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Evaluation of Four Potato Varieties for Stem Height, Late Blight, Yield and Taste Qualities at Kabwum District in Morobe Province, Papua New Guinea

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***Abstract* – The potato late blight (PLB) disease outbreak in the highlands of Papua New Guinea (PNG) in 2003 had severely devastated the production of the commonly grown Sequoia potato variety. Kabwum district in Morobe Province was one of the potato producing regions that was affected by this epidemic. The district had limited or no access to seed sources and appropriate technologies to control the adverse effects of the late blight. This reduced both food supply and cash income for potato growers. This study was designed to evaluate four PLB-resistant potato varieties at three different sites in Kabwum to assess the stem height, PLB, yield, fresh tuber and taste qualities. The experiment was carried out using a Complete Randomized Block Design with three replicates. Stem heights of variety E24, Kumdi and E2 were significantly high compared to E11 at 49–70 days after planting (DAP). The same three varieties were highly resistant to PLB disease, whereas E11 attained a 90 % resistance level. Marketable, seed and total tuber number plant^{-1} and yield tons per hectare (t ha^{-1}) of these three varieties were significantly higher compared to E11. Similarly their fresh tuber morphological features and taste qualities were preferred by the Kabwum farmers. Variety E24, E2, and Kumdi were observed to be suitable for Kabwum agro-climatic conditions. Additional research over consecutive production cycle is needed to further strengthen the findings of this study.**

***Keywords* – Potato Variety, Stem Height, Late Blight, Tuber Yield and Taste Qualities**.

I. INTRODUCTION

The Irish potato (*Solanum tuberosum*) is increasingly becoming an important tuber crop. It is widely grown for both food and cash income by smallholder farmers in the high altitudes (1,600-2,800 m above sea level) of Papua New Guinea (PNG) (Sawanga, 1991; Bang and Lutulele, 2001; FAO, 2009; Anton et al., 2020). The production of potato for formal trade in the country using the Sequoia variety is largely undertaken by smallholder farmers on small farm ranging from 0.1 - 0.5 hectares (ha) in size. The country's production level is estimated at 15,000 tons per annum with a farm gate value of around PGK10-15 million (Pitt and Wicks, 2003; Anton et al., 2020). The incursion of PLB disease caused by the fungus *Phytophthora infestans* in the highlands of PNG in 2003 caused a significant decline in the production of the common Sequoia variety. The disease infected the leaves and stems of potato plants, leading to 100 % yield reductions and subsequent economic losses (Rowe et al., 1993). This affected the livelihoods of the potato growing communities, reducing both food supply and income generating opportunities for households that depend on this crop (Drenth et al., 1993; NARI TOKTOK, 2011). In response to PLB incursion and as part of the organization's research and development efforts, the National Agriculture Research Institute (NARI) developed an integrated disease management strategy that included the trial and release of four potato clones (E24, E2, E11 and E20) that exhibit high levels of resistance against the causative agent of PLB in 2011 and 2013 respectively (Minemba and Kerru, 2014). According to the same authors, these newly introduced varieties attained similar yield levels to that of the

common Sequoia variety but at reduced production costs – mostly associated with PLB management practices. This led to a subsequent increase in marketable potato production levels from 15,000 to 18,000 tons per annum with an ensuing market value of PGK 16-18 million (Fresh Produce Development Agency Annual Report, 2013).

Kabwum district in Morobe Province was also one of the areas that were severely affected by the onset of PLB in 2003. Since then, smallholder potato production in that region has been completely lacking. This is because farmers had limited access to elite PLB resistance potato seed sources and relevant technologies, such as those developed by NARI to manage PLB incidences. A few farmers in that area were observed to be growing PLB resistant varieties (E2, E11, and E24) obtained from the 2013 NARI Agricultural Innovations show in Bubia. This study was implemented to assess the stem height, PLB infestation rate, yield performance, fresh tuber morphology and taste quality of four PLB resistant potato varieties across three sites in Kabwum. The study also aims to (a) identify PLB resistant varieties that are suitable for Kabwum's environmental conditions and, (b) help farmers revive potato production in Kabwum district for food security and income generating purposes.

