (Table 2). The cultivars reached 50% flowering and maturity later at Haramaya than at Hirna by additional durations of about 4 and 1.5%, respectively. The earlier flowering and maturity observed at Hirna than Haramaya might be linked to the relatively higher growing temperature at the former than the latter. The mean annual temperature of Hirna and Haramaya was reported as 24^{o}C (HURC, 1996) and16°C (Mishra *et al*., 2004), respectively. This indicates a difference of 8^{o}C between the two locations that made Hirna relatively warmer than Haramaya. This suggestion is consistent with that of Asmamaw (2007), who reported that earlier flowering and maturity of potato at Adet than at Chilga and Dabat could be attributed to the higher growing temperature in the former than the latter.

Average stem number

Average main stem number per hill was significantly ($P < 0.01$) influenced by the main effect of genotype but not by that of location. This parameter was also not significantly influenced by the interaction effect of cultivar and location. The highest number of stem was recorded for Chala (near to 7) and Jarso (near to 6), closely followed by Batte. Farmers' cultivar Mashenadima (2.41) had the lowest stem number. Thus, the stem number of Chala exceeded that of Mashenadima by about 173%. This difference among the cultivars in stem number could be ascribed to the inherent variations in the number of buds per tubers which is in turn influenced by the size of the tuber (Table 2).

The results obtained in this study are also in agreement with that of Morena *et al*. (1994) who showed that the number of stems per plant (hill) is influenced by variety. The number of stems per tuber may also relate to the number of eyes. Thus, the more the number of eyes per tuber, the higher will be number of stems. This idea is related to that of Hanan and Lodhi, (1979), who reported that less number of stems in Draga and Adora than in other varieties were likely to be due to less number of eyes on the tubers.

Plant height

The main as well as the interaction effect of cultivars and location significantly ($P < 0.01$) influenced plant height. The tallest plants were obtained from the cultivars Zemen (106.48 cm), Badhasa(104.85cm) and Chiro(100.08cm), closely followed by Batte, Gabbisa, Chala, Daddafa and Jarso at Hirna. The farmers' cultivar Mashenadima had the shortest plants at Hirna (Table 3). At this location, the mean plant height of Zemen (with the tallest plant) exceeded the mean height of Mashenadima (with the shortest plant) by about 61%. At Haramaya, cultivar Zemen, Chiro and Daddafa had taller plants exceeding the farmers' cultivar Batte (39.93cm) that had shorter plants by about 44, 33 and 26%, respectively (table 3). The difference in plant heights of the cultivars may be attributed to genetic differences, which may have led to the variable performances in growth and development. Corroborating this suggestion, Singh and Singh (1973), stated that plant height is a quantitative trait controlled and determined by many genes.

At Haramaya, all cultivars had plants that were significantly shorter than the corresponding plants observed at Hirna. In most cases, the heights of plants of each cultivar recorded at Hirna reduced by about more than 100% at Haramaya. The significant increases in plant height at Hirna compared to Haramaya may be ascribed to better availability of soil nutrients at Hirna than at Haramaya. Vos and Frinking, (1997); El-Tohamy *et al*. (2006) stated that the highest plant height is due to better availability of soil nutrients in the growing areas, especially Nitrogen and Phosphorus which have enhancing effect on the vegetative growth of plants by increasing cell division and elongation and the varietal variability to absorb nutrients from the soil. In this connection, even though, the available plant nutrients were measured in different years and not on this study cropping season it has been found that available plant nutrients to be higher at Hirna than at Haramaya.

Table 3.The effect of cultivars and location on days to 50% flowering and maturity and stem number per hill different potato cultivars.

	Parameter		
	Days to 50% Flowering	Days to50% maturity	Stem number per hill
Location			
Haramaya	51.26[a]	100.74[a]	4.35[a]
Hirna	49.11[b]	99.30[b]	4.33[a]
LSD (0.05)	0.74	0.71	0.35
F-test	**	**	Ns
Cultivars			
Badhasa	52.83[b]	97.67[e]	4.08[cd]
Batte	50.83[c]	102.83[b]	4.93[b]
Chala	48.33[d]	102.83[b]	6.58[a]
Jarso	43.83[e]	99.83[d]	5.83[a]
Chiro	50.83[c]	87.17[g]	4.34[bc]
Mashenadima	57.67[a]	100.17[cd]	2.41[e]
Zemen	51.17[c]	93.83[f]	4.00[cd]
Daddafa	47.67[d]	114.33[a]	3.48[d]
Gabbisa	48.50[d]	101.50[bc]	3.45[d]
LSD (0.05)	1.53	1.40	0.79
F-test	**	**	**
CV (%)	2.66	1.28	14.75

Treatment means followed by the same letter within a column are not significantly different. ** = significant at 1% probability level. ns = non significant at 5% probability level.

Table 4. The interaction effect of cultivars and location on days to 50% emergence, plant height, and leaf area index of potato cultivars.

