Original scientific paper
Journal of Central European Agriculture, 2022, 23(4), p.807-816

DOI: /10.5513/JCEA01/23.4.3553

Yield and tuber quality performance of eight European potato (*Solanum tuberosum*) cultivars in a short-day temperate climate

Nomali Ziphorah NGOBESE[1] (✉), Morgan NAIDOO[2], Tilahun Seyoum WORKNEH[3]

[1] School of Geo and Spatial Sciences, Faculty of Natural and Agricultural Sciences, North-West University, Potchefstroom, South Africa

[2] Department of Agriculture and Rural Development, KwaZulu-Natal, South Africa

[3] School of Engineering, University of KwaZulu-Natal, Pietermaritzburg, South Africa

✉ Corresponding author: nomalingobese@gmail.com

Received: March 8, 2022; accepted: September 12, 2022

ABSTRACT

The potato cultivar base is quite wide in South Africa as new genotypes often are adopted from European countries. However, the performance of many cultivars is not well-understood, and this is compounded by agro-climates and changes in the climate. The aim of this study was to evaluate the yield and potato quality performance of seven recently introduced European cultivars (Panamera, Electra, Savanna, Navigator, Melanto, Sifra and Innovator) against Mondial (a well-established cultivar in the country) to inform cultivar selection decisions in the potato industry. The experiment was conducted in Pietermaritzburg, under temperate agro-climatic conditions in a randomised complete block design. Results showed significant ($P \leq 0.05$) differences among cultivars, with Innovator having the highest dry matter content (20%) and specific gravity (1.063). Electra and Navigator had the highest and lowest yields (54 and 21 t/ha), respectively. All cultivars had a low occurrence of internal defects (≤ 10%) and produced high marketable yield (≥ 80%). These results suggest five out of the eight cultivars to be economical for production in the region. Only Navigator, Panamera and Savanna did not exceed the 35 t/ha yields currently achieved in the country.

Keywords: cultivar differences, high crop yields, food security, potato cultivation

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the top vegetable crop produced in South Africa by volume, representing >50% of all vegetables (Geyer, 2014). The crop is considered quite economical for production due to its reputation as the highest yielding crop. One hectare is estimated to yield two to four times the food quantity of grain crops (International Potato Centre, 2021). Accordingly, potato is gaining attention in food security initiatives aimed at alleviating food inaccessibility in socio-economic groups vulnerable to poverty. Food security is a primary concern in many South African households as the country ranks among those with the highest rate of income inequality in the world, albeit having one of the fastest growing economies on the African continent (Altman et al., 2009; Masekoameng and Malawichi, 2014; Ngidi and Hendriks, 2014). The domestic potato industry has been rising to this challenge, substantially increasing production to 2.25 million tons and yields to 34 t/ha over the past two decades, mainly through improvements of the seed potato industry and improving cultivation practices (Hofmeyr, 2015; Food & Agriculture Organization, 2021; HZPC, 2021). Developments in the South African potato industry have been coupled with an expansion of the number of foreign cultivars introduced into the country, which is a strategic effort for yield and disease tolerance improvement. However, relatively few cultivars are cultivated at a commercial scale (Ngobese and Workneh, 2017). Most of the cultivars introduced are sourced from Europe since the region boasts a large cultivar database due to high breeding capacity, catering for various potato markets, and a large seed export capacity (Almekinders et al., 2014). Owing to differences in agro-climatic and agronomic conditions between regions and specific adaptation of cultivars to regions, the performance of these cultivars cannot be predicted and needs to be established. Although potatoes are originally a short-day crop from the highlands of the South American Andes, most modern-day European cultivars are long-day adapted following crossing with Chilean cultivars to achieve high yields in European conditions (Gutaker et al., 2019). South Africa, on the other hand, is characterized by short-day lengths with moderate temperatures.

Previously in South Africa, new cultivar introductions and improvement efforts have mainly focused on obtaining high-yielding cultivars for profitability. However, focus has shifted to potato quality as consumer awareness about food quality is increasing (Badenhorst, 2014). Developments in the potato industry are now seeing more focus being placed on promoting the consumption of potatoes as a competitive replacement to other starchy staple products, such as maize, pasta, bread and rice. Consumers generally select potatoes based on prominent sensory characteristics, such as size, colour and shape. South African families purchase the produce at least once a month and consume 70% of the potatoes in stews, as French fries and as mash (Badenhorst, 2014). Production potential of cultivars and potato quality have been reported to vary according to region and production season in a number of studies, with differences in achievable yields, dry matter content, specific gravity, reducing sugar and mineral content, and starch properties being frequently cited (Elfnesh et al., 2011; Galdon et al., 2012; Ćota et al., 2012; Šimková et al., 2013; Wekesa et al., 2014). Therefore, the objective of the present study is to evaluate the performance of foreign cultivars to understand their productivity and qualitative value under the temperate agro-climatic conditions of Pietermaritzburg (a representative potato production region). Such information can be used to inform potato producers of cultivar selection, determine suitability for culinary usage and as a directive when addressing market demands in the potato industry.

MATERIALS AND METHODS

Seven European potato cultivars of white to yellow flesh colour, which have been introduced in South Africa within the last decade, were planted at Ukulinga Research Farm (Table 1) alongside Mondial (an established cultivar).

