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Performance Evaluation of Irish Potato Varieties (*Solanum tuberosum* L.) Under Irrigation at Selected Districts of Central Ethiopia Region

[1]*Mohammed Ahmed*, [2]*Muhammed Sitot and* [3]*Bilal Temam*
[1]*Central Ethiopia Agricultural Research Institute, Worabe Agricultural Research Center, P.O. Box 21, Irrigation Researcher, Worabe, Ethiopia*
[2]*Central Ethiopia Agricultural Research Institute, Worabe Agricultural Research Center, P.O. Box 21, Plant Breeding and Horticulture Researcher, Worabe, Ethiopia*
[3]*Central Ethiopia Agricultural Research Institute, Worabe Agricultural Research Center, P.O. Box 21, Plant Pathology Researcher, Worabe, Ethiopia*

ABSTRACT

Background and Objective: In Alicho Wuriro and Misrak Azernet Worabe, farmers produced potatoes under rain-fed and irrigation to ensure income generation, food security, and food self-sufficiency. However, farmers in these areas continue to use local potato varieties that have low yield potential and susceptible to disease due to a lack of innovation in potato technology. The study aimed to select and recommend the best Irish potato varieties under irrigation conditions. **Materials and Methods:** It was conducted in Alicho Wuriro and Misrak Azernet District of Siltie zone, in 2017/18. The treatments consisted of five improved varieties (Gudene, Belete, Degemegn, Jalene, and Guassa) and one local variety. A randomized complete block design with three replications was adopted. Data on plant height, tuber number plant, total tuber yield in ton/ha, severity of late blight, and powdery mildew disease and analyzed using SAS 9.3 software. **Results:** The interaction effect of varieties*locations revealed significant variations in tuber per plant, total yield, and disease response combined over two locations. Based on the mean performance variety Degemegn recorded the highest total tuber yield in ton/ha at Alicho Wuriro District and Guassa variety also gave the highest tuber yield in ton/ha at Misrak Azernet District. **Conclusion:** The Degemegn variety in Alicho District and Guassa variety were the two highest-performing varieties in specific environments. Therefore, genotypes Degemegn for Alicho Wuriro and Guassa for Misrak Azernet District which produced lower disease severity coupled with higher tuber yield, can be recommended for production under irrigation in the study area.

KEYWORDS

Irish potato, irrigation, tuber yield, susceptible environments, (*Solanum tuberosum* L.)

INTRODUCTION

Potato (*Solanum tuberosum* L.) originated in the Andean highlands of South America[1] and was introduced to Europe in the 16th century. Potato is a major economic crop in the world, as well as one of the tuber crops that are important in the human diet for energy and protein. Potatoes are an excellent energy

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source for humans due to their relatively high carbohydrate and low fat content[1]. In the tropical highlands of Sub-Saharan Africa, potatoes are regarded as a crop that contributes to food security and helps to meet the growing demand for food[2]. One of the most productive food crops in terms of yield and high-quality protein per unit area and time is the potato. Because it can yield a high-quality product per unit input with a shorter crop cycle, it is considered a crop with high potential for food security[3]. One of the most important crops grown and consumed worldwide is the potato[4,5]. An estimated 359,071,407 tons of potatoes are produced worldwide each year on 16,494,810 ha of land[6]. There are 15 million hectares of land in Ethiopia that could be used for irrigated agriculture. However, approximately 4-5% of the 640,000 ha covered by the current, fully equipped irrigation infrastructures are watered[7]. Irrigated agriculture makes a substantial contribution to food security by producing about 40% of food and agricultural commodities on 17% of agricultural land[8].

The Ethiopian government has put a great strategy to use and implement irrigation projects for maximizing the production and productivity of different food-securing crops including potatoes. The results will contribute to an increase in the production of this important crop under irrigation conditions. It will significantly benefit and impact Ethiopia's regional and national Irish potato improvement programs.