		Parameter		
Location	Cultivars	Days to 50% Emergence	Plant height(cm)	Leaf area index
Haramaya	Badhasa	12.00[f]	45.90 [ghi]	2.50[b-g]
	Batte	15.67[b]	39.93[i]	2.19[fgh]
	Chala	12.67[f]	41.17[hi]	2.16[gh]
	Jarso	15.00[bcd]	47.32[ghi]	1.99[hi]
	Chiro	12.33[f]	53.25[fg]	2.72[abc]
	Mashenadima	19.00[a]	41.03[hi]	1.79[i]
	Zemen	12.00[f]	57.43[ef]	2.52[b-f]
	Daddafa	14.33[de]	50.22[fgh]	2.56[a-d]
	Gabbisa	12.00[f]	40.68[hi]	2.41[c-g]
Hirna	Badhasa	10.00[g]	104.85[a]	2.90[a]
	Batte	15.33[bc]	87.67[b]	2.63[a-d]
	Chala	12.00[f]	85.47[b]	2.34[d-h]
	Jarso	14.67[cd]	71.93[bc]	2.15[gh]
	Chiro	10.67[g]	100.08[a]	2.83[ab]
	Mashenadima	18.67[a]	66.28[de]	2.45 [c-g]
	Zemen	10.00[g]	106.48[a]	2.72[abc]
	Daddafa	13.67[e]	80.58[bc]	2.21[e-h]
	Gabbisa	10.00[g]	86.93[b]	2.63[a-d]
LSD (0.05)		0.80	10.07	0.36
F-test		**	**	**
CV (%)		3.60	9.05	8.86

Treatment means followed by the same letter within a column are not significantly different. ** = significant at 1% probability level.

Leaf area index

The main as well as the interaction effect of cultivar and location significantly ($P < 0.01$) influenced leaf area index. The highest leaf area index values were recorded for Badhasa (2.90), Chiro (2.83), Gabbisa, Zemen and Batte at Hirna and for Chiro and Daddafa at Haramaya. The smallest leaf area index values were obtained for Mashenadima (1.79) and Jarso (1.99) at Haramaya. For example, the mean leaf area index value of Badhasa at Hirna exceeded the mean leaf area index value of Mashenadima (with the shortest leaf area index) at Haramaya by about 62%.The result of this study indicates that some of the cultivars differed in leaf area index possibly due to genetic differences, which was influenced by environment. This finding is corroborated by the results of a study conducted by Putz (1986) that different varieties showed significant variations in leaf area index. Timlin *et al*. (2006) also reported that, tuber formation is the result of leaf photosynthesis, which is influenced by variety. Dhital *et al.* (2009) also found that young and fully expanded leaves led to better tuberization in potato cultivars than the very young or very old leaves with less leaf area index. Furthermore, it was observed that, except the mean leaf area index value of Daddafa, which significantly increased, and that of Chiro which remained high and the same, the mean leaf area index values of all other cultivars reduced significantly at Haramaya (Table 3).

This result indicates that for growth and leaf expansion of most of the cultivars, Hirna was much more suitable than Haramaya. This result gives information that growing environment has effect on leaf area index of potato cultivars. This result is similar with those of Van Oijen (1991); Allen *et al*. (1992); Boyd *et al*. (2002) who sated that leaf area index can vary widely according to growing conditions. The optimum leaf area index for high tuber yield of potato ranges between 3.0 to 6.0 (Marschner, 1995). In addition, Nganga (1982) also reported that tuber growth rate and tuber yield were the function of tuber growth and duration of bulking which is highly dependent on the amount of leaf area index. Consistent with this statement, plants that grew better at both locations had leaf area index that neared the lower limit for optimum growth of the plant, i.e. 3.0.

Shoot fresh mass and shoot dry mass

The main as well as the interaction effect of cultivar and location significantly ($P < 0.01$) influenced shoot fresh and dry mass. The heavier shoot fresh mass was recorded for Batte (330.95g) at Hirna, closely followed by cultivar Daddafa at both Hirna and Haramaya and for Badhasa at Hirna. The lowest shoot fresh mass was recorded for Jarso (12.36g) and (60.37g) at both Hirna and Haramaya, respectively) (Table 4). For example, the shoot fresh mass of Batte at Hirna was significantly higher than that of Jarso at Haramaya by about 448%. The highest values of dry mass were, however, recorded for Chala (63.45g), Batte (56.91g), Badhasa (55.88g) and Chiro (51.77g) at Haramaya as well as for Daddafa at both Haramaya and Hirna. The lowest shoot dry matter values were recorded for Jarso, Chiro, Zemen, Gabbisa and Daddafa at Hirna. The differences in the shoot fresh mass among the cultivars may be explained by varietal differences as well as environmental factors (Table 4).

Similar to the other attributes such as plant height and leaf area index, shoot fresh mass of the cultivars were lower at Haramaya than at Hirna. However, the shoot dry mass were generally significantly higher at Haramaya than Hirna, indicating more moisture contents in the biomass of plants grown at the former than the latter. The fresh and dry masses of Jarso were extremely low because the cultivar succumbed to late blight disease (*Phytophtora infestans*). Corroborating this idea, Bekele and Hailu, (2001) stated that Late blight caused by *Phytophthora infestans* is the major destructive and the most serious fungal disease of potato affecting its leaves, stems and tubers. This result also indicates that there wide variations among cultivars in resistance/tolerance or susceptibility to diseases.