Location

Ukulinga Research Farm is part of the University of KwaZulu-Natal, which is located in Pietermaritzburg. Pietermaritzburg is a midland region of the KwaZulu-Natal province, and the farm is located at 781 m above sea level (30°24′E, 29°40′S). Disease-free seed tubers (certified by the South African Seed Certification Service), which had been stored at 4°C in a dark constant temperature room for 2-3 months after harvest (Table 1), were obtained from WesGrow Potatoes Ltd (Christiana, South Africa). The seed was subsequently transferred to ambient temperatures (20-25°C) for 6 weeks to allow sprouting. Cultivation was thereafter conducted, using a randomised complete block design having three replications, in a 1 750 m^2 field, in a spring-summer season.

Weather and soil conditions

The area received moderate average maximum and minimum air temperatures (26°C and 17°C, respectively), which are common for potato production in South Africa (Geremew et al., 2007), with high relative humidity (81%) and low wind speeds (1.2 m s^{-1}), during the production season (Figure 1). Standard cultural agronomic practices, for commercial potato production in South Africa, were applied. Soil samples were randomly taken from the top 15 cm of the field. Soil analysis indicated adequate soil pH levels (4.9), organic carbon contents (1.9%) and clay content (29%) for potato production. Each cultivar was planted on an area of a 56.7 m^2 plot with seven rows of

Table 1. Cultivars used in the study and seed mass before cultivation

Cultivar	Origin	Parentage*	Maturity*	Flesh Colour*	Seed Mass (g)**
Mondial	Netherlands	Spunta x SVPVE66 295	Intermediate to late	Cream	97[b]
Panamera	Netherlands	Voyager x Fabula	Late	Light yellow	74[cd]
Electra	Ireland	C1992 x Picasso	Intermediate to late	Yellow	95[bc]
Savanna	Ireland	Famosa x Atlantic	Late	White	89[bcd]
Navigator	Netherlands	BRU93-136 x Victoria	Late	Light yellow	97[b]
Melanto	Netherlands	Impala x POS97-1	Intermediate to late	Yellow	95[bc]
Sifra	Netherlands	Mondial x Robinta	Late	Cream	87[bcd]
Innovator	Netherlands	Shepody x RZ-84-2580	Early	Light yellow	160[a]

* Source: European Cultivated Potato database (2015) and HZPC (2015)

**Values express mean (n = 10). LSD = 19.44, CV = 11.8%. Values with the same letters differ non-significantly (*P*>0.05)

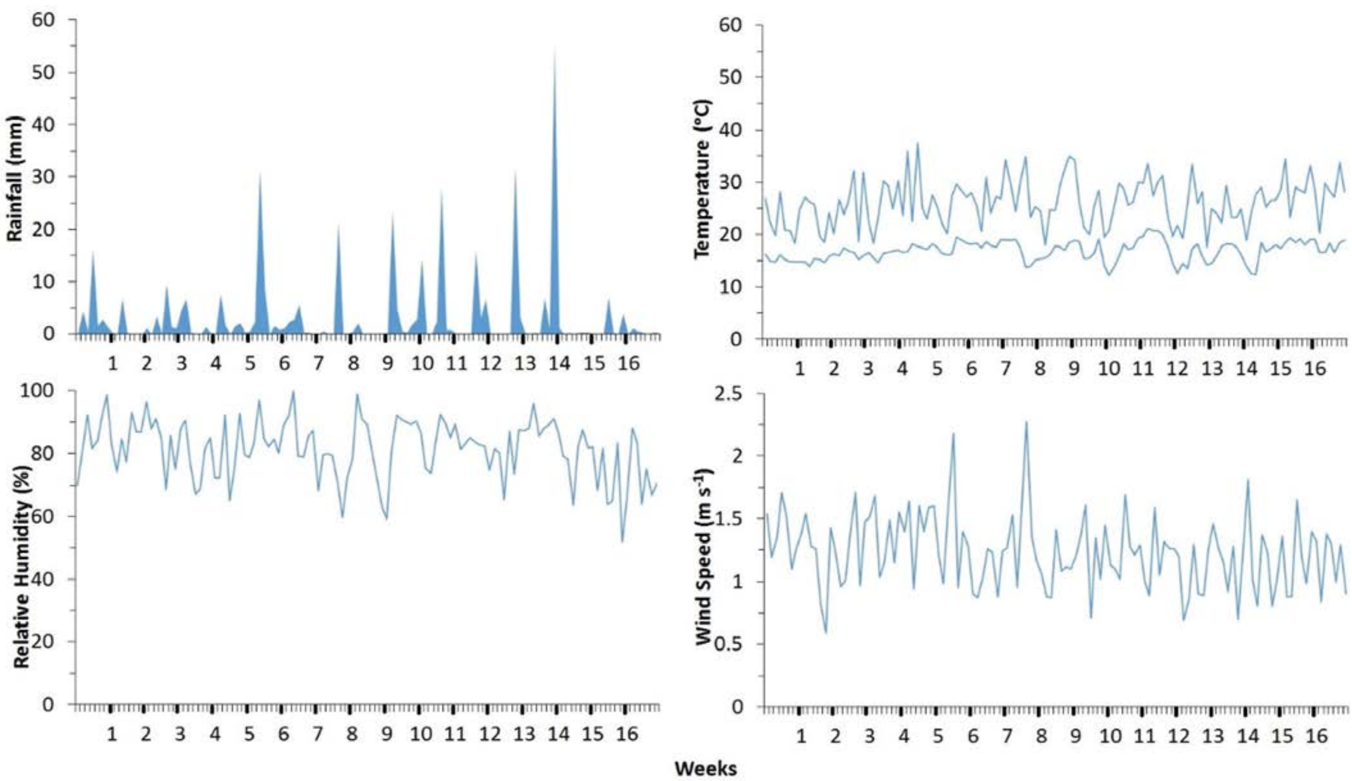

Figure 1. Rainfall (a), relative humidity (b), temperature (c) and wind speed (d) during the growing season

