ISSN: 2641-6379
DOI: 10.33552/WJASS.2020.04.000582
World Journal of Agriculture and Soil Science
Iris Publishers

Research Article

Adaptability and Performance Evaluation of Potato (*Solanum Tuberosum L.*) varieties under irrigation for Tuber Yield

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Received Date: January 12, 2020

Published Date: January 23, 2020

Abstract

Potato is an important food security crop and a major source of household income for smallholder farmers in highlands of Ethiopia. However, lack of well adapted varieties across the potential agro-ecologies for potato production and productivity are one of the constraints that account for low yield and small area cropped to the nation. So that adaptability of crops can vary from location to location depending on the agro-ecologies of a particular area. Therefore, it is essential to conduct location specific adaptation trial to identify suitable varieties. Accordingly, an adaptation trial of potato varieties was conducted in central highlands of Ethiopia with the objective of evaluating the performance and adaptability of introduced and improved varieties in different potato growing agro-ecologies of the country. Treatments include five potato varieties introduced from Republic of South Korea (Chubak, Seohong, Goun, Jowon, Haryung) and three nationally released varieties (Awash, Gudanie and Belete) were evaluated for their vegetative growth performance and tuber yield under irrigation conditions. The experimental field was laid out in Randomized Complete Block Design (RCBD) with three replications. The results revealed that plant height, main stem number, average tuber number and average tuber weight per plot were highly significant. Belete variety had the highest plant height (65.43cm) and stem numbers of 6.58 per hill whereas; Chubak variety had the lowest plant height (26.22 cm) and stem number 3.57 per hill among the other varieties. Potato variety Haryung gave the highest average tuber number (52.73/ m2) followed by Gown (42.39). The highest total yield (30.08 t/ha) and marketable tuber yield (17.72t/ha) recorded for Gudanie variety followed by Haryung (27.09 t/ha) and (18.48 t/ha) and Seohong (25.54t/ha) and (19.44t/ha), respectively. Finally, the result of the study revealed that the genotype and growing environment has a great influence on yield and yield components of potato tubers. It is concluded that the study evidently demonstrated the effect of varietal difference on the growth potential of potato varieties under irrigation or for short rain-fed areas. Thus, in both seasons among the introduced potato varieties Haryung and Seohong were well adapted and gave a comparative tuber yield with nationally released potato varieties and can be used as alternative varieties in potato producing regions of the country especially under irrigation and short rain fed conditions.

Keywords: Potato; Adaptation; Vegetative growth; Total tuber yield; Marketable tuber yield

Introduction

In Ethiopia, potato (*Solanum tuberosum L.*) has promising prospect in improving the quality of the basic diet in both rural and urban areas [1]. Potato is an important crop for smallholder farmers in Ethiopia, serving both as a cash crop and food security crop. It is one of the root crops widely grown in the country because of increasing demand and emerging markets that have provided a great opportunity for resource-poor farmers to generate additional income (Bekele et al., 2011) It is a short duration crop that can mature within short period of time. It contains practically all essential dietary constituents like carbohydrates, essential nutrients, protein, vitamins, and minerals [2]. Potato production has been considered as the first priority compared to other food crops because of its contribution to food security, income generation and double cropping advantages and its utilization in different forms [3,4]. It is one of the strategic crops, enhancing food security and

economic benefits to the country. In Ethiopia, it became one among the most economically important crops as a source of food and cash especially on the highland and mid-altitude areas of the country [5,6]. Potato is regarded as a high-potential food security crop because the crop produces large quantities of dietary energy (30 to 35t/ha starch-based produce in 3 to 4 months) and has relatively stable yields under conditions in which other crops may fall [7,8]. There is also an increasing demand for potato as an ingredient in other fast foods that entail salad and processed products such as French fries and crisps, as a result of dietary diversification among urban dwellers, emerging fast food restaurants and roadside small-scale fryers [9]. The majority of potato growing smallholder farmers uses low yielding and late blight susceptible local varieties due to the limited availability of improved seed potatoes in the country during the main cropping season [10]. Thus, evaluation and selection of potato genotypes which best adapt to various agro-ecologies with potential production area under irrigation condition is one of the means to solve production constraints and it is a significant constituent of research activity.