Total biomass

The main effects of cultivar and location significantly influenced total biomass. Cultivar and Location also interacted to significantly ($P < 0.01$) influence this parameter. The heaviest total biomass was obtained for Chala (324.16g) and Chiro (293.05g) at Haramaya whereas the lowest was found for Jarso at both locations (148.94g) at Haramaya (85.35g) at Hirna. This may be attributed to genetic differences, location as well as biotic factors. The lowest total biomass yield could be attributed to the high susceptibility of the cultivar to the late blight disease, as observed during the experiment. Corroborating this suggestion, Gebremedhin *et al.* (2001) reported significant differences among the potato cultivars Cara, Spunta, Diamond, Cardinal, Barka, Ajax, and Alpha in total biomass yield. Of these varieties, only Cara is reported still in production in some semi-arid and lowland areas. The others have been completely eliminated by late blight. Other than local cultivar with different level of resistance the remaining cultivars are resistant to late blight disease possibly because of their genetic trait especially improved cultivars that are used in this study. Kidane-mariam, (1980) reported that local varieties are susceptible to diseases and pests. Similarly, Bekele and Hailu, (2001) also stated that Late blight is the major destructive and the most serious fungal disease of potato that affect its leaves, stems and tubers. The average number of active haulms per plant contributes to total biomass yield. Thus, the average number of active haulms per plant is a variable that is most affected by cultivar characteristics (Susnochi, 1982; Morena *et al*., 1994); however, diseases and environmental stresses affect its development.

Table 5. The interaction effect of cultivar and location on shoot fresh and dry mass and total biomass of potato cultivars

Location	Cultivar	Parameter		
		Shoot fresh mass (g/plant)	Shoot dry mass (g/plant)	Total biomass (g/plant)
Haramaya	Badhasa	133.20^{ghi}	55.88^{a-e}	245.70^{c-h}
	Batte	145.25^{fgh}	56.91^{a-d}	224.28^{efh}
	Chala	185.15^{def}	63.45^{a}	324.16 ^{a}
	Jarso	60.37^{k}	30.16^{i}	148.94^{j}
	Chiro	101.53^{ji}	51.77^{a-f}	293.05^{ab}
	Mashenadima	119.36^{ghi}	45.62^{d-h}	174.80^{ij}
	Zemen	87.53^{jk}	31.23^{i}	252.22^{c-f}
	Daddafa	244.12^{bc}	58.79^{a-c}	265.58^{b-d}
	Gabbisa	124.67^{hij}	36.49^{hi}	235.56^{d-h}
Hirna	Badhasa	278.87^{b}	45.64^{d-h}	280.44^{bc}
	Batte	330.95^{a}	48.09^{c-g}	267.56^{b-d}
	Chala	278.34^{b}	44.23^{e-h}	263.24^{b-e}
	Jarso	12.36^{l}	8.55^{j}	85.35^{k}
	Chiro	172.23^{efg}	30.48^{i}	216.61^{fh}
	Mashenadima	221.25^{cd}	44.80^{e-h}	245.99^{c-h}
	Zemen	192.20^{de}	39.31^{d-h}	208.52^{hi}
	Daddafa	321.40^{b}	59.61^{ab}	212.22^{hi}
	Gabbisa	183.87^{def}	29.26^{i}	252.73^{c-f}
LSD (0.05)		40.67	11.39	40.23
F-test		**	**	**
CV (%)		13.82	15.83	10.34

Treatment means followed by the same letter within a column are not significantly different. ** = significant at 1% probability level.

Conclusion

At both locations, Mashenadima (farmers' cultivar) required the highest number of days to reach 50% emergence, closely followed by Batte and Jarso. In contrast, Gabbisa, Zemen, Badhasa and Chiro (released cultivars) required the smallest number of days for 50% emergence. The cultivar that reached 50% flowering significantly earlier than all other cultivars was Jarso, closely followed by Daddafa, Chala and Gabbisa.

The tallest plants were obtained from the cultivars Zemen, Badhasa and Chiro, closely followed by Batte, Gabbisa, Chala, Daddafa and Jarso at Hirna. The farmers' cultivar Mashenadima had the shortest plant at Hirna. At Haramaya, all cultivars had plants that were significantly shorter than the corresponding plants observed at Hirna. In most cases, the heights of plants of each cultivar recorded at Hirna reduced by about more than 100% at Haramaya.

The highest number of stem was recorded for Chala and Jarso, closely followed by Batte. The farmers' cultivar Mashenadima had the lowest stem number. The highest leaf area index values were recorded for Badhasa, Chiro, Gabbisa, Zemen and Batte at Hirna and for Chiro and Daddafa at Haramaya. The smallest leaf area index values were obtained for Mashenadima and Jarso at Haramaya. The heaviest total biomass was obtained for Chala and Chiro at Haramaya whereas the lowest was found for Jarso at both locations.

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