9 m length, with 0.9 m spacing between rows and 0.3 m between plants in the same row (Wekesa et al., 2014). Planting was done at a soil depth of 20 cm, preceded by an application of a 2:3:4 (30) fertilizer blend supplying 120 kg/ha N, 125 kg/ha P and 170 kg/ha K at a 25 cm depth.

Agrotechnical operations

The plants were ridged six weeks after planting when most cultivars were flowering, which was followed by an additional application of 120 kg/ha N through a limestone ammonium nitrate (LAN, 28% N) side-dressing. The crop was grown under a sprinkler irrigation system and received a total water supply of 474 mm, of which 393 mm was provided by rainfall. Soil moisture content at a 30 cm depth was monitored twice a week using a Diviner 2000 soil moisture probe (Sentek, Australia), of which the access tubes were installed at the centre of each plot of the second replicate. Irrigation was provided when necessary, such that soil moisture content did not fall below 70% of field capacity (data not shown). Standard disease and pest control measures, including spraying with Bravo (1 L/ha), Ridomil (2.5 L/ha), Vondozeb (3 kg/ha), Kemprin (0.150 L/ha) and Monocrotophos (0.150 L/ha), were applied. Weed control was implemented through a pre-season application of Glysophase (5 L/ha) and Dual Gold (1 L/ha), and manual weeding during crop growth.

Sample collection and quality analysis

Potatoes were harvested manually 2-3 weeks following observation of shoot death. During production, the number of weeks to 75% shoot emergence and maturity for the respective cultivars was recorded. After harvesting, potatoes were hand-washed with tap water and the surface was allowed to dry under ambient conditions. All harvested potatoes were weighed to ascertain the total yield (t/ha), then potatoes without external defects nor harvest injury were considered to be marketable and manually graded according to commercial size class standards (i.e. large [> 250 g], medium [100-250 g] or small and baby [< 100 g]) to determine size frequency distribution. Thereafter, marketable and processing yield (medium to large-sized potatoes without external defects) were calculated and recorded as a percentage. Thirty randomly selected medium-sized potatoes were then measured with a pair of digital Vernier Callipers to determine the length and width which was used to calculate the tuber form index using Equation 1 (Steyn et al., 2009). Tube form index was used to categorise shape as either round (< 109), short-oval (110-129), oval (130-149), long-oval (150-1.69) or long (≥ 170) (Ekin, 2011). Fifteen medium-sized potatoes were cut into 10 mm x 10 mm French fry strips using a chipper and visually examined for the occurrence of internal defects. Thereafter, a 100 g sample of peeled fresh potato was homogenised with a blender and oven-dried at 105°C to a constant weight to determine the dry matter content using Equation 2 (Abong et al., 2009). A 3.5 kg potato sample was weighed, first in air and then in water, using an electronic balance (BEL Engineering, USA) to determine specific gravity using Equation 3 (Geremew et al., 2007). Three potatoes, freshly cut along the length, were assessed for colour using a ColorFlex EZ benchtop spectrophotometer (Hunter Lab, USA) to obtain the L*, a* and b* coordinates, which express the lightness, redness and yellowness of the flesh, respectively, as described by Yang et al. (2016).

$$\text{TFI} = \text{Length} / \text{Width} \quad (1)$$

$$\text{Dry Matter Content} = ([\text{Dry mass}] / [\text{Fresh mass}]) * 100 \quad (2)$$

$$\text{Specific Gravity} = (\text{Mass in air}) / (\text{Mass in air} - \text{Mass in water}) \quad (3)$$

Data analysis

Statistical analysis was performed using GenStat for Windows (14th edition; VSN International, United Kingdom). Analysis of variance (ANOVA) was used to test for differences and the Duncan's multiple range test was performed to separate the means at 95% probability level (P<0.05). Correlation between parameters was tested and a Principal Component Analysis was used to determine discriminating variables.

RESULTS AND DISCUSSION

Maturity, potato shape and defection

Shoots of Innovator emerged first, two weeks after planting, with the other cultivars emerging in the third week (Table 2). Consistently, there were highly significant (P<0.001) differences in maturity period among the tested cultivars, which were positively correlated with time to emergence (r = 0.89). Innovator matured in 12 weeks, while Panamera and Navigator matured after 16 weeks. Mondial, Electra, Savanna, Melanto and Sifra were of an intermediate maturity period, with shoot death occurring from 14 to 15 weeks. All the cultivars evaluated in this study had a low prevalence of internal defects, which was largely non-significantly different (P>0.05), with none of the cultivars having a total occurrence exceeding 10%. This was considered a good performance under the agronomic cultural conditions used, as some of the cultivars have been shown to be susceptible to diseases like early blight (*Alternaria solani* [Prasad and Dutt, 1980]), late blight (*Phytophthora infestans* [Speiser et al., 2006]) and leafminer (*Liriomyza huidobrensis* Blanchard [López et al., 2010]), in India, Europe and Argentina.