II. Materials And Methods

Site Description

The trial was implemented across three different local-level governments (LLGs) within Kabuwm district. All trials were conducted from December 2017 to April 2018 and data for all parameters obtained within that period. Table 1 below presents detailed information of the three trial sites. The elevation of the trial locations was generated using a GPS device and soil type identification was done during the trial implementation. The rainfall data was collected by Mr Prepa Mute (DPI officer) using a Nylex® rain gauge mounted at Kabwum Department of Primary Industry (DPI) station. The mean total rainfall over the four months growing seasons was 714 mm.

Table 1. Shows the altitude (m) and soil type of the three trial sites in Kabwum.

Trial location	LLG	Altitude (m)	Soil Type
Kabwum station	Selepet	1,379	Loam
Konge Primary School	Komba	1,844	Loam
Ongukey	Diamus	1,810	Volcanic ash soil

Potato Varieties

The four potato varieties; E2, E24, E11, and Kumdi were selected for evaluation across selected sites in Kabwum. These varieties were observed to be highly resistant to PLB disease causing agents across various trials conducted by Minemba and Kerru (2014) and Anton et al. (2018). Varieties E2, E24, and E11 were released by NARI in 2011 and 2013 respectively, and Kumdi is a local potato variety that is currently being evaluated by NARI for its yield and PLB resistance potential. The commonly grown variety Sequoia was excluded from the trial due to its high susceptibility to PLB, thus variety E2 was selected as a control. Third generation seeds for E2 and E24 were obtained from Fresh Produce Development Agency while the sixth

generation for E11 and Kumdi were obtained from NARI. All potato varieties were bulked up and stored in Tambul, Western Highlands Province before being transported to the project sites in Kabwum.

Trial Design

The experiment was conducted in a Complete Randomized Block Design with three replicates. Potato variety is the main factor which was evaluated to assess the stem height, PLB, yield and taste qualities. The trial was repeated at three different locations in Kabwum to generate a mean data for analysis.

Planting and Management Practices

Land preparation was done manually using spades and seeds were planted at a standard spacing of 80 cm within rows and 40 cm between seeds in-line with the specifications described by Minemba and Kerru (2014) and Anton et al. (2020). Sixteen plots of 2.5 m x 5 m per plot having sixteen data plants and twenty guard row plants totaling up to 36 plants in each plot was used. Potato mix fertilizer comprising of N (10 %), P (25 %), K (12 %), MgO (2 %) and B (0.2 %) was manually applied at a rate of 1,200 kg ha^{-1} in prepared rows. All the seeds were germinated in 14 to 21 days-after-planting (DAP). Hilling and weeding were also done manually at 10 days after germination. Insecticide Karate® (active ingredient, 25 g L^{-1} Lambda) was applied at the rate of 2 ml L^{-1} to prevent insect damage from cutworms (*Agrotis spp*.), aphids (*Aphidae*), and plant hoppers (*Delphacidae*) at the initial development stage. The fungicides were not applied to all the treatments.

Data Collection

The stem heights were measured three times at every 21 days intervals from the ground level to the last opened leaf until the maturity stage. PLB disease was assessed using the blight rating system across all plants (CIP Guidelines). Tuber yield of each variety was recorded as tuber number $plant^{-1}$ and tuber weight (g, $plant^{-1}$) in the following categories: marketable (>100 g), seed (10–99 g) and damaged (Anton et al., 2018). The weights for each treatment were converted to tones ha^{-1} for analysis. The tubers for each variety harvested were grouped and more than 30 farmers were asked to vote for tuber morphological feature preferences at the field. A sensory assessment through tasting panels was carried out across the three trial sites on fresh boiled and fried chips. Fifteen to twenty questionnaires were developed and used for assessing the taste preferences.

Data Analysis

The data obtained for all variables across three sites were averaged and generated the mean data for analysis using Microsoft Excel (2007). Also shorting of data and data quality check was done using the Microsoft Excel. A one-way analysis of variance (ANOVA) was done to detect significant differences in P-value of 5 % using GENSAT Discovery Version 3. A least significant difference (LSD) test was then used to separate means where significant effects were detected in the ANOVA. The mean data obtained from the farmers' preferences on fresh tuber morphologies and taste qualities were used for generating graphs using the Microsoft Excel (2007).