Adaptability of crops can vary from location to location depending on the agro-ecology of a particular area. Therefore, it is essential to conduct location specific adaptation trial to identify suitable potato variety/varieties [11]. But lack of well adapted cultivars to various abiotic stresses is one of a production problem that account for low yield and small area cropped to the nation [12]. Accordingly, an adaptation trial of potato varieties was conducted in central highlands of Ethiopia to identify potato varieties that is better in adaptation, yield and other agronomic characteristics, and pest and disease tolerant. Despite high potential production environments and marked growth, the national average potato yield in Ethiopia is 13.9 t ha^{-1} [13] which is lower than the experimental yields of over 35 t ha^{-1}Baye, et al. [14] and world average yield of 20 t ha^{-1} FAOSTAT [15] as well as other top potato producing countries in Africa. The low yields are the result of a number of production constraints mainly involving abiotic and biotic stress factors (Hirut, 2015). Among the biotic constraints late blight, bacterial wilt, virus diseases and potato tuber moth constitute the major threats to potato production, while the abiotic stresses include soil nutrient deficiency, frost, drought, erratic rainfall, and air and soil high temperature especially in marginal areas [5,16].

There are many complicated reasons for this low yield of potato in the country. Lack of good quality seed, soil fertility, unbalanced mineral nutrition, inadequate application of fertilizers, pests and disease, irregularity of water supply and traditional irrigation schemes and schedules are the main reason which accounts for the low productivity of potato [17]. Although irrigated potato production system contributed the lion's share both in the country and the region, its productivity (3.7 t ha^{-1}) was lower than the rainfed (10.5 t ha^{-1}) system [18]. This could be due to differences in climatic conditions and production constraints of the two production systems. Furthermore, in Ethiopia researchers have never released improved varieties for the irrigated potato production system. The prevailing average monthly maximum temperature is higher in the irrigated potato production system than in the rainfed system. The average monthly minimum temperature is low and causes frost injury to the plant during the irrigated potato production system. Therefore, irrigated potato production is affected both by the prevailing higher maximum and lower minimum temperature compared to the rainfed potato production system [19]. Yield is a complex trait in potato and is generally considered to have low heritability [20]. Hence, indirect selection could be useful strategy to bring considerable genetic improvement on potato tuber yield. Therefore, the objective of this study was to evaluate the growth and yield performance and adaptability of commercial potato introduced from Korea and nationally released potato varieties for fresh/table purposes under irrigation production systems.

Materials and Methods

Description of the study area

The field experiment was conducted under irrigation conditions during the year 2017/18 and 2018/19 cropping season at Holetta, Kulumsa, Debre Birhan, Mekelle and Haramaya, in various agro-ecologies of potato growing regions of Ethiopia.

Holetta agricultural research center is located at 090 00'N, 380 30'E at an altitude of 2400 m.a.s.l. It is 29 km away from Addis Ababa on the way to Ambo and characterized by a mean annual rainfall of 1041.4 mm, mean relative humidity of 58.70%, and mean maximum and minimum temperature of 21.70 °C and 6.70 °C, respectively. The main rainy season is from June to September, which account for 70% of the rainfall while the remaining thirty percent is from February to April [21]. The soil of the center is red Nitosol, which is characterized with an average organic matter content of 1.8%, Nitrogen 0.17%, pH 5.24, and phosphorus 4.55 ppm [22]. Haramaya University research farm is located at 2020 meters above sea level, 9 °41 ''N latitude and 42 °03 ''E longitude. The area has a bimodal rainfall distribution with mean annual rainfall of 760 mm [23]. The long rainy season extends from June to October and accounts for about 45% of the total rainfall. The mean maximum temperature is 23.4 °C while the mean minimum annual temperature is 8.25 °C [24]. The soil of the experimental site is a well-drained deep alluvial with a sub-soil stratified with loam and sandy loam. Kulumsa agricultural research center is located at 8°01'N, 39°09'E at an altitude of 2200 m.a.s.l with 10.5 °C minimum and 22.8 °C temperature, respectively. The annual rainfall is 850 mm. Similarly, Adet agricultural research center is located 11°16'N, 37°29'E at an altitude of 2240 m.a.s.l with 12 °C minimum and 24°C maximum temperature, respectively. The annual rainfall is 1250 mm. And Mekelle agricultural research center is located 13.3N, 39.4E, with altitude of 1970 m.a.s.l with 9.7°C minimum and 26.6 °C maximum temperature, respectively. The annual rainfall is 550 mm. Debre Berhan is located 9°45'N latitude 39°31'E longitude, 130 km far from Addia Ababa in the North direction. It is situated on plateaus in the central Ethiopia highland at average elevation of between 2800 and 2845 above sea level. The temperature of Debre Berhan is in average between 6.6 °c-24 °c; and average rainfall is 964mm and the climate is totally highland [25].