The maturity period of the cultivars was consistent with the performance achieved in the respective countries of origin, except for Savanna and Sifra, who displayed an intermediate, instead of a late maturity period (Table 1). The maturity of Sifra was attributed to a genetic influence, as the cultivar is a descendant of Mondial. Internal defects occurring in cultivars were nutsedge (*Cyperus esculentus*) damage, vascular discoloration, brown centre and hollow heart (Figure 2). Among these, nutsedge damage was the most common defect and occurred in five of the eight, cultivars planted. Moreover, Sifra and Savanna had the highest prevalence of defects (10%), while Mondial, Electra and Innovator were free of all internal defects. The low occurrence of defects in potatoes qualifies cultivars for consideration for processing, as it falls within the 10% occurrence limit set by the USDA (2015). However, the prevalence of vascular discoloration would be a limiting factor for Navigator (7%), as vascular discoloration occurrence should not exceed 5% in processing cultivars.

Yield performance

Electra was the highest yielding cultivar among those evaluated, yielding a total of 54 t/ha, followed by Melanto, Sifra, Mondial and Innovator, yielding 52, 48, 40, 38 t/ha, respectively (Figure 3a). Navigator, Panamera and Savanna resulted in significantly (P=0.001) lower yields, with averages of 21, 26 and 35 t/ha, respectively. The cultivars evaluated in this study produced a high percentage of potatoes (≥ 80%) without defection (i.e. marketable yield; Figure 3b). Processing yield significantly (P≤0.01) differed among cultivars, and Mondial, Navigator and Panamera produced the lowest processing yields (69, 70 and 55 %, respectively), while all other cultivars achieved a processing yield ≥ 70% (Figure 3b). Processing yield signifies size distribution, which has implications on produce uniformity. The higher frequency of potatoes weighing < 100 g in Mondial, Navigator and Panamera indicates a greater suitability to cater for the

Table 2. Cultivar maturity indices, potato shape and occurrence of internal defects

Cultivar	Weeks to Emergence*	Weeks to Maturity*	Tuber Form Index**	Potato Shape	Occurrence of Internal Defects (%)***			
					Nutsedge Damage	Vascular Discoloration	Brown Centre	Hollow Heart
Mondial	2.7^{b}	14^{c}	138^{b}	Oval	0^{0}	0^{b}	0^{b}	0^{ac}
Panamera	3.0^{b}	16^{ab}	123^{b}	Short-oval	2^{b}	2^{ab}	0^{b}	0^{ac}
Electra	3.0^{b}	15^{ac}	114^{b}	Short-oval	0^{b}	0^{b}	0^{b}	0^{b}
Savanna	3.0^{b}	15^{abcd}	129^{b}	Short-oval	4^{b}	0^{b}	4^{a}	2^{a}
Navigator	3.0^{b}	16^{a}	141^{b}	Oval	2^{b}	4^{a}	0^{b}	0^{ac}
Melanto	3.0^{b}	15^{abc}	136^{b}	Oval	4^{b}	2^{ab}	0^{b}	0^{ac}
Sifra	3.0^{bc}	14^{cd}	127^{b}	Short-oval	11^{a}	0^{b}	0^{b}	0^{ac}
Innovator	2.0^{d}	12^{e}	180^{a}	Long	0^{0}	0^{b}	0^{b}	0^{ac}
LSD	0.330	0.990	0.274	-	6.220	3.812	2.201	2.201
CV (%)	6.5	3.9	11.7	-	133.6	225.0	259.8	519.6

Values with letters express mean (n = *3, **30 or ***15). Values with the same letters within a column differ non-significantly (P>0.05). CV = Coefficient of variation; LSD = Least significant difference