Despite the large amounts of potatoes produced globally, abiotic stressors, pests, climate change, and subpar production methods all contribute to yield disparities[9]. In the end, closing the potato yield gaps will contribute to ensuring both present and future food security[5]. Approximately 70% of Ethiopia's arable land is located in the country's highlands, making it ideal for potato production[5]. A basic item, potatoes are important for improving livelihoods and ensuring food security in Ethiopia[5]. In contrast to the global average of 20.11 ton/ha and other African nations such as South Africa (37.3 ton/ha), Algeria (31.2 ton/ha), and Egypt (29.2 ton/ha)[6], the productivity of potatoes (13.3 ton/ha) is extremely low[5]. Low potato productivity is caused by a wide range of intricate biotic and abiotic factors, such as poor soil fertility management, disease, and insect pest prevalence, improper agronomic practices, high seed tuber costs, and insufficient facilities for marketing and storage[6]. Irish potato cultivation has a lot of promise in the Central Ethiopia Region, and it is currently typical to grow this crop under irrigation in addition to rain feed. Farmers in Alicho Wuriro and Misrak Azernet Worabe grew potatoes using irrigation and rain to provide food security, self-sufficiency, and revenue generation. Nevertheless, farmers in these regions continue to employ native potato varieties that are prone to disease and have limited yield potential because of a lack of innovation in potato technology. Additionally, poor post-harvest and agronomic techniques, such as using unimproved varieties and earthling up often, are being used by farmers. Therefore, by recognizing these problems, the present study was conducted in Alicho Wuriro and Misrak Azernet Worabe to identify, select and recommend the best Irish potato varieties in yield, yield components, and disease resistance under irrigation conditions in the study area.

MATERIALS AND METHODS

Description of the study area: The current study was conducted in two locations of Siltie Zones of Central Ethiopia Region specifically, in Alicho Wuriro and Misrak Azernet Worabe during 2017/18. In Alicho Wuriro, it was done in '*Silo*' kebele located 7°45'17"N and 37°55'14'E with an altitude of 2478 m above sea level. On the other hand in Misrak Azernet Worabe, it was done in '*Lay Umnan*' kebele located 7°8'05"N and 38°0'03"E with an altitude of 2483 m above sea level. Each kebeles was selected based on their water potentiality and production potential.

Experimental treatments and design: In the current study, five released Irish potato varieties were collected from Hawassa ARC, and one local variety was used (Table 1). Treatments were laid down in RCBD design with three replications. Each treatment was arranged randomly in a randomized complete block design. Plot sizes were kept constant at 3×3 m between plots 1 m and between replications 1.5 m. Plants

Table 1: Description of Irish potato varieties used in the current study

S.N	Variety	Year of release	Maintaining center	Altitude (m.a.s.l)	References
1	Gudene	2006	HARC	1600-2800	Tessema *et al.*[10]
2	Belete	2010	HARC	1600-2800	Getachew[11]
3	Jalene	2002	HARC	1600-2800	Tessema *et al.*[10]
4	Degemegn	2002	HARC	1600-2800	Tessema *et al.*[10]
5	Guassa	2002	ADARC	2000-2800	Getachew[11]

HARC: Holeta Agricultural Research Center and ADARC: Adet Agricultural Research Center

were grown at a spacing of 75 by 30 cm. Each experimental plot contains four rows and the two middle rows were used for data collection and analysis. Weeding was carried out by hand and cultivated three times until harvest. A side dressing of NPS was applied at a rate of 200 kg/ha and one-third of 100 kg/ha UREA was applied at planting, the remaining two-thirds of UREA was applied as top dressing during flowering.

Data collected: Samples of five plants were selected randomly from each experimental plot and measured the following agronomic parameters. The growth parameters and yield and yield components were collected from the middle rows. The data was taken from the central two rows and the net area of each plot, this is to avoid border effects. The data includes plant height, number of tubers per plant; total tuber yields tons per hectare, and severity of late blight and powdery mildew on a 1-9 scale, in which plants that scored 1 to 3 were considered resistant 3 to 4, moderately resistance and plants scored 4 to 9 were susceptible.

Data analysis: The collected data like yield, yield components, and disease reaction to late blight and powdery mildew of Irish potato were analyzed by using Statistical Analysis System (SAS) version 9.3 using the procedure of general linear model (SAS) for the variance analysis. Mean comparisons were carried out to estimate the differences between treatments. The Least Significant Difference (LSD) at a 5% probability level was used to compare the treatments.

For the combined analysis of variance over locations, the linear mixed model was applied as follows:

$$Y_{lmn} = \mu + g_l + e_m + bk_{(n)m} + (g*e)_{lm} + \varepsilon_{lmn}$$

where, Y_{lmn} is the response of Y trait from the l^{th} genotype, grown in the n^{th} block of m^{th} locations. The μ is the Grand mean, g_l is the effect of the l^{th} genotype, e_m is the effect of m^{th} locations, $bk_{(n)\,m}$ is the effect of n^{th} block/rep in m^{th} locations. The $(g*e)_{lm}$ is the interaction between the l^{th} genotype and m^{th} locations. The ε_{lmn} is a pooled error.

RESULTS AND DISCUSSION

Combined analysis of variance: The analysis of variance showed that there was a highly significant interaction effect of treatment*location effect at $p<0.005$ for plant height, total yield, and severity response of late blight and powdery mildew diseases (Table 2). Indicating, that specific recommendations should be made for each study area under irrigation conditions. Implying, its importance to select and recommend, in each specific Worabe, the best performed Irish potato variety under irrigation conditions. Previously, a highly significant interaction effect of treatment with locations has been reported Jafar *et al.*[12], Abbas *et al.*[13], Asefa *et al.*[14] and Mohammed[15]; which supports the current findings.

The results of separate analysis of variance revealed significant variation among Irish potato varieties for the trait number of tuber per plant and powdery mildew disease ($p<0.05$) at Alicho Wuriro District (Table 3). A highly significant difference ($p<0.001$) was observed for the trait total tuber yield and late blight disease (Table 3) and a non-significant difference ($p<0.05$) among tested varieties for the trait plant height Alicho Wuriro District.

Table 2: Mean square values of Irish potato varieties for yield, yield component, and disease resistance under irrigation combined over location

Source	DF	Ph (cm)	TPP (No.)	TY (ton/ha)	LB (scale 1-9)	PMW (scale 1-9)
Trt	5	122.47**	24.66^{ns}	303.1**	16.38**	3.67**
Rep (loc)	4	4.94^{ns}	6.55^{ns}	4.55^{ns}	1.68^{ns}	0.69^{ns}
Error	19	9.41	10.61	7.07	0.76	0.76
Loc	1	307.24**	99.44*	11.3^{ns}	0.26^{ns}	0.08^{ns}
trt*loc	5	17.92^{ns}	11.27^{ns}	60.7**	0.68^{ns}	0.47^{ns}

DF: Degree of freedom, Ph: Plant height in centimeter, TPP: Tuber per plant in number, TY: Total yield in tons per hectare, LB: Late blight severity in 1-9 scale, PMW: Powdery mildew severity in 1-9 scale, **Implies highly significance differences and ^{ns}Implies non-significance difference

Table 3: Mean square of potato varieties for yield, yield component, and disease resistance at Alicho Worabe, during the 2017/18 cropping season

Source	DF	Ph (cm)	TPP (No.)	TY (ton/ha)	LB (scale 1-9)	PMW (scale 1-9)
Trt	5	109.6^{ns}	41.3*	178.5**	14.6**	4.5*
Rep	2	29.1	0.4	13.2	0.4	0.7
Error	10	43.4	2.5	6.1	0.65	0.6

DF: Degree of freedom, Ph: Plant height in centimeter, TPP: Tuber per plant in number, TY: Total yield in tons per hectare, LB: Late blight severity in 1-9 scale, PMW: Powdery mildew severity in 1-9 scale, **Implies highly significance differences, *Implies significance difference and ^{ns}Implies non-significance difference

Table 4: Mean values of potato varieties for yield, yield component, and disease resistance at Alicho Worabe, during the 2017/18 cropping season

Variety	Ph (cm)	TPP (No.)	TY (ton/ha)	LB (scale 1-9)	PMW (scale 1-9)
Gudene	73.0^{b}	13^{bc}	29.6^{a}	5.6^{b}	3.6^{b}
Belete	73.6^{b}	12^{bc}	16.0^{cd}	2^{d}	4.3^{b}
Degemegn	71.0^{b}	18^{a}	33.0^{a}	3^{d}	2.5^{b}
Jalene	85.6^{a}	11^{c}	20.6^{bc}	4.6^{bc}	3.6^{b}
Guassa	77.6^{ab}	14^{b}	22.6^{b}	3^{d}	4^{b}
Local	68.6^{b}	7^{d}	13.0^{d}	8.3^{a}	6.3^{a}
CV	8.7	12	11.7	17	19
LSD	11.9	2.9	4.8	1.4	1.4

Ph: Plant height in centimeter, TPP: Tuber per plant in number, TY: Total yield in tons per hectare, LB: Late blight severity in 1-9 scale, PMW: Powdery mildew severity in 1-9 scale and Means in columns and rows followed by the same letter(s) are not significantly different at a 5% level of significance

Table 5: Mean square of potato varieties for yield, yield component, and disease resistance at Misrak Azernet Worabe, during 2017/18 cropping season

Source	DF	Ph (cm)	TPP (No.)	TY (ton/ha)	LB (scale 1-9)	PMW (scale 1-9)
Trt	5	88.1^{ns}	64.3**	198.6**	13.3**	7.8*
Rep	2	18.2	8.2	6.16	0.7	1.7
Error	10	18.9	1.6	5.9	0.7	0.9

DF: Degree of freedom, Ph: Plant height in centimeter, TPP: Tuber per plant in number, TY: Total yield in tons per hectare, LB: Late blight severity in 1-9 scale, PMW: Powdery mildew severity in 1-9 scale, **Implies highly significance differences, *Implies significance difference and ^{ns}Implies non-significance difference

Again, a highly significant difference was observed among tested varieties, for the trait tuber number per plant, total tuber yield, and late blight ($p<0.001$) at Misrak Azernet District (Table 5). Significant differences ($p<0.05$) were observed for the trait powdery mildew disease and non-significant differences ($p<0.05$) among varieties for the trait plant height in the Misrak Azernet District (Table 5).

In Alicho Wuriro District, the maximum plant height was recorded from Jalene (85.6^{a}) followed by Guassa (77.6^{ab}) and the minimum height was recorded from Local (68.6^{b}) according to Table 4. The highest average tuber number per plant was recorded from varieties 'Degemegn' (18^{a}) and 'Local' (7^{d}) with the lowest tuber number per plant (Table 4). Regarding total tuber yield the maximum yield was observed from Degemegn (33^{a} ton/ha) followed by Gudene (29^{a} ton/ha), while the minimum was recorded from the local (13^{d} ton/ha) variety (Table 4).

Table 6: Mean values of potato varieties for yield, yield component and disease resistance at Misrak Azernet Worabe, during 2017/18 cropping season

Variety	Ph (cm)	TPP (No.)	TY (ton/ha)	LB (scale 1-9)	PMW (scale 1-9)
Gudene	68^{b}	16^{b}	26.0^{b}	4.3^{b}	4.0^{b}
Belete	62^{b}	11^{c}	16.0^{d}	1.6^{d}	3.6^{b}
Degemegn	64^{b}	16^{b}	22.0^{bc}	3.3^{bc}	3.0^{b}
Jalene	77^{a}	14^{b}	21.3^{c}	3.6^{bc}	3.3^{b}
Guassa	64^{b}	21^{a}	32.6^{a}	2.3^{cd}	3.3^{b}
Local	64^{b}	7^{d}	9.0^{e}	7.6^{a}	7.3^{a}
CV	6.5	8.8	1.4	21	23
LSD	7.9	2.3	4.4	1.4	1.7

Ph: Plant height in centimeter, TPP: Tuber per plant in number, TY: Total yield in tons per hectare, LB: Late blight severity in 1-9 scale, PMW: Powdery mildew severity in 1-9 scale, Means in columns and rows followed by the same letter(s) are not significantly different at a 5% level of significance

Considering the disease response varieties Belete (2^{d}), Degemegn (3^{d}) and Guassa (3^{d}) were identified as resistant to late blight, and Gudene (5.6^{b}), Jalene (4.6^{bc}) and Local (8.3^{a}) as susceptible varieties under irrigations conditions (Table 4) at Alicho Wuriro District. Again, variety Degemegn (2.5^{b}) was identified as having a resistance reaction, Gudene (3.6^{b}) and Jalene (3.6^{b}) as having a moderately resistance reaction, and Belete (4.3^{b}), Guassa (4^{b}) and Local (6.3^{a}) as having susceptible reaction for powdery mildew at Alicho Wuriro District (Table 4).

In Misrak Azernet District, the highest average tuber number per plant was recorded from the varieties 'Guassa' (21^{a}) and 'Local' (7^{d}) with the lowest tuber number plant (Table 6). Regarding total tuber yield the maximum yield was observed from Guassa (32.6^{a} ton/ha), while the minimum was recorded from local (9^{e} ton/ha) variety (Table 6). Considering the disease response varieties Belete (1.6^{d}) and Guassa (2.3^{cd}) were identified as resistant to late blight, and Degemegn (3.3^{bc}) and Jalene (3.6^{bc}) as having moderately resistance reaction and Gudene (4.3^{b}) and Local (7.6^{a}) as susceptible varieties under irrigations conditions (Table 6) at Misrak Azernet District. Again, variety Degemegn (3^{b}) was identified as having resistance reaction, Belete (3.6^{b}) Jalene (3.3^{b}) and Guassa (3.3^{b}) as having moderate resistance reaction, and Gudene (4^{b}) and Local (7.3^{a}) as having susceptible reaction for powdery mildew at Misrak Azernet District (Table 4).

The existence of extremely significant differences between potato varieties provided useful information about the existence of adequate genetic differences that may be connected to the varieties' genetic composition. There have also been reports of genetic variations among 17 Ethiopian potato cultivars in terms of late blight disease resistance and total tuber yield[15]. The phonological and growth characteristics of Irish potato types were also found to differ significantly in Eastern Ethiopia[12]. The existence of highly significant genotype differences by region is unmistakable proof of the environment's substantial impact on the characteristics of Irish potato cultivars under study. The relationship between variety and environment affected the varieties' performances for the remaining attributes, indicating that the varieties responded differently at each site. In Ethiopia's Eastern regions, a similar study was published by Elfinesh *et al.*[16] that demonstrates the substantial impact of genotypes, growing conditions, and their interactions on some potato features. Several researchers have reported similar findings regarding potatoes[13-15].

Mean performance of varieties for growth traits: In both areas (Alicho Wuriro and Misrak Azernet District), the variety Jalene had the tallest plants. It was also noted that there was a significant variation in plant height between potato genotypes and growing conditions in Northern Ethiopia[10]. Plant genetics, the quality of the plant material, and the cultivars' reactions to their growing conditions could all be contributing factors to these variations in plant height[17].

Mean performance of varieties for yield components and yield: The results of separate analysiss of variance revealed that the highest average tuber number per plant was recorded from variety 'Degemegn' and lowest was from 'Local' at Alicho Wuriro District. While the variety 'Guassa' gave the highest and 'Local' with the lowest tuber number plants, respectively at Misrak Azernet District. Jafar *et al.*[12] also reported a significant variation between varieties, growing environment, and their interaction in potatoes for the average tuber number per hill in Eastern Ethiopia. Similarly, Fetena and Eshetu[18], also reported a significant difference in tuber numbers per hill among 5 different potato varieties in Southern Ethiopia. According to the current study's findings, tuber weight was influenced by both genetic variation and the growth environment. In Eastern Ethiopia, potato genotypes, location, and their interactions all had a significant impact on average tuber weight, according to Jafar *et al.*[12]. It was found that sixty potato genotypes examined in Northern Ethiopia had statistically significant differences[10]. Genetics, management techniques, seed quality, or the agro-ecological circumstances of the experimental sites could all contribute to variations in the weight of tubers per plant among types[17]. According to a separate examination of each location, the tuber yields of varieties "Degemegn" and "Local" were the highest at 33 ton/ha and the lowest at 13 ton/ha in the Alicho Wuriro District. Once more, in the Misrak Azernet District, the varieties "Guassa" and "Local" yielded the most tubers (32 ton/ha) and the least (9 ton/ha), respectively. As a result, different cultivars performed differently in terms of tuber yield at various sites. This could be the result of environmental influences or the genetic composition of different types. Several Ethiopian researchers have observed similar tuber yield fluctuation results on potatoes[10,15,18]. The observed yield variations among varieties and settings may have been caused by changes in tuber size, plant spacing, and other factors in addition to the genetic composition of the varieties[19].

Mean performance of potato varieties for disease resistance: The lowest mean severity for late blight was recorded from varieties Belete (2^{d}), Degemegn and Guassa while the highest was recorded from Local (8^{a}) at Alicho Wuriro District (Table 4). However, the remaining varieties (Gudene and Jalene) were also recorded as having susceptible reactions to late blight disease. Showing Belete variety responds to resistance reaction and local Irish potato variety with susceptible reaction for late blight disease. In Misrak Azernet District, varieties Belete (1.6) and Guassa (2.3) were observed with resistance performance, Degemegn and Jalene with moderate resistance, and Gudene and local varieties with a susceptible response (Table 6). Regarding Powdery mildew disease, the lowest mean severity was observed from variety Degemegn (2.5^{b}), whereas, the highest was recorded from the Local (6.5^{a}) variety at Alicho Wuriro District (Table 4). Variety Degemegn was having the lowest mean severity and Local with the highest severity reaction to powdery mildew disease at Misrak Azernet District (Table 6). In the present study, varieties Jalene and Gudene with moderately resistance reactions in Alicho Wuriro District (Table 4) and Guassa, Jalene, and Belete in Misrak Azernet District (Table 6).

Indeed, the current finding has great implications for potato improvement programs to identify and use the best varieties for maximizing potato production under irrigation conditions. So, it has practical applications for farmers in the considered areas to ensure income generation, food security, and food self-sufficiency. More importantly, one of the limitations of the present study is it is limited to specific sites which doesn't address all irrigation potential sites (Specifically in the midland areas of the regions). It needs to be addressed with the recently released Irish potato varieties in high irrigation potential areas of the Central Ethiopia Region. Overall, the two Irish potato varieties specifically Degemegn for Alicho Wuriro District and Guassa for Misrak Azernet District were selected with better yield and disease resistance and recommended for production for farmers in the study area under irrigation in the future.

CONCLUSION AND RECOMMENDATIONS

In the study, it was investigated highly significant variation observed among Irish potato varieties for their adaptability and performance under irrigation conditions. The study revealed the presence of potential Irish potato varieties to be expanded for farmers for production in the study area. The two Irish potato

varieties specifically Degemegn for Alicho Wuriro District and Guassa for Misrak Azernet District were selected with better yield and disease resistance and recommended for production for farmers in the study area under irrigation for the future.

SIGNIFICANCE STATEMENT

Potatoes are an excellent energy source for humans due to their relatively high carbohydrate and low fat content. The study aimed to select and recommend the best Irish potato varieties under irrigation conditions. One of the most important points here the adaptable variety was identified for further PVS and demonstration study. The present study will contribute the basic information for horticulturist professionals for further study in Irish potato crops for agronomic, pathology, and pre-extension study in the considered areas.

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