Experimental treatment and design

The performance of eight potato varieties was assessed in this study. Five of them are varieties commercial potato varieties introduced from Republic of South Korea and three nationally released potato were evaluated for adaptability and tuber yield and yield components using irrigation. A total number of eight (8) potato genotypes were used for the experiment. The experiment was laid out as a Randomized Complete Block Design (RCBD) with three replications. Each plot was 3.0m x 3.0m = $9m^2$ wide consisting of four rows, which accommodated 10 plants per row and thus 40 plants per plot. The spacing between plots and adjacent replication was 1m. At each site, medium sized 39-75g Lung'aho et al. [3] and well sprouted tubers were planted using irrigation during Feb. 2017 and 2018 for two consecutive years at the spacing of 75 cm between ridges and 30cm between tubers. Fertilizer was applied as the recommendation made by Holetta Agricultural Research Centre, which Phosphorus and Nitrogen fertilizer was applied at the rate of 92 kg P_2O_5 ha^{-1} and 110 kg ha^{-1}, respectively [26]. All other cultural practices were applied according to Holetta Agricultural Research Centre recommendation. For data estimation, tubers were harvested from 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 effect [27].

Data was collected on plant emergence, plant height as well as number of stem per plant during vegetative growth stage, number of tubers per plant, tuber yield(t/ha), average tuber weight (ATW) in gram, average tuber number (ANT)/plant were recorded. Quality parameters such as dry matter content and specific gravity were taken during harvesting.

Data analysis

The data were subjected to analysis of variance (ANOVA) following the standard procedure given by [28]. After fitting ANOVA model for those significant response variables, a mean separation was carried out using LSD method at 5% level of significance. All the statistical analyses were carried out using SAS-9.2 statistical software package [29].

Results and Discussion

Results of analysis of variance (ANOVA) of five growth characters for eight (8) improved potato varieties were shown in Table 1. Accordingly, all the growth parameters considered revealed highly significant difference (P<0.01) among the tested varieties. The presence of significant differences among varieties indicates the presence of genetic variability for each of the characters among the tested varieties. During 2017/18 off-season using irrigation, the highest plant height was recorded for Gudanie variety followed by Belete. The highest main stem number was observed for Chubak followed by Seohong and Haryung. As indicated in (Table 1) the highest average tuber number was recorded for Awash variety followed by Seohong and Gudanie. The highest average tuber weight was recorded for Awash variety followed by Seohong and Belete. In line with study, Kena [30] reported that the interaction effect of variety, location and year showed significant different (p<0.05) on number of main stems per plant. The difference in plant height among the varieties might be associated to genetic differences, which may lead to the variable performances in growth and development [31]. The differences might be due varietal effect and plant canopy which determine main stem to different locations [32]. In the irrigated potato production system, marketable tuber yield showed positive and statistically significant association with number of main stems per plant, plant height and number of tubers harvested per plot [19].

In addition, De la Morena et al. [33] described that the difference in number of number main stem among the varieties might be due to the inherent genotypic variation in the number of buds per tuber which is in turn influenced by the size of the tubers, physiological age of the seed, storage condition, and number of viable sprouts at planting, sprout damage at the time of planting and growing conditions. Similar to other parameters, the highest marketable tuber number was obtained from variety Awash followed by Gudanie and Chubak. Even though there were inconsistence results with regard to the growth parameters, the introduced potato varieties showed comparable average tuber number, tuber weight as well as marketable tuber number. The result at Haramaya indicated that during 2017/18 the highest total and marketable tuber yield was recorded from variety Seohong followed by variety Haryung which gave a total and marketable tuber yield. However, the lowest total and marketable tuber yield was obtained from variety Goun. Thus, the yield differences between these varieties may be related to their genetic makeup in the efficient utilization of inputs like nutrient as reported by [34] (Table 1).

Table 1: Performance of eight potato varieties for Plant height (PH), Main Stem Number (MSN), Average Tuber Number (ATN), Average Tuber Weight (ATW) and Marketable Tuber Number at Holetta, D. Berihan & Kulumsa during 2017/18.