DOI: /10.5513/JCEA01/23.4.3553

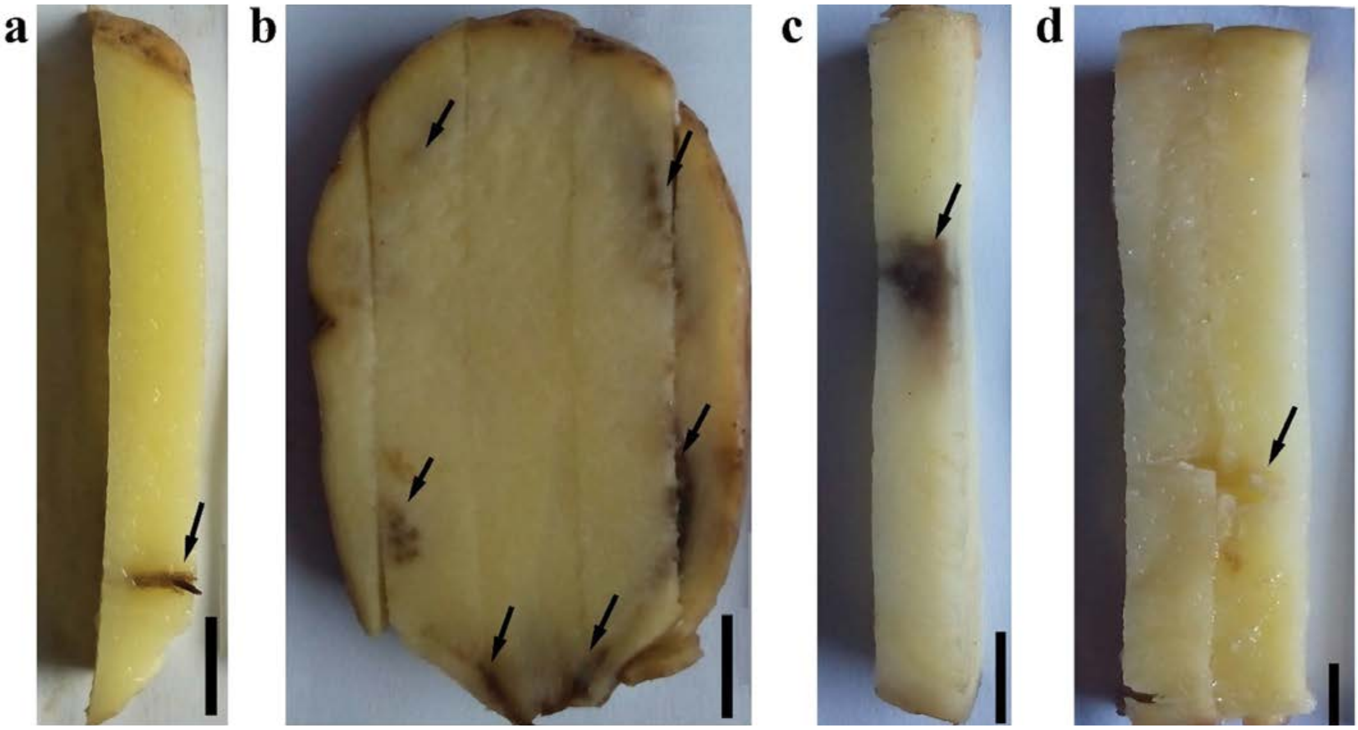

Figure 2. Internal defects found in potatoes. (a) Nutsedge damage, (b) vascular discoloration, (c) brown centre and (d) hollow heart. Arrow pointing to the area of defection; scale bar = 10 mm

baby potato industry. It is of note that, in the case of Navigator, this is coupled with the highest occurrence of vascular discoloration and the lowest yielding capacity. These observations indicate a need for research aiming to evaluate the nutrient content of cultivars to test if size and yield differences have implications on the nutritional value of potatoes. The high yield capacity of six of the cultivars evaluated, Navigator and Panamera excepted, suggests good economic potential for the domestic potato industry. South Africa currently achieves 35 t/ha with the crop (HZPC, 2021). In countries with underdeveloped potato industries such as Malawi, yields as low as 10 t/ha are acceptable (Masamba et al., 2014). A slightly higher yield performance (51 t/ha, correlated with a low dry matter content of 13%) for Mondial has been reported in Israel (Levy and Tai, 2013). Differences in yield performance between production regions due to agro-ecological differences and seasons are characteristic to the crop (Ćota et al., 2012). Notwithstanding, the trial experiment reported in the present study could not be replicated, due to financial constraints. Therefore, it is recommended that the results reported in the present study should be treated with caution.

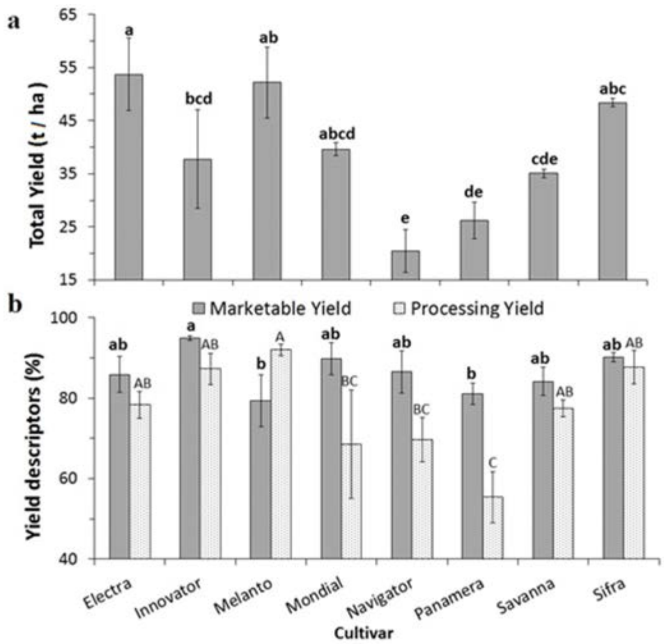

Figure 3. Total yield (a) and marketable and processing yields (b) of cultivars. Bars represent mean±SEM. Values with same letter differ non-significantly ($P>0.05$)

Potato quality characteristics

The tuber form index of Innovator significantly ($P<0.01$) differed from the other cultivars (TFI=180) and was the highest (Table 2). This indicated that the potatoes from this cultivar were of a long shape, while the other cultivars produced oval-shaped potatoes. This result was expected given that the seed mass from Innovator was significantly the highest among cultivars (Table 1). Moreover, dry matter content significantly (P<0.001) differed among the cultivars, with Melanto and Electra exhibiting the lowest values (16%) and Innovator exhibiting the highest (21%). Differences among the other cultivars were non-significant, falling between 18% and 20% (Figure 4).