III. RESULT AND DISCUSSION

Stem Height

The mean stem height result of four potato varieties trialed at three locations in Kabwum is presented in Figure 1. No significant differences between the stem heights of all four varieties were detected at 28 DAP

however, stem heights were significant *(P<0.05)* at 49–70 DAP. Variety E24 was significantly *(P<0.05)* taller (83 cm) followed by Kumdi (72 cm), E2 (61 cm) and E11 (49 cm) respectively at 70 DAP. Variety E11 was significantly *(P<0.001)* lower in stem height compared to the other three varieties. These results were comparable to the observations of Minemba and Kerru (2014) during the CIP potato variety evaluation trial conducted in the highlands of PNG. These findings were also in line with the results obtained in the second and third seasonal trials conducted by Anton et al. (unpublished) using different planting densities and fertilizer rates on these varieties. Anton et al. (2020) stated that variety E24 is significantly taller followed by Kumdi and E2 varieties in that order. The differences in stem height were significantly *(P<0.001)* affected by the genetic make-up of each variety (Mangani et al., 2015). The growth of E11 was affected by the PLB infestation on the leaves and stems at 49–70 DAP (Figure 2). Additionally, the E11 seeds planted did not fully sprout unlike the seeds of other varieties.

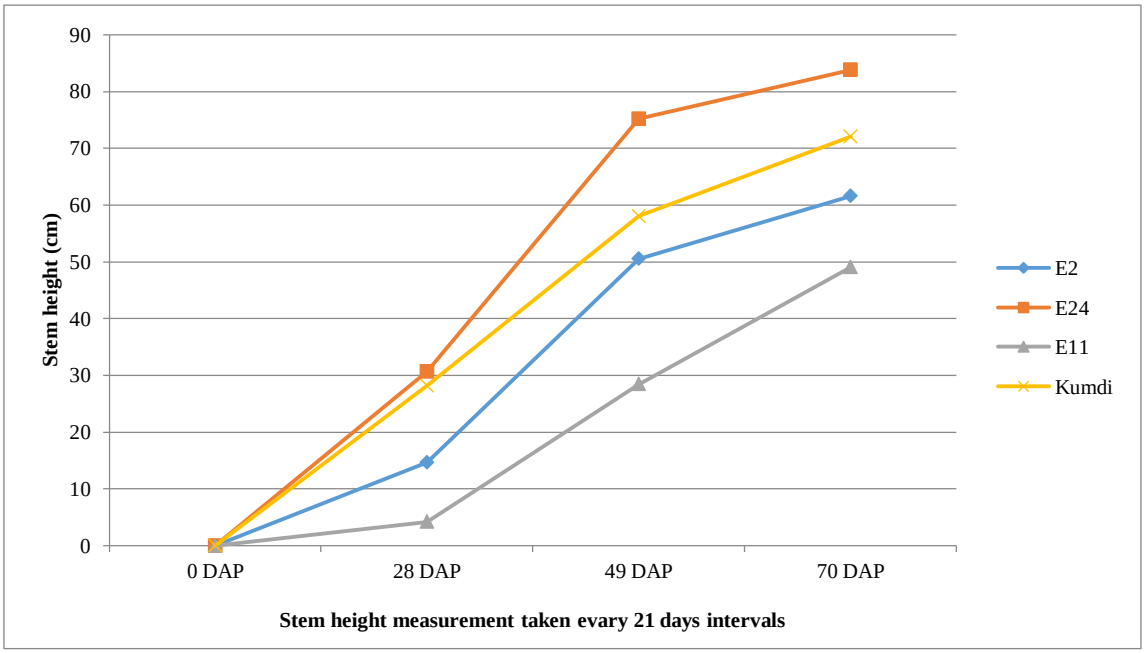

Fig. 1. Mean stem heights of four potato varieties measured 21 days interval from 28 DAP – 70 DAP at Kabwum.

Potato Late Blight Disease Assessment

Generally, all potato varieties offered some resistance to PLB at 28–70 DAP except E11 without fungicide application (Figure 2). Varieties E2, E24, and Kumdi showed high resistance to PLB pathogen and lesions were not identified during the assessments across all sites. Few lesions were identified on the leaves and stems of E11 at 49–70 DAP, but it was below 10 % of the infestation rate. This is not considered as widespread or severe as it was below the economic threshold level. The results from these trials confirmed results presented by Minemba and Kerru (2014) in the CIP potato variety evaluation trial as well as figures presented by Anton et al. (2018) in a drought and frost management trial using similar potato varieties. The same authors stated that these varieties have genetic traits that are highly resistant to PLB disease. Minemba and Kerru (2014) released these varieties to farmers in 2011 and 2013 based on this quality. All trials conducted in Kabwum confirmed that varieties E2, E24, and Kumdi were highly resistant to PLB while E11 exhibited up to 90 % resistance level. Generally, all varieties evaluated had high production potential without fungicide application and this will reduce the cost of labor and fungicide (Ovah and Anton, unpublished).