No	Varieties	PH (cm)	MSN/ Plant	ATN/m^2	ATW (g)	MTN/ Plot
1	Chubak	56.71^{b}	6.27^{a}	11.61^{bc}	75b^{c}	141.33^{ab}
2	Seohong	47.56^{c}	5.93^{ab}	12.91^{ab}	89^{a}	140.88^{ab}
3	Goun	40.47^{d}	3.64^{e}	7.32^{f}	57^{d}	97.33^{c}
4	Jowon	33.27^{e}	3.62^{e}	9.60^{de}	65^{cd}	85.66^{c}
5	Haryung	35.98^{de}	5.49^{abc}	8.32^{ef}	71^{bc}	103.22^{c}
6	Awash	55.47^{b}	4.51^{de}	14.03^{a}	91^{a}	152.55^{a}
7	Gudanie	64.60^{a}	5.20^{bcd}	12.39^{ab}	65^{cd}	141.44^{ab}
8	Belete	63.22^{a}	4.82^{cd}	10.57^{cd}	82^{ab}	124.00^{b}
	CV (%)	11.3	19.66	17.5	19.37	16.41
	LSD (0.05%)	5.32	0.92	1.8	0.14	19.2
	P-Value	<.0001	<.0001	<.0001	<.0001	<.0001

Means followed by the same letters within the same column are statistically non-significant at p<0.05 according to the least significant difference (LSD) test. CV= Coefficient of Variation

There was highly significant (P< 0.01) variation among the tested varieties with respect to total p<0.01 tuber yield, marketable tuber yield, dry matter content and specific gravity among the evaluated varieties as indicated in (Table 2). During 2017/18 the

over locations results showed highly significant (P< 0.01) variation for the tested clones however the interaction effects p<0.01 of varieties and locations were non-significant. The highest total and marketable tuber yield was recorded from variety Seohong followed by Chubak. The lowest total and marketable tuber yield were obtained from variety Goun. With regard to dry matter content and specific gravity, the highest result was obtained from Belete followed by Haryung, Goun and Seohong in descending order (Table 2). However, except Chubak variety, the other tested genotypes and Belete gave similar specific gravity values. In line with the result Getachew [35] found that, varieties Belete and Gudanie produced tubers with higher dry matter content. In consistent with this result, Tai et al. [36] reported that dry matter content is subjected to the influence of both the environment and genotypes. In the same manner, Rytel et al. [37] reported that quality of potato tubers and their chemical composition are influenced by genetics, soil fertility, weather conditions and chemical treatments that are applied. Similarly, Habtamu et al. [38] also reported the highest specific gravity (1.0967) for variety Belete evaluated at three locations of eastern Ethiopia. In general, the current investigation also agreed with these different scholars' findings. Kena [30] described that, the variation in total yield of potato genotypes at different location may be due to a response of the genotypes 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 [30] (Table 2).

Table 2: Performance of eight potato varieties for Marketable Tuber Yield (MTY), Total Tuber Yield (TTY), Dry matter content (DM) and Specific gravity at Holetta, D. Berhan, Kulumsa, Mekele & Haramaya during 2017/18.

No	Varieties	MTY (t/ha)	TTY (t/ha)	DM (%)	SG(g/cm^3)
1	Chubak	30.95^{b}	33.52^{bc}	20.83^{c}	1.07^{c}
2	Seohong	37.95^{a}	41.78^{a}	23.45^{ab}	1.08^{ab}
3	Goun	20.07^{d}	22.49^{d}	24.31^{a}	1.08^{ab}
4	Jowon	23.84^{cd}	27.20^{cd}	21.53b^{c}	1.08^{b}
5	Haryung	28.61^{bc}	31.44^{bc}	24.47^{a}	1.09^{a}
6	Belete	31.07^{b}	34.38^{b}	25.19^{a}	1.09^{ab}
	CV (%)	29.07	28.13	12.61	1.22
P-value	Var	<.0001	<.0001	0.0005	0.001
	Loc	<.0001	<.0001	<.0001	<.0001
	Var*Loc	NS	NS	NS	NS

Means followed by the same letters within the same column are statistically non- significant at p<0.05 according to the least significant difference (LSD) test. NS= non-significant, Var= Variety, Loc= location, Var*Loc= Interaction of variety with location, CV= Coefficient of Variation.

This experiment was repeated during 2018/19 at same locations except Haramaya University. The data from remaining testing locations Holetta, Kulumsa, Debre Birhan and Mekelle Agricultural research centers summarized in Table 3. The ANOVA table indicates that, the growth parameters were highly significant (P<0.01) for the evaluated varieties as well as for locations except marketable tuber yield. There was highly significant (P<0.01) difference for interaction effect of varieties and locations also. The highest main stem number was recorded for variety Haryung and Gudanie followed by Belete and Seohong. The lowest main stem number was recorded by Chubak variety. The highest average tuber number was produced by variety Haryung followed by Gown and Gudanie, respectively. The lowest average tuber number was recorded by Belete variety. The highest total and marketable tuber yield recorded for Gudanie variety followed by Haryung and Seohong, respectively (Table 3). Similarly, other researchers also investigated that marketable yield was significantly varied by variety, location and genotypes x environment interaction Kumar et al. [39] Table 3.

Table 3: Performance of eight potato varieties for Main stem number (MSN), Average tuber number (ATN), Average tuber weight (ATW), Marketable tuber Yield (MTY) and Total tuber yield (TTY) for at Holetta & Kulumsa-2018/19.

No	Varieties	MSN	ATN/m^2	ATW/plant	MTY (t/ha)	TTY(t/ha)
1	Chubak	3.57^{b}	37.37^{b}	50.19^{c}	14.73b^{c}	19.28c
2	Seohong	6.27^{a}	30.09^{c}	51.27^{c}	19.44^{a}	25.54b
3	Goun	6.19^{a}	42.39^{b}	78.21^{a}	16.12^{ab}	23.60bc
4	Jowon	4.18^{b}	41.23^{b}	81.86^{a}	19.17^{a}	22.77bcd
5	Haryung	6.68^{a}	52.73^{a}	49.14^{c}	18.48^{ab}	27.09ab
6	Awash	5.90^{a}	36.79^{b}	60.55^{b}	12.19^{c}	18.53d
7	Gudanie	6.68^{a}	40.43^{b}	59.76^{b}	17.72^{ab}	30.08a
8	Belete	6.58^{a}	29.78^{c}	62.68^{b}	14.98^{bc}	24.65b
	CV (%)	18.81	12.31	10.49	18.29	14.72
P-value	VAR	<.0001	<.0001	<.0001	0.0025	<.0001
	LCO	<.0001	1	<.0001	NS	<.0001
	LC*VAR	0.0076	0.0016	<.0001	<.0001	<.0001

Means followed by the same letters within the same column are statistically non- significant at p<0.05 according to the least significant difference (LSD) test. NS= non-significant, Var= Variety, Loc= location, Var*Loc= Interaction of variety with location, CV= Coefficient of Variation.

The implication of the study showed that the varieties studied had good and promising agronomic and tuber yield traits useful for breeding and utilization purposes particularly towards irrigation production system. The studied varieties indicated that there was genetic variability and the varieties can be utilized for various agro-ecologies based on their performance. In addition to the nationally released potato varieties, those introduced Haryung and Seohong which adapted very well and produced comparable tuber yield was recommended as alternative varieties under irrigation production. The limitation of the study was that, those nationally released varieties were not properly included across locations to exploit their potential yield under irrigation and need further evaluation.

Conclusion and Recommendation

The study showed the presence of genetic variability among potato genotypes for tuber yield and adaptability for various agro-ecologies of potato production. The result of the study justifies that different varieties had different genetic potential

across locations. However, the findings indicate that there was no superior genotype for all tested characteristics as compared to the nationally released varieties. The mean analysis showed that Haryung and Seohong varieties produced equivalent total and marketable tuber yield across locations that was comparable to nationally released varieties, Gudanie and Belete under Holetta and Kulumsa conditions for irrigation production system. Therefore, the introduced potato varieties showed comparable tuber yield with the nationally released varieties for tuber yield, dry matter and specific gravity and other related agronomic traits at Holetta, Kulumsa, Debre Birhan and Mekelle conditions. Among the tested potato varieties, Haryung and Seohong were recommended for wide adaptability and better tuber yield and quality across testing locations. Moreover, dissemination of this variety to the farmer is vital to increase production and productivity of potato in the areas under irrigation production system [40-43].

Acknowledgement

We would like to thank the Ethiopian Institute of Agricultural Research (EIAR) through Agricultural Growth Program (AGP_II) for financing this research and Holetta Agricultural Research Centre (HARC) to facilities and operate the research. It's our pleasure to thank RDA of South Korea and International Potato Centre (CIP) for provision of potato germplasm. Administration and research technicians involved in the activity are acknowledged.

Conflict of Interest

No conflict of interest.

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