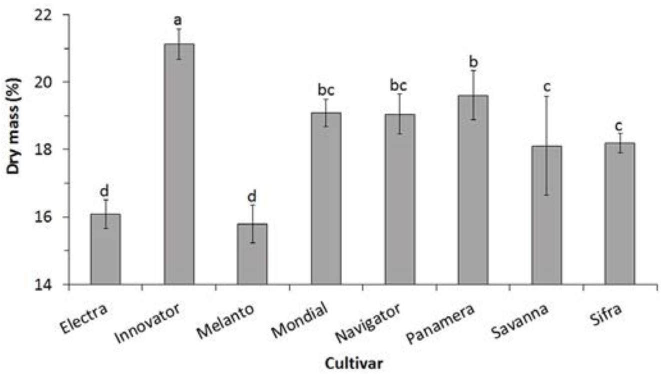

Figure 4. Dry matter content of potatoes. Values with same letter differ non-significantly (P>0.05)

The differences in dry matter content were strongly correlated to the differences in specific gravity (r=0.72), which affirmed potatoes of Innovator and Panamera to be of the same specific gravity (1.063) and Electra and Melanto to have the lowest values (1.052 and 1.051, respectively; Table 3). The results on specific gravity show Savanna (1.060), Sifra (1.059) and Mondial (1.058) to closely follow Innovator and Panamera (1.063; Table 3).

Specific gravity positively correlated with flesh lightness in the present study (r=0.65). However, differences in lightness were found to be non-significant (Table 3). Flesh yellowness and redness significantly (P<0.001 and P<0.05, respectively) differed among cultivars. Electra showed the greatest intensity of yellowness, followed by Melanto, Navigator, Mondial, and Innovator. Savanna was the least yellow of all the cultivars, followed by Sifra and Panamera, respectively. Differences in the yellowness of Navigator, Mondial and Innovator were non-significant (P≥0.05). Furthermore, the differences in yellowness were positively correlated to the differences in redness (r=0.66), with Electra showing the greatest degree of redness and Innovator showing the least. In addition, yellowness negatively correlated to lightness (r= -0.76) and likewise lightness negatively correlated with redness (r= -0.62).

Table 3. Flesh colour properties (L^* = lightness, a^* = redness and b^* = yellowness)

Cultivar	L^*	a^*	b^*
Mondial	79.19^{ab}	1.64^{ab}	37.88^{abc}
Panamera	81.9^{ab}	1.14^{abc}	34.28^{bc}
Electra	78.64^{ab}	1.80^{a}	44.85^{a}
Savanna	81.33^{ab}	0.67^{bc}	28.08^{c}
Navigator	72.66^{b}	1.65^{ab}	30.82^{c}
Melanto	78.57^{ab}	1.26^{abc}	41.93^{ab}
Sifra	80.37^{ab}	0.35^{c}	28.09^{c}
Innovator	82.73^{a}	0.28^{bc}	37.65^{abc}
LSD	8.757	0.876	9.18

Values express mean (n = 3). Values with the same letters differ non-significantly (P>0.05). CV = Coefficient of variation; LSD = Least significant difference

There is currently a need for processing cultivars in South Africa and Innovator has good potential for this market due to its high dry matter content, specific gravity and tuber form index. Considering the appreciable balance in size distribution, which is split between large- and medium-sized potatoes, this cultivar is already being used for the commercial production of frozen French fries in the country. A recent survey revealed a 70% preference for medium and large-sized potatoes by South African consumers (Badenhorst, 2014), which indicates potential if this cultivar were to be sold in fresh produce markets. The lighter colour of the flesh makes it favourable for the production of processed products, even though assessments on the sugar content would give more insight about its chipping quality. Particularly, dry matter content and specific gravity are integral characteristics determining the processing quality (Feltran et al., 2004); and due to the quality of Innovator in this regard, the cultivar is listed as a good French fry candidate in the European Cultivated Potato Database (2021). However, the low specific gravity displayed by all the cultivars in this study is a concern as the cut-off specific gravity for processing French fries is 1.070, which often correlates to a dry matter content within a 20-24% range (Elfnesh et al., 2011). A comparably high dry matter content for Innovator (19.68-21.63%) has also been reported by Evangelista, Nardin, Fernandes, and Soratto (Evangelista et al., 2011), in Brazil, who also reported a firmer pulp, higher nutritional quality and higher mineral content relative to nine other cultivars. Although the other cultivars evaluated in the present study are less popular, Mondial is well-known for exhibiting good table market properties, with a number of studies reporting on specific gravity not exceeding 1.060 and a dry matter content not exceeding 20% in different countries (Feltran et al., 2004; Levy and Tai, 2013; Abu-Zinada and Mousa, 2015). The results from the present study are in agreement with those records.

Principal Component Analysis

The principal component analysis indicated that four principal components explained the variance among cultivars and that the first two components explained 57.22% of the total variance (Figure 5).

Principal component 1 explained 36.62% of the total variance and principal component 2 explained 20.60%, indicating dry matter content, flesh lightness, occurrence of internal defects and marketable yield as the variables that differentiated cultivars. Only internal defects had negative loadings for principal component 1, while marketable yield was the only variable with negative loadings for principal component 2 (Figure 5a). The distribution of cultivars along principal component 1 was described dry matter content, potato flesh lightness and marketable yield, indicating that Innovator, Mondial and Sifra scored highly in these variables. In principal component 2, the distribution was described by the occurrence of internal defects, where Panamera, Navigator and Savanna had a higher occurrence of defects.