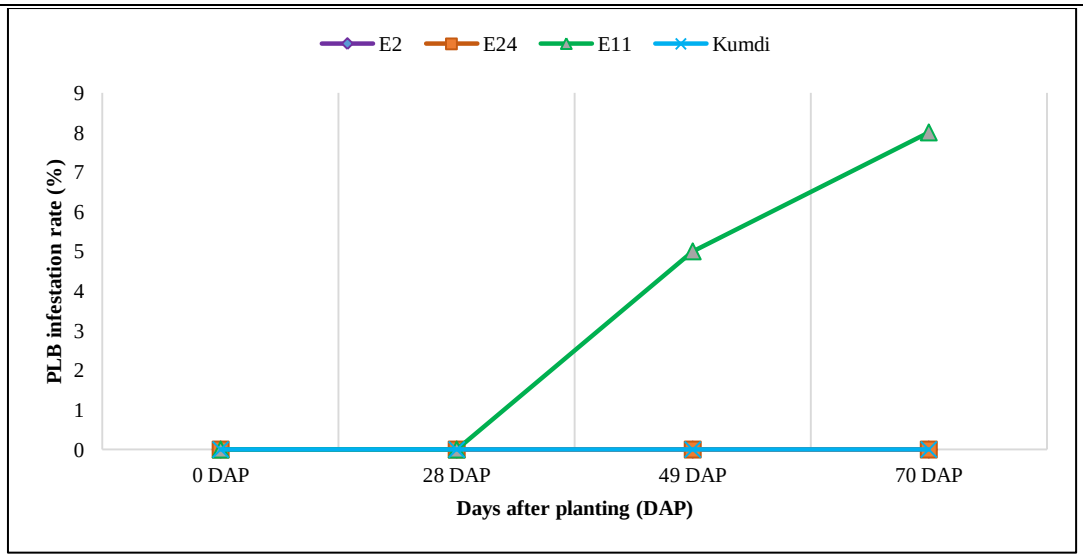

Fig. 2. PLB disease assessments from 28 – 70 DAP using the Modified Blight Rating system of four potato varieties trialed at Kabwum.

Tuber Number Per Plant

Significant differences *(P<0.001)* were shown in marketable, seed, and total tuber yield plant^{-1} while damaged tuber showed no significant difference (Table 2). Marketable tuber number plant^{-1} for varieties E24 and Kumdi were statistically similar and significantly *(P<0.001)* many when compared with the tuber numbers of varieties E2 and E11. Variety E2 yielded moderate marketable tuber plant^{-1} while E11 yielded few marketable tuber plant^{-1}. The highest seed tuber plant^{-1} was yielded by varieties E2 and Kumdi. They were statistically similar and significantly *(P<0.001)* high when compared with the seed yield of E24 and E11. Variety E11 yielded the lowest seed tuber plant^{-1} while E24 yielded moderately. Varieties E2 and Kumdi yielded more total tuber plant^{-1} (15 tuber plant^{-1}) followed E24 (13 tuber plant^{-1}) and E11 (8 tuber plant^{-1}) respectively. Varieties E24 and Kumdi had genetic traits which influenced the highest marketable tuber number plant^{-1} followed by E2. Mangani et al. (2015) stated that different varieties have different capacities of producing different tuber sizes. E24 and Kumdi with the highest stem height had the highest marketable tuber plant^{-1} followed by E2 and then E11 respectively. PLB pathogen also had a significant influence on tuber number plant^{-1}. Varieties E24, Kumdi, and E2 with tall stem heights (Figure 1) and resistance to PLB pathogens (Figure 2) resulted in the highest marketable tuber plant^{-1} (Minemba and Kerru, 2014; Anton et al., 2018) whereas E11 had short stem height and was affected with PLB resulted in low tuber number plant^{-1}. Tall stem height had higher biomass without any defects of PLB disease which increased photosynthesis activities (Vandermeiren et al., 2005) and thus resulted in high marketable tuber number plant^{-1}. Varieties E2 and Kumdi also had the highest potential of yielding the high number of seeds plant^{-1} resulting in high total tuber plant^{-1} followed by E24.

Table 2. Mean tuber number plant^{-1} of four potato varieties evaluated at Kabwum**.**

Tuber Category		Variety			Grand Mean	LSD	(P<0.05)	CV(%)
	E11	E2	E24	Kumdi				
Marketable	3^{a}	4^{b}	5^{c}	5^{c}	**4.3**	1	**	11
Seed	5^{a}	10^{c}	7^{b}	9^{c}	**7.8**	2	**	14

Tuber Category		Variety			Grand Mean	LSD	(P<0.05)	CV(%)
	E11	E2	E24	Kumdi				
Damage	0	1	1	1	**0.8**	1	N/S	35
Total tuber	8^{a}	15^{c}	13^{b}	15^{c}	**12.8**	2	**	11

Note: ****** = Significant at P<0.001; N/S = Not-significant; The mean not sharing a common letter in a column and row differ significantly at P<0.05.

Tuber Yield (t ha^{-1})

Similar to tuber number plant^{-1}, highly significant differences *(P<0.001)* were observed for marketable, seed and total tuber yield tons per hectare (t, ha^{-1}). Yields of E24 and E2 were statistically similar and significantly *(P<0.001)* high when compared with the yields of Kumdi and E11 respectively (Table 3). The yield of E11 was lower than the other three varieties while Kumdi yielded moderately. Variety E2 yielded significantly *(P<0.001)* highest seeds (8.51t, ha^{-1}), followed by Kumdi (5.31t, ha^{-1}) then E24 (3.93t ha^{-1}) and E11 (2.37t, ha^{-1}) respectively. E2 with the highest seed tuber yield and second highest marketable tuber yield resulted in the highest total tuber yield followed by E24, Kumdi, and E11. The total tuber yield of E2 and E24 were statistically similar and significantly *(P<0.001)* high when compared with the other two varieties. Yield differences in varieties could have been affected by the variations in the genetic make-up of each variety (Mangani et al., 2015). Varieties E24, E2, and Kumdi with the high number of tuber plant^{-1} resulted in the highest tuber yield tones ha^{-1}. High marketable yield results for E24, E2, and Kumdi in these trials were also observed by Minemba and Kerru (2014) and Anton et al. (2018) in their evaluation trials conducted in the highlands. The same authors also stated that the yield of variety E24 was significantly lower than E2 and Kumdi but the result from this trial showed that yield of E24 was significantly high. This could be influenced by the climatic factors (Pereira et al., 2008). The yield of E11 was low due to PLB infestation (Figure 2) and seeds planted were not fully sprouted. Varieties E24, E2, and Kumdi were resistant to PLB pathogens (Figure 2) and had an elevated stem height (Figure 1) which influenced high marketable and seed tuber resulting in higher total tuber yield. In their potato economic analysis report, Ovah and Anton (unpublished) stated that cultivation of PLB resistant varieties reduced production cost (fungicide and labor) and this will be a plus for Kabwum farmers to cultivate the three varieties for their food security and cash income.

Table 3. Average tuber yield plant^{-1} of four potato varieties evaluated at Kabwum.

Tuber Category		Variety			Grand Mean	LSD	(P<0.05)	CV(%)
	E11	E2	E24	Kumdi				
Marketable	7.85^{a}	14.34^{cb}	16.29^{c}	11.15^{b}	12.41	3.54	**	12.6
Seed	2.37^{a}	7.84^{c}	3.93^{ab}	5.31^{b}	4.86	2.11	**	10.9
Damage	0.47	1.42	1.57	0.96	1.11	1.00	N/S	38.0
Total tuber	10.69^{a}	23.60^{c}	21.79^{c}	17.42^{b}	18.38	4.19	**	12.1

Note: ****** = Significant at P<0.001; N/S = Not-significant; The mean not sharing a common letter in a column and row differ significantly at P<0.05.

Tuber Morphology and Taste Preferences

About 45 % of the farmers preferred Kumdi's fresh tuber physical morphologies and 26 % preferred both E2 and E24 fresh tuber physical morphologies (Figure 3). Only 3 % of the farmers preferred the fresh tuber physical morphologies of E11. The fresh boiled taste for Kumdi variety was also preferred by the farmers at three sites. About 40 % preferred Kumdi fresh boiled taste, 36 % preferred E24 and 12 % preferred both E2 and E11 (Figure 3). The highest number of farmers preferred fried chips taste for E24 (33 %) followed by E2 (29 %), Kumdi (21 %) and E11 (17 %) respectively. Generally, the fresh tuber physical morphologies and fresh boiled taste for Kumdi were most preferred by the farmers followed by E24, E2, and E11 accordingly. Farmers' assessments on potato tuber morphological features vary depending on different genetic traits in each variety (Skrzypiec et al., 2018). The same authors further stated that "tuber quality traits such as tuber shape, flesh color, eye depth, and weight were influenced by the varietal genotype. The quality of tuber flesh attracts buyers when selling the fresh tubers at different markets. Buyers prefer potatoes with good tuber flesh qualities. Generally, Kumdi, E2, and E24 were attractive and preferred by the farmers at three different trial sites in Kabwum. The freshly boiled taste differences in potatoes were affected by different levels of sugar and dry matter content in tubers (Pevicharova, 2015; Lisinska et al., 2009). Most farmers preferred Kumdi and E24 fresh boiled taste and few farmers preferred E2 and E11 (Figure 3). The fried chips taste preference results of the four potato varieties were different based on the specific gravity, dry matter, and sugar content of each variety (Aggarwal, 2017; Nairobi, 1998). Lisinska et al. (2009) stated that "potato selected for chips should have a round or oval shape and internal traits of 21–25 % dry matter content, 16–20 % starch and below 0.25 % of reducing sugar." The processing qualities of the four potato varieties evaluated are yet to be analyzed to confirm these findings. Generally, the fried chips taste for E24, E2, and Kumdi were favored and preferred by farmers at Kabwum. Additional cooking and sensory quality assessments are needed to ascertain these observations.

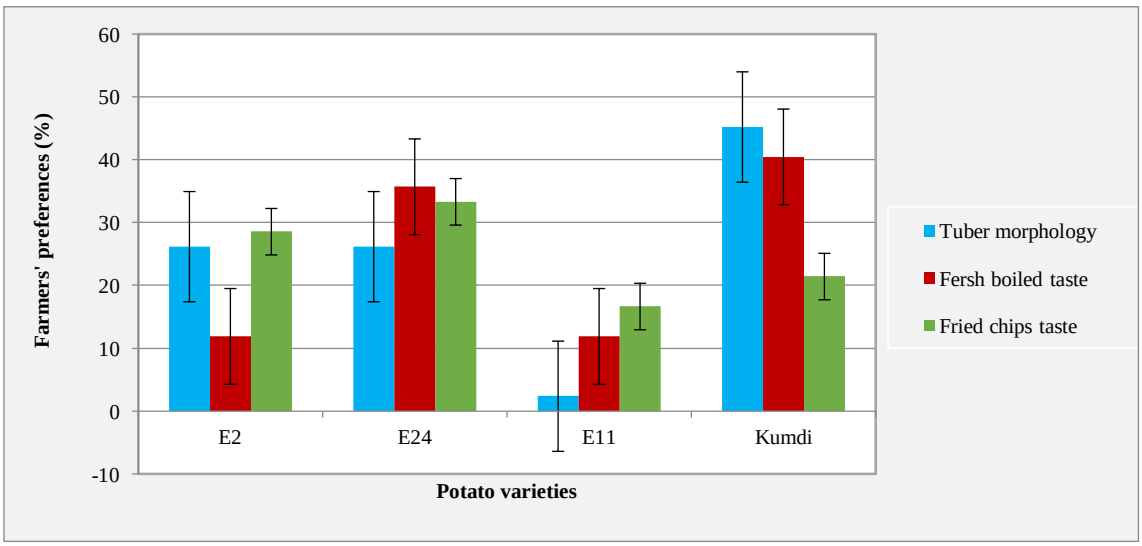

Fig. 3. Fresh tuber morphological features, boiled and fried taste preferences of four potato varieties evaluated at Kabwum.

IV. CONCLUSION

All potato varieties evaluated generally showed favorable attributes for Kabwum district. Varieties E24, E2, and Kumdi looked more promising with tall stem heights, high PLB disease-resistance levels, favorable yield performances and preferred fresh tuber physical and sensory qualities. Though few PLB were observed on the

leaves and stems of variety E11 but it was below the economic threshold level. With these promising qualities from the trials, the three varieties (E2, E24, and Kumdi) were recommended for cultivation to support food security and cash income for smallholder farmers in the district. Additional varietal evaluation studies using the same generation of seeds are needed to ascertain the observations of this study. Studies on the processing qualities of these varieties are also worth pursuing.

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