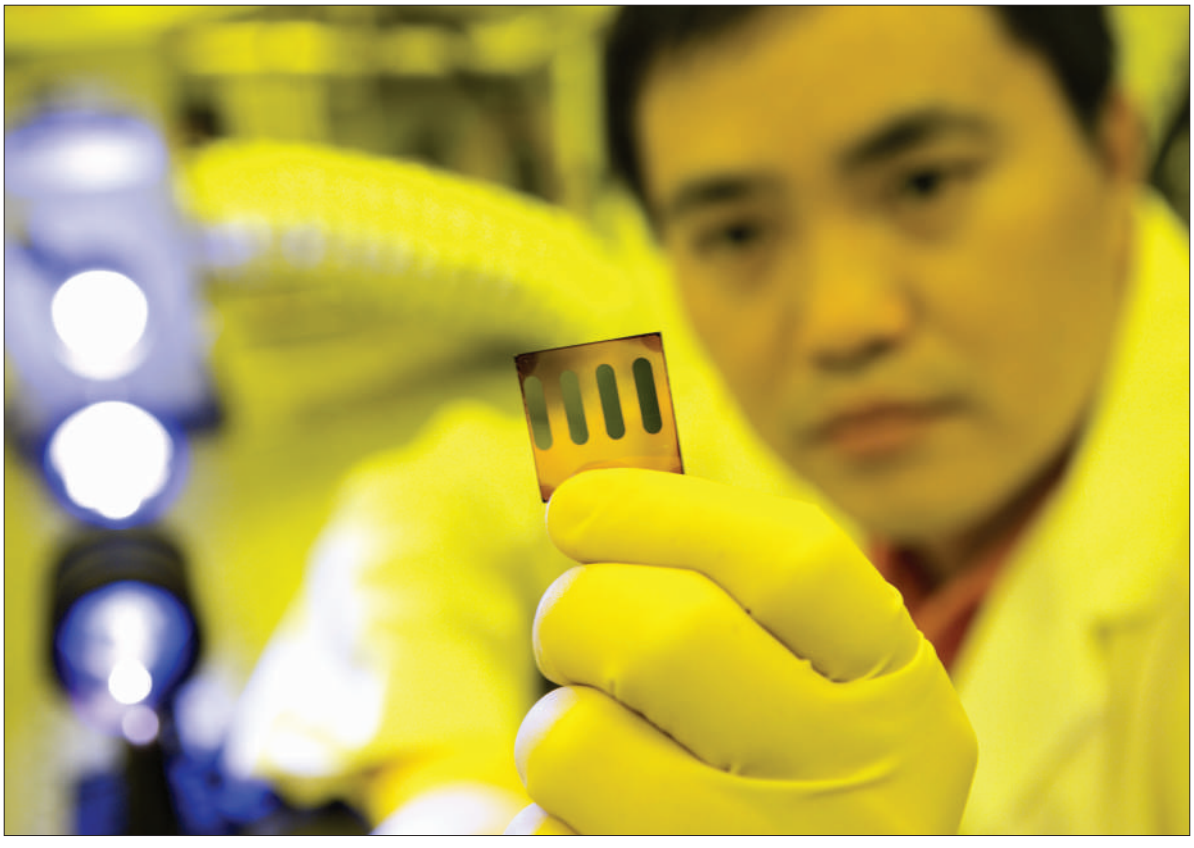

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Research Article
Performance Evaluation of Potato (*Solanum tuberosum* L.) Varieties under Irrigation for Tuber Yield and Adaptability in Central Highlands of Ethiopia

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Abstract

Background and Objective: Potato is an important crop for smallholder farmers in Ethiopia. The performances of different released and introduced commercial potato varieties were not yet evaluated under irrigation in the study areas. The objective of the study was evaluating the performance and adaptability of released and commercial potato varieties for fresh/table purposes in different potato growing agro-ecologies of the country. **Materials and Methods:** Treatments include five commercial and three nationally released potato varieties were evaluated for their vegetative growth performance and high tuber yield under irrigation conditions. The experimental field was laid out in randomized complete block design (RCBD) with 3 replications. **Results:** Among evaluated varieties, Belete variety had the highest plant height and stem number of per plant whereas, Chubak variety had the lowest plant height and stem number, plant among the other varieties. Statistically significant differences ($p<0.05$) were recorded among the varieties for average tuber number and tuber weight per plant. Potato variety Haryung gave the highest average tuber number followed by Gown. The highest total yield and marketable tuber yield recorded for Gudanie variety followed by Haryung and Seohong, respectively. **Conclusion:** It is conclude that the study evidently demonstrated the effect of varietal difference on the growth potential of potato varieties under irrigation. Thus, in both seasons during 2017/18 and 2018/19 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.

Key words: Potato, adaptation, vegetative growth, total tuber yield, marketable tuber yield, irrigation

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

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[2]. 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[3]. 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[4,5]. It is one of the strategic crops, enhancing food security and economic benefits to the country. 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[6]. But lack of well adapted cultivars to various abiotic stresses is one of a production problems that account for low yield and small area cropped to the nation[7]. 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[8] is 13.9 t ha^{-1}, which is lower than the experimental yields of over[9] 35 t ha^{-1} and world average yield[10] of 20 t ha^{-1} 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[11]. 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[12,13].

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[14]. 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[15]. 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[16]. Yield is a complex trait in potato and is generally considered to have low heritability[17]. 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 performance and adaptability of released potato varieties and commercial potato introduced from Korea 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.

The evaluation of potato varieties under irrigation was conducted at Holetta Agricultural Research Centre, which is located in the Oromia National Regional State and about 29 km far from Addis Ababa in West direction. The site, Holetta Agricultural Research Center, lies at 9°00′ N latitude, 38°30' E longitude and with an elevation of 2400 (m.a.s.l) in central Ethiopia. The daily average minimum and maximum temperatures of the area were 6.42 and 27.2°C, respectively and the mean annual rainfall was 918.31 mm. The soil of the experimental site is predominantly Nitisols, which is characteristically reddish to brown in color. It has soil pH of 5.24 and clay in texture with contents of 62.5% clay, 30.0% silt and 7.5% sand. The soil has organic matter content of 2.18% and total nitrogen, available phosphorus and exchangeable potassium contents of 0.18%, 30.58 ppm and 0.14 meq 100 g^{-1} soils, respectively[18]. 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[19]. The long rainy season extends from June-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[20]. The soil of the experimental site is a well-drained deep alluvial with a sub-soil stratified with loam and sandy loam.

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 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 3.0×3.0 m = 9 m^2 wide consisting of 4 rows, which accommodated 10 plants/row and thus 40 plants/plot. The spacing between plots and adjacent replication was 1 m. At each site, medium sized (39-75 g)[4] and well sprouted tubers were planted using irrigation during February, 2017 and 2018 for two consecutive years at the spacing of 75 cm between ridges and 30 cm 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[21]. 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[22].

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^{-1}), average tuber weight (ATW/g), average tuber number (ANT)/plant and tuber physical characteristics like skin color, shape, eye depth and flesh color were recorded. Quality parameters such as dry matter content and specific gravity were taken during harvesting.

Statistical analysis: The data were subjected to analysis of variance (ANOVA) following the standard procedure given by Montgomery[23]. 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 analysis were carried out using SAS-9.2 statistical soft ware package[24].

RESULTS AND DISCUSSION

Results of analysis of variance (ANOVA) indicated that 5 growth characters for 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. 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 *et al.*[25] reported that the interaction effect of variety, location and year showed significant different ($p<0.05$) on number of main stem/plant. The difference in plant height among the varieties might be associated to genetic differences, which may led to the variable performances in growth and development[26]. The differences might be due varietal effect and plant canopy which determine main stem to different locations[27]. 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/plot[16].

Table 1: Plant height (PH), main stem number (MSN), average tuber number (ATN), average tuber weight (ATW) and marketable tuber number for adaptation of Korean potato, varieties at Holetta, D. Berhan and Kulumsa during 2017/18

Varieties	PH (cm)	MSN/plant	ATN/plant	ATW (g)	MTN/plot
Chubak	56.71^{b}	6.27^{a}	11.61^{bc}	75^{bc}	141.33^{ab}
Seohong	47.56^{c}	5.93^{ab}	12.91^{ab}	89^{a}	140.88^{ab}
Goun	40.47^{d}	3.64^{e}	7.32^{f}	57^{d}	97.33^{c}
Jowon	33.27^{e}	3.62^{e}	9.60^{de}	65^{cd}	85.66^{c}
Haryung	35.98^{de}	5.49^{abc}	8.32^{ef}	71^{bc}	103.22^{c}
Awash	55.47^{b}	4.51^{de}	14.03^{a}	91^{a}	152.55^{a}
Gudanie	64.60^{a}	5.20^{bcd}	12.39^{ab}	65^{cd}	141.44^{ab}
Belete	63.22^{a}	4.82^{cd}	10.57^{cd}	82^{ab}	124.00^{b}
CV (%)	11.30	19.66	17.50	19.37	16.41
LSD (0.05%)	5.32	0.92	1.80	0.14	19.20
p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

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

Table 2: Marketable tuber yield (MTY), total tuber yield (TTY), dry matter content (DM) and specific gravity (SG) for adaptation of Korean potato varieties (Holetta, D. Berhan, Kulumsa, Mekelle and Haramaya) during 2017/18

Varieties	MTY (t ha^{-1})	TTY (t ha^{-1})	DM (%)	SG (g cm^{-3})
Chubak	30.95^{b}	33.52^{bc}	20.84^{c}	1.075^{c}
Seohong	37.95^{a}	41.78^{a}	23.46^{ab}	1.088^{ab}
Goun	20.07^{d}	22.49^{d}	24.32^{a}	1.089^{ab}
Jowon	23.84^{cd}	27.20^{cd}	21.54^{bc}	1.086^{b}
Haryung	28.61^{bc}	31.44^{bc}	24.47^{a}	1.097^{a}
Belete	31.07^{b}	34.38^{b}	25.19^{a}	1.094^{ab}
CV (%)	29.07	28.13	12.61	1.220
p-value				
Variety	<0.0001	<0.0001	0.0005	0.0010
Location	<0.0001	<0.0001	<0.0001	<0.0001
Var×Loc	NS	NS	NS	NS

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

In addition, De la Morena *et al.*[28] described that the difference in of number main stem among the varieties might be due to the inherent genotypic variation in the number of buds/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 Tisdale *et al.*[29].

There was highly significant (p<0.01) variation among the tested varieties with respect to total 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 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 was 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[30] found that, varieties Belete and Gudanie produced tubers with higher dry matter content. In consistent with this result, Tai and Coleman[31] reported that dry matter content is subjected to the influence of both the environment and genotypes. In the same manner, Rytel *et al.*[32] 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, Gebreselassie *et al.*[33] 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 *et al.*[25] 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[25].

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

Table 3: Main stem number (MSN), average tuber number (ATN), average tuber weight (ATW), marketable tuber yield (MTY) and total tuber yield (TTY) for adaptation of Korean potato varieties at Holetta Kulumsa, Debre Birhan and Mekelle -2018/19

Varieties	MSN	ATN m^{-2}	ATW (g/plant)	MTY (t ha^{-1})	TTY (t ha^{-1})
Chubak	3.57^{b}	37.37^{b}	50.19^{c}	14.73b^{c}	19.28^{c}
Seohong	6.27^{a}	30.09^{c}	51.27^{c}	19.44^{a}	25.54^{b}
Goun	6.19^{a}	42.39^{b}	78.21^{a}	16.12^{ab}	23.60^{bc}
Jowon	4.18^{b}	41.23^{b}	81.86^{a}	19.17^{a}	22.77^{bcd}
Haryung	6.68^{a}	52.73^{a}	49.14^{c}	18.48^{ab}	27.09^{ab}
Awash	5.90^{a}	36.79^{b}	60.55^{b}	12.19^{c}	18.53^{d}
Gudanie	6.68^{a}	40.43^{b}	59.76^{b}	17.72^{ab}	30.08^{a}
Belete	6.58^{a}	29.78^{c}	62.68^{b}	14.98^{bc}	24.65^{b}
CV (%)	18.81	12.31	10.49	18.29	14.72
p-value					
Location	<0.0001	0.0001	<0.0001	NS	<0.0001
Variety	<0.0001	<0.0001	<0.0001	0.0025	<0.0001
Loc×Var	0.0076	0.0016	<0.0001	<0.0001	<0.0001

Means followed by the same letters with in the same column are statistically non-significant at $p<0.05$ according to the least significant difference (LSD) test, Var×Loc: Interaction of variety with location, CV: Coefficient of variation, NS: Non-significant

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×environment interaction[34].

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. Thus, 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 produced equivalent total and marketable tuber yield across locations that was comparable to nationally released varieties (Gudanie and Belete) under all testing locations under irrigation production system.

SIGNIFICANCE STATEMENT

This study discovered the importance of evaluating different potato varieties under irrigation, since climate change is one of the challenges threatening potato production. This study can be beneficial for potato producer to improve the production and productivity as well as to exploit the potential of the crop. This study will help the researchers to uncover the critical areas of potato water use efficiency that many researchers were not able to explore. Thus a new theory on genetic variability under irrigation production system may be arrived at.

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