These results suggest that the cultivars could be classified into three groups. Group 1, comprised of Innovator, had the lightest flesh colour, the highest dry matter content and marketable yield, and a low occurrence of internal defects. Group 2, comprising Electra and Melanto, scored lower in all Group 1's variables and had the lowest occurrence of internal defects. Group 3, comprising Panamera, Savanna, Navigator, Sifra and Mondial, scored high in all Group 1's variables but had the highest occurrence of internal defects. These can be used to make suggestions for culinary usage, with Group 1 showing qualities favourable for processing and Group 3 showing qualities of multipurpose potatoes. Since marketable yields were relatively high (≥ 80%) and

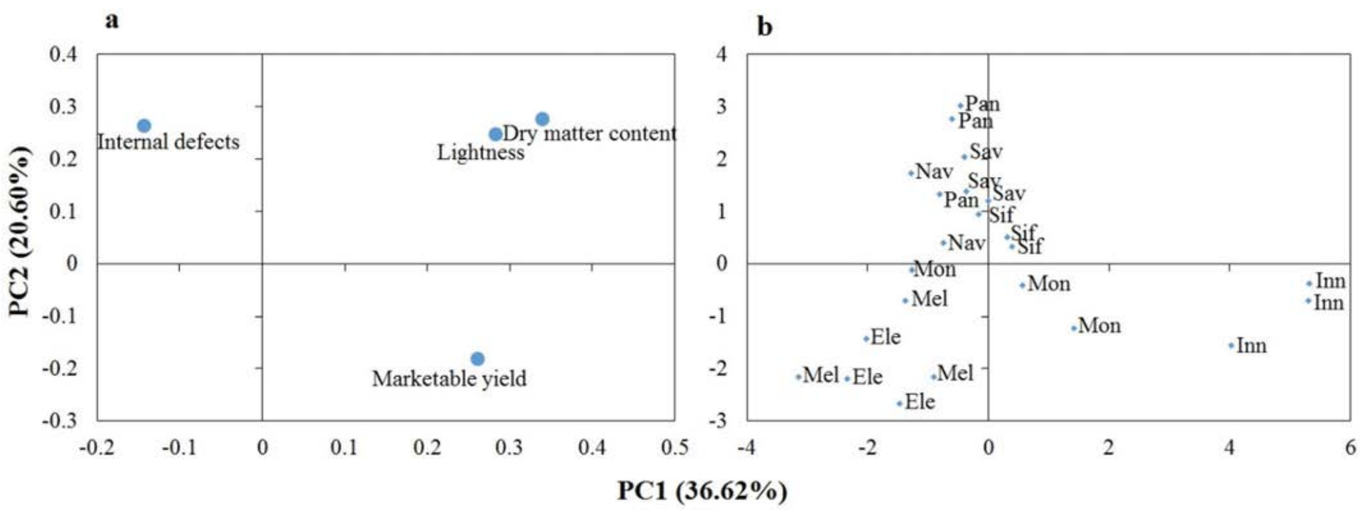

Figure 5. Loadings (a) and scores (b) of cultivar properties on principal components 1 and 2. Cultivar names coded using the first three letters

the occurrence of internal defects was relatively low (≤ 10%) in the present study, Group 2 cultivars qualify for the table potato market and have potential for improving profit margins for potato producers, as achieved total yields were high. Studies on the nutritional quality, starch and amylose content would be beneficial in separating the cultivars classified into Group 3 for specific culinary methods.

CONCLUSION

Five out of the eight cultivars evaluated in this study produced a relatively high total and marketable yields in the South African context and had a low occurrence of internal defects. The exceptions were Navigator, Panamera and Savanna. Innovator was the earliest maturing cultivar, producing long potatoes of the highest dry matter content and a lighter flesh colour. This validated the cultivar as a good candidate for industrial processing of French fries in South Africa. The low dry matter content and the higher degree of yellowness of Melanto and Electra make them unsuitable for processing. However, they are economical, as they produced the highest yields in this study. Furthermore, Sifra, Innovator and Mondial are also economical, resulting in yields higher than the current achievements in the country. The dry matter content and specific gravity performance of Panamera, Navigator, Savanna, Sifra and Mondial denotes them as cultivars for multipurpose usage, with possible culinary usage, including stews, mashing, baking, boiling and in salads. Studies on the nutritional quality, starch and amylose content would be beneficial in separating these cultivars for specific culinary methods. Since the results reported in the present study are based on a single trial experiment, future studies, evaluating the performance of the tested cultivars, are recommended over multiple seasons and/or regions within the South African context. Furthermore, investigations aiming to identify and quantify the causes of external defects in potatoes (resulting in differences in marketable yields among cultivars) are recommended.

REFERENCES

Abong, G.O., Okoth, M.W., Imungi, J.K., Kabira, J.N. (2009) Evaluation of selected Kenyan potato cultivars for processing into potato crisps. American Journal of Agricultural and Biological Sciences, 1, 886-893. DOI: http://dx.doi.org/10.5251/abjna.2010.1.5.886.893

Abu-Zinada, I.A., Mousa, W.A. (2015) Growth and productivity of different potato varieties under Gaza Strip conditions. International Journal of Agriculture and Crop Sciences, 8, 433-427.

Almekinders, C.J.M., Mertens, L., van Loon, J.P., van Bueren, E.T.L. (2014) Potato breeding in the Netherlands: a successful participatory model with collaboration between farmers and commercial breeders. Food Security, 6, 515-524.

Altman, M., Hart, T.G.B., Jacobs, P.T. (2009) Household food security status in South Africa. Agrekon, 48, 345-361.

Badenhorst, R. (2014) Potatoes South Africa 2014 consumer research study. Chips, 28 (4), 20-29.

Ćota, J., Hadžic, A., Hodžic, I., Ćota, J. (2012) New Dutch potato varieties in Bosnia and Herzegovina. In: S. Terzic´ (ed.), Proceedings of the international conference on bioscience: biotechnology and biodiversity - step in the future (pp. 165-175). Publisher Institut za Ratarstvo i Povrtarstvo & Semenarska Asocijacija Srbije: Serbia.

Ekin, Z. (2011) Some analytical quality characteristics for evaluating the utilization and consumption of potato (*Solanum tuberosum* L.) tubers. African Journal of Biotechnology, 10, 6001-6010. DOI: https://hdl.handle.net/10.5897/AJB11.042

Elfnesh, F., Tekalign, T., Solomon, W. (2011) Processing quality of improved potato (*Solanum tuberosum* L.) cultivars as influenced by growing environment and blanching. African Journal of Food Science, 5, 324-332. Available at: https://academicjournals.org/journal/AJFS/article-full-text-pdf/71031A23523 [Accessed 23 June 2022].

European Cultivated Potato Database (2021) Variety index. Available at: https://www.europotato.org/varieties [Accessed 20 November 2021].

Evangelista, R.M., Nardin, I., Fernandes, A.M., Soratto, R.P. (2011) Qualidade nutricional e esverdeamento pós-colheita de tubérculos de cultivares de batata. Pesquisa Agropecuaria Brasileira, 46, 953-960. Available at: https://www.scielo.br/j/pab/a/mTdqDNrrTT4tfWfhH7HCBZM/?format=pdf&lang=pt [Accessed on 23 June 2022].

Feltran, J.C., Lemos, L.B., Vietes, R.L. (2004) Technological quality and utilization of potato tubers. Scientia Agricola, 61, 598-603. Available at: https://www.scielo.br/j/sa/a/HMdFqxXNxcbbjw5p9JwtkXd/?format=pdf&lang=en [Accessed 23 June 2022].

Food & Agriculture Organization (2021) FAOSTAT. http://faostat3.fao.org/download/Q/QC/E (Accessed 20 November 2021)

Galdon, B.R., Rodriguez, L.H., Mesa, D.R., Leon, H.L., Perez, N.L., Rodriguez, E.M.R., Romero, C.D. (2012) Differentiation of potato cultivars experimentally cultivated based on their chemical composition and by applying linear discriminant analysis. Food Chemistry, 133, 1241-1248. DOI: https://doi.org/10.1016/j.foodchem.2011.10.016

Geremew, E.B., Steyn, J.M., Annandale, J.G. (2007) Evaluation of growth performance and dry matter partitioning of four processing potato (*Solanum tuberosum*) cultivars. New Zealand Journal of Crop and Horticultural Science, 35(3), 385-393. DOI: https://doi.org/10.1080/01140670709510204

Geyer, G. (2014) Potatoes for the nation: trade and marketing. Farmlink Africa, 4(2), 39. DOI: https://hdl.handle.net/10520/EJC165893

Gutaker, R.M., Weiß, C.L., Ellis, D., Anglin, N.L., Knapp, S., Fernández-Alonso, J.L., Prat, S., Burbano, H.A. (2019) The origins and adaptation of European potatoes reconstructed from historical genomes. Nature Ecology & Evolution, 3(7), 1093-1101. DOI: https://doi.org/10.1038/s41559-019-0921-3

Hofmeyr, I. (2015) Africa beckons for the potato industry: Agribusiness update. FarmBiz, 1(3), 16-19. Available at: https://journals.co.za/doi/epdf/10.10520/EJC169484 [Accessed 23 June 2022].

HZPC (2021) Varieties. Available at: https://www.hzpc.com/our-potato-varieties. [Accessed 21 November 2021]

International Potato Centre (2021) Potato facts and figures. Available at: http://cipotato.org/potato/facts/. [Accessed 20 November 2021]

Levy, D., Tai, G.C.C. (2013) Differential response of potatoes (*Solanum tuberosum* L.) to salinity in an arid environmental and field performance of the seed tubers grown with fresh water in the following season. Agricultural Water Management 116, 122-127. DOI: https://doi.org/10.1016/j.agwat.2012.06.022

López, R., Carmona, D., Vincini, A.M., Monterubbianesi, G., Caldiz, D. (2010) Population dynamics and damage caused by the leafminer *Liriomyza huidobrensis* Blanchard (Diptera: Agromyzidae), on seven potato processing varieties grown in temperate environment. Neotropical Entomology 39(1), 108-114. DOI: https://doi.org/10.1590/S1519-566X2010000100015

Masamba, K., Mwenye, O., Demo, P., Chipungu, F., Benesi, I., Chimwala, L. (2014) On-farm evaluation of potato genotypes for yield and late blight resistance in Malawi. Available at: https://cipotato.org/publications/on-farm-evaluation-of-potato-genotypes-for-yield-and-late-blight-resistance-in-malawi/ [Accessed 20 November 2021]

Masekoameng, M., Malawichi, L.L. (2014) The status of food access in Limpopo province: A case of rural households in Sekhukhune district, South Africa. Journal of Human Ecology, 46, 39-46. DOI: https://doