



# Screening of Potato Germplasms for Heat Stress in Lowland, Fafan, Somali Region, Ethiopia

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## Authors' contributions

All of the authors worked together to complete this work. The study's concept, methods, and first draft were all created by author ASA. The author AHM carried out fieldwork, who also oversaw data collection, assisted with data analysis, and revised the text. Author MDA offered invaluable assistance with the manuscript's revision, which included proofreading, grammar correction, sentence structure improvement, and formatting following the target journal's requirements. The final draft of the work was examined, commented on, and approved for submission by all authors.

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## ABSTRACT

Potato (*Solanum tuberosum* L.) is a critical food security crop and a key source of income for smallholder farmers in Ethiopia. Despite its potential to produce high yields on limited land and within a short growing period, potato production in lowland areas remains limited due to high temperature stress. Developing and evaluating heat-tolerant potato genotypes adapted to these agro-ecologies is therefore essential. This study aimed to assess the yield performance of fifteen potato genotypes under lowland conditions at the Fafen Agricultural Research Station in the Somali Region during the 2021 and 2022 cropping seasons. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The results showed highly significant differences among genotypes and between years for most yield-related traits, except days to flowering and maturity. Significant genotype  $\times$  year interaction effects were observed for all traits except days to flowering, maturity, plant vigor, and plant height. Among the tested genotypes, CIP312923.522 and CIP312906.575 exhibited superior performance, producing the highest marketable tuber yields in categories I ( $>80 \text{ g tuber}^{-1}$ ) and II ( $>30 \text{ g tuber}^{-1}$ ), and total tuber yield, respectively. These promising genotypes are recommended for further evaluation in variety verification trials under on-station and on-farm conditions in the study area and other similar lowland agro-ecologies.

**Keywords:** *Potato genotypes; heat stress; lowland agro-ecologies; tuber yield; Somali region; Ethiopia.*

## 1. INTRODUCTION

Potatoes are a precious source of food for many low-income people in both urban and rural areas. Potato is the world's third most important food crop in overall production after rice and wheat, and is a food security crop in Ethiopia (Devaux *et al.*, 2014). It is mainly used as a vegetable and is available in the market throughout the year at a reasonable price. It is of great importance in the country's rural economy compared to other vegetable crops in Ethiopia. It can be consumed in different forms, such as boiled, roasted, fried, and chipped (Seid *et al.*, 2024). Potatoes are a vital source of carbohydrates, resistant starch, high-quality proteins, vitamins C and B6, and potassium (Camire *et al.*, 2009). In addition to their nutritional value, potatoes are rich in antioxidants that play a role in preventing degenerative and age-related diseases. Yellow-fleshed potato varieties, for example, are abundant in lutein and zeaxanthin (Burgos *et al.*, 2009, Kärenlampi and White., 2009), while purple and red-fleshed landraces are rich in anthocyanins (Burgos *et al.*, 2013b). These pigmented varieties are traditionally cultivated and widely consumed in countries such as Peru, Bolivia, Ecuador, and Colombia.

They are a source of different minerals like iodine (I), copper (Cu), iron (Fe), potassium (K), manganese (Mn), phosphorous (P), zinc (Zn), magnesium (Mg) and calcium, (Ca) (USDA, 2014). It is also an important food security crop in

eastern Ethiopia in particular and in Ethiopia in general (Tewodros and Belay, 2015, Arifa *et al.*, 2018).

In Ethiopia, potatoes are mostly cultivated in the central, northwestern, southern, and eastern parts of the country (Semagn *et al.*, 2016, Asefa *et al.*, 2016). The crop has potential for improving the livelihoods of millions of smallholder farmers in the highland area of the country. The potential for higher yield per unit area, early maturity, and excellent food value gives the potato crop greater potential for improving food security, increasing household income, and reducing poverty than other crops (Semahagn Asredie *et al.*, 2015, Ebrahim *et al.*, 2018). However, high temperatures pose a significant challenge to potato production. They adversely affect yields by inhibiting tuber formation, reducing the transport of carbon to storage organs, and limiting photosynthetic efficiency (Hancock *et al.*, 2014). Research indicates that temperatures above 25 °C can delay tuber initiation (Dahal *et al.*, 2019), while extreme heat, 35 °C during the day and 28 °C at night, can completely prevent tuber development in certain cultivars (Tang *et al.*, 2018).

Potato is a significant crop with substantial nutritional and economic value. Although it holds potential importance for food security and income generation in the Somali Region, there is currently no local potato production. All potatoes consumed in the region are imported from neighboring areas. This absence of production is

likely due to the lack of potato varieties adapted to the region's specific agroecological conditions.

To address this issue, it is necessary to conduct a variety of adaptability trials to identify potato genotypes that can thrive under the local environmental conditions. Such trials will enable farmers to select the most suitable varieties based on performance indicators relevant to their needs and preferences. In light of this, a variety of adaptability trial projects were initiated to introduce appropriate potato technology to the Somali Region. The primary objective of this study was to evaluate the performance of different potato genotypes in terms of tuber yield and yield-related traits under the conditions at the Fafen Research Centre, located in the Somali Regional State.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Materials, Design, and Procedure

A total of 15 potato genotypes were used in the study: CIP312921.550, CIP312926.502, CIP312923.522, CIP312923.562, CIP312920.538, CIP312927.550, CIP312916.591, CIP312897.548, CIP312898.640, CIP312911.508, CIP312906.575, CIP312896.509, CIP312905.530, CIP312901.638, and Belete (St.ck). The genotypes were arranged in a Randomized Complete Block Design (RCBD) with two replications due to a shortage of seed. Each gross plot measured 3 m × 3 m (9 m<sup>2</sup>) and consisted of four rows, with each row containing 10 plants, resulting in 40 plants per plot. Row and plant spacing were maintained at 0.75 m and 0.30 m, respectively. The spacing between plots and adjacent replications was set at 1 m and 1.5 m, respectively. Data were collected from the two central rows of each plot. The experimental field was plowed to a depth of 25–30 cm using a tractor, and ridges were formed manually after leveling the land. Planting depth was maintained at 10–15 cm. All other agronomic practices, including weeding, cultivation, and application of Redomil fungicide, were uniformly applied across all treatments. The soil at the experimental site was classified as sandy clay loam in texture.

### 2.2 Data Collection and Statistical Analysis

Data were collected on various agronomic traits to evaluate the performance of the potato genotypes. Days to 50% flowering were recorded as the number of days from planting until half of

the plants in each plot had flowered. Likewise, days to 50% maturity were determined by counting the days from planting until 50% of the plants in the central two rows exhibited yellowing of the haulms. Plant height was measured from the soil surface to the tip of the main stem on at least eight randomly selected plants from the central two rows. The average of these measurements was calculated to determine the mean plant height, expressed in centimeters. The number of plants harvested was recorded by counting all plants from the central two rows of each plot.

**Marketable tubers** were classified into two categories:

- *Category I*: tubers weighing more than 80 grams or measuring 40–60 mm in diameter.
- *Category II*: tubers weighing between 30–80 grams or measuring 20–40 mm in diameter. non-marketable tubers were defined as those weighing less than 30 grams or measuring under 20 mm in diameter.

The number of tubers in each category was counted from the central two rows. Additionally, the weights of marketable tubers (Categories I and II) and non-marketable tubers were measured in kilograms per plot. The total tuber yield per hectare was calculated by summing the weights of both marketable and non-marketable tubers and converting the result to kilograms per hectare. All collected data were subjected to analysis of variance (ANOVA) using GenStat 18th Edition software, following a Randomized Complete Block Design (RCBD). Treatment means that exhibited significant differences were compared using the Least Significant Difference (LSD) test at the 5% significance level.

## 3. RESULTS AND DISCUSSIONS

Genotype and year had a significant effect on all measured plant traits, except for days to flowering and maturity (Table 1). The significant differences observed among the varieties indicate the presence of genetic variation among the tested genotypes. The interaction between genotype and year also showed significant effects on most of the measured parameters, except for days to flowering, days to maturity, plant vigor, and plant height. These interactions may be attributed to the genetic characteristics of the genotypes and the variability in weather patterns at the experimental site.

**Table 1. Combined ANOVA Mean Squares for Plant and Yield Traits of Potato Genotypes (2021–2022) at Fafen**

Source of variation	DF	Mean square												
		DsF	PU	PV	DM	PH	AvSN	NMTCI	NMTCII	NNoMTP	MTWCI	MTWCII	NoMTWP	TTY
Rep	1	112.07	0.2667	0.267	0.267	228.74	14.2009	3.267	36.817	12.15	0.998	0.299	0.5419	1.412
Genotype	14	21.59ns	6.2571**	5.429*	4.245ns	151.48**	0.7671ns	413.874**	529.493**	322.62**	157.888**	19.314**	0.7590**	227.671**
Year	1	4.27ns	41.6667**	17.067**	8.067ns	218.62*	1.2760ns	1401.667**	13053.750**	5208.02**	1136.897**	798.766**	2.6014**	4044.100**
G*Y	14	21.80ns	6.2381**	2.781ns	2.602ns	78.24ns	0.6426ns	237.774**	138.036**	318.98**	111.525**	5.312**	0.8960**	125.962**
Error	29	14.51	0.4046	2.198	9.749	45.73	0.5150	9.336	9.093	12.63	6.404	1.436	0.1056	7.891
Total	59													

Keys: \*, \*\*: significant at 5% and 1% respectively, Rep= replication, Y= year, V \* Y=variety verses year, DF=degree of freedom DsF=days to flowering, DM=days to maturity, PH=plant height, PU= plant uniformity, PV= plant vigor, NMCTI=Number marketable tubers category I, NMCTII= Number marketable tubers category II, MNoMTP= Number of non-marketable tubers/plot, MTWCI= Marketable tuber weight category I, MTWCII= Marketable tuber weight category II, NoMTWP= Non-marketable tuber weight, TTY(kg/ha)=total tuber yield

**Table 2. Combined mean of potato genotypes on agronomic traits and tuber yield over two years**

Genotype	PU	PV	DM	PH	NMTCI	NMTCII	NNoMTP	MTWCI	MTWCII	NoMTWP	TTW
CIP312921.550	7.500 <sup>l</sup>	6.500 <sup>c</sup>	110.5 <sup>a</sup>	63.56 <sup>cde</sup>	47.00 <sup>c</sup>	39.25 <sup>de</sup>	45.25 <sup>bc</sup>	20.68 <sup>fg</sup>	8.228 <sup>bcd</sup>	2.568 <sup>c-f</sup>	31.48 <sup>ef</sup>
CIP312926.502	4.500 <sup>bc</sup>	5.000 <sup>abc</sup>	110.2 <sup>a</sup>	52.42 <sup>abc</sup>	33.50 <sup>f</sup>	16.00 <sup>h</sup>	26.50 <sup>f</sup>	23.18 <sup>def</sup>	3.377 <sup>hi</sup>	1.884 <sup>hi</sup>	28.44 <sup>f</sup>
CIP312923.522	6.500 <sup>hi</sup>	7.000 <sup>c</sup>	110.0 <sup>a</sup>	65.66 <sup>e</sup>	64.00 <sup>a</sup>	44.50 <sup>bc</sup>	47.75 <sup>ab</sup>	35.25 <sup>a</sup>	9.196 <sup>abc</sup>	2.969 <sup>abc</sup>	47.41 <sup>a</sup>
CIP312923.562	5.000 <sup>cde</sup>	7.500 <sup>c</sup>	109.0 <sup>a</sup>	65.73 <sup>e</sup>	34.50 <sup>ef</sup>	48.25 <sup>ab</sup>	39.50 <sup>de</sup>	19.76 <sup>fg</sup>	9.582 <sup>ab</sup>	2.011 <sup>ghi</sup>	31.35 <sup>ef</sup>
CIP312920.538	3.500 <sup>a</sup>	5.500 <sup>abc</sup>	109.5 <sup>a</sup>	55.13 <sup>b-e</sup>	39.75 <sup>d</sup>	28.00 <sup>g</sup>	39.50 <sup>de</sup>	29.65 <sup>bc</sup>	6.002 <sup>fg</sup>	2.531 <sup>c-f</sup>	38.19 <sup>cd</sup>
<b>CIP312927.550</b>	6.000 <sup>gh</sup>	5.000 <sup>abc</sup>	111.0 <sup>a</sup>	62.53 <sup>b-e</sup>	27.75 <sup>g</sup>	37.25 <sup>e</sup>	40.75 <sup>cd</sup>	13.98 <sup>i</sup>	7.276 <sup>def</sup>	2.796 <sup>a-e</sup>	24.05 <sup>g</sup>
CIP312916.591	6.500 <sup>g-j</sup>	6.500 <sup>c</sup>	110.0 <sup>a</sup>	60.32 <sup>b-e</sup>	41.25 <sup>d</sup>	25.25 <sup>g</sup>	36.00 <sup>de</sup>	24.93 <sup>de</sup>	5.388 <sup>g</sup>	2.260 <sup>f-i</sup>	32.58 <sup>ef</sup>
CIP312897.548	5.500 <sup>c-g</sup>	7.000 <sup>c</sup>	108.8 <sup>a</sup>	64.05 <sup>de</sup>	53.00 <sup>b</sup>	41.00 <sup>cde</sup>	37.50 <sup>de</sup>	29.58 <sup>bc</sup>	8.678 <sup>a-d</sup>	3.258 <sup>a</sup>	41.51 <sup>bc</sup>
CIP312898.640	4.000 <sup>ab</sup>	6.500 <sup>c</sup>	108.0 <sup>a</sup>	60.22 <sup>b-e</sup>	40.75 <sup>d</sup>	42.25 <sup>cd</sup>	51.75 <sup>a</sup>	17.93 <sup>gh</sup>	7.784 <sup>cde</sup>	2.924 <sup>a-d</sup>	28.64 <sup>f</sup>
CIP312911.508	7.500 <sup>ij</sup>	7.000 <sup>c</sup>	111.2 <sup>a</sup>	58.05 <sup>b-e</sup>	52.25 <sup>b</sup>	51.75 <sup>a</sup>	45.50 <sup>bc</sup>	26.66 <sup>cd</sup>	10.133 <sup>a</sup>	3.144 <sup>ab</sup>	39.93 <sup>bc</sup>
CIP312906.575	4.500 <sup>bcd</sup>	6.500 <sup>c</sup>	109.8 <sup>a</sup>	54.18 <sup>a-d</sup>	46.50 <sup>c</sup>	31.75 <sup>f</sup>	35.25 <sup>de</sup>	32.90 <sup>ab</sup>	7.466 <sup>c-f</sup>	2.467 <sup>d-g</sup>	42.83 <sup>b</sup>
CIP312896.509	6.500 <sup>g-k</sup>	4.000 <sup>ab</sup>	110.0 <sup>a</sup>	51.63 <sup>ab</sup>	37.75 <sup>def</sup>	24.00 <sup>g</sup>	34.75 <sup>e</sup>	25.55 <sup>de</sup>	6.098 <sup>efg</sup>	2.759 <sup>b-e</sup>	34.41 <sup>de</sup>
CIP312905.530	7.000 <sup>h-l</sup>	6.500 <sup>bc</sup>	108.5 <sup>a</sup>	56.18 <sup>b-e</sup>	50.50 <sup>bc</sup>	36.75 <sup>e</sup>	37.00 <sup>de</sup>	30.00 <sup>bc</sup>	8.044 <sup>bcd</sup>	2.517 <sup>c-f</sup>	40.56 <sup>bc</sup>
CIP312901.638	5.000 <sup>b-f</sup>	3.500 <sup>a</sup>	111.8 <sup>a</sup>	43.95 <sup>a</sup>	26.00 <sup>g</sup>	12.50 <sup>h</sup>	18.00 <sup>g</sup>	15.45 <sup>hi</sup>	2.706 <sup>i</sup>	1.831 <sup>i</sup>	19.99 <sup>h</sup>
Belete (St.ck)	6.000 <sup>e-h</sup>	6.000 <sup>bc</sup>	109.8 <sup>a</sup>	62.56 <sup>b-e</sup>	39.00 <sup>de</sup>	26.25 <sup>g</sup>	24.75 <sup>f</sup>	22.59 <sup>ef</sup>	5.002 <sup>gh</sup>	2.351 <sup>e-h</sup>	29.94 <sup>ef</sup>
<b>Mean</b>	5.700	6.00	109.87	58.41	42.23	33.65	37.32	24.54	7.00	2.55	34.09
<b>CV%</b>	11.2	24.7	2.8	11.6	7.2	9.0	9.5	10.3	17.1	12.7	8.2
<b>LSD</b>	0.9199	3.032	4.516	9.780	4.419	4.361	5.140	3.660	1.733	0.470	4.062

Keys: DM=days to maturity, PH=plant height, PU= plant uniformity, PV= plant vigor, NMCTI=Number marketable tubers category I, NMCTII= Number marketable tubers category II, MNoMTP= Number of non-marketable tubers/plot, MTWCI= Marketable tuber weight category I, MTWCII= Marketable tuber weight category II, NoMTWP= non-marketable tuber weight

### 3.1 Growth and Phonological Parameters

#### 3.1.1 Plant uniformity and vigor

Analysis of variance showed that genotypes had a highly significant effect ( $p < 0.01$ ) on plant uniformity (Table 1). The highest uniformity score was recorded from genotype *CIP312921.550* (7.50), which was statistically similar to *CIP312911.508* (7.50). The lowest plant uniformity was observed in *CIP312920.538* (3.50), followed by *CIP312898.640* (4.00) (Table 2). This variation in plant uniformity may be attributed to genetic differences in growth habits among genotypes, as previously reported by Luitel et al. (2016) and Tessema et al. (2020). Statistical analysis revealed that plant vigor was significantly ( $p < 0.01$ ) influenced by genotype (Table 1). The most vigorous genotype was *CIP312901.638* (3.50), while the least vigorous was *CIP312923.562* (7.50) (Table 2).

#### 3.2 Days to 50% Maturity and Plant Height (cm)

Genotypes did not show a statistically significant difference in days to 50% maturity (Table 1). However, *CIP312901.638* matured earlier (111.8 days), while *CIP312923.562* matured later (109.0 days), with an overall mean of 109.87 days (Table 2). Genotypes had a highly significant ( $p < 0.01$ ) effect on plant height (Table 1). Heights ranged from 43.95 cm to 65.50 cm, with an overall mean of 58.41 cm. The tallest plants were from *CIP312923.562* (65.73 cm), closely followed by *CIP312923.522*, while the shortest was from *CIP312901.638* (43.95 cm) (Table 2). Differences in plant height are likely due to genetic variability among genotypes, as reported in previous studies (Patel et al., 2018).

### 3.3 Yield Components

#### 3.3.1 Number of marketable tubers category I (>80 g/tuber):

Genotypes exhibited highly significant ( $p < 0.01$ ) differences in the number of marketable tubers in Category I (>80 g/tuber) during both cropping seasons (Table 1). *CIP312923.522* produced the highest number (64.00), followed by *CIP312897.548* (53.00). The lowest was from *CIP312901.638* (26.00), statistically similar to *CIP312927.550* (27.75) (Table 2). Similar results were reported by Binod et al. (2020).

#### 3.3.2 Number of marketable tubers-category II (>30 g/tuber)

Highly significant differences ( $p < 0.01$ ) were also observed in the number of Category II marketable tubers (>30 g/tuber) (Table 1). *CIP312911.508* produced the most (51.75), followed by *CIP312923.522* (47.75). The lowest was from *CIP312901.638* (12.50), statistically at par with *CIP312926.502* (16.00) (Table 2). These findings align with those of Abebe (2020), Binod et al. (2020), and Raphael (2022).

#### 3.3.3 Number of non-marketable tubers (<30 g/tuber)

There was a highly significant difference ( $p < 0.01$ ) in the number of non-marketable tubers (Table 1). The highest count was recorded in *CIP312898.640* (51.75), followed by *CIP312923.522* (47.75), while the lowest was in *CIP312901.638* (18.00) (Table 2). This variation is likely due to genotypic traits, canopy development, and environmental conditions. Similar findings were reported by Aweko et al. (2021), Getie et al. (2018), and others.

#### 3.3.4 Marketable tuber weight-categories I & II (>80 g and >30 g)

The effect of genotype on marketable tuber weight was highly significant ( $p < 0.01$ ) in both cropping seasons (Table 1). The highest Category I tuber weight was from *CIP312923.522* (35.25 kg/ha), followed by *CIP312906.575* (32.90 kg/ha), while the lowest was from *CIP312927.550* (13.98 kg/ha). For Category II, the highest was from *CIP312911.508* (10.13 kg/ha), followed by *CIP312923.562* (9.58 kg/ha), with the lowest from *CIP312901.638* (2.71 kg/ha) (Table 2). These results agree with the findings of Binod et al. (2020) and Raphael (2022).

#### 3.3.5 Non-marketable tuber weight (<30 g)

Genotypes also differed significantly ( $p < 0.01$ ) in non-marketable tuber weight (Table 1). The highest was observed in *CIP312897.548* (3.25 kg/ha), followed by *CIP312911.508* (3.14 kg/ha), while the lowest was in *CIP312901.638* (1.83 kg/ha). This variation may be attributed to genotype heritability and seasonal effects.

### 3.4 Total Tuber Yield (kg/ha)

A highly significant difference ( $p < 0.01$ ) was observed among genotypes for total tuber yield

in both cropping seasons (Table 1). CIP312923.522 had the highest yield (45.10 kg/ha), followed by CIP312906.575 (42.83 kg/ha) and CIP312897.548 (41.51 kg/ha), whereas CIP312901.638 had the lowest (19.99 kg/ha) (Table 2). These differences are likely due to genotypic efficiency in nutrient utilization. Similar variations were reported by Raphael (2022), Abebe Chindi et al. (2020, 2021), Awoke et al. (2021), and others.

#### 4. CONCLUSION AND RECOMMENDATIONS

Screening is essential in the continuous effort to identify superior genotypes. To enhance potato productivity in research areas and similar agroecological zones, it is crucial to prioritize varieties exhibiting desirable agronomic traits, particularly high yield and market preference. In this study, the evaluated potato genotypes exhibited statistically significant differences across most of the measured parameters. Notably, genotype CIP312923.522 produced the highest total tuber yield (47.41 kg/ha), followed by CIP312906.575 (42.83 kg/ha) and CIP312897.548 (41.51 kg/ha). These results indicate that these genotypes possess superior yield potential and are therefore recommended for promotion to the next stage of evaluation-variety verification trials on-farm and on-station, within the study area and other comparable agroecologies.

#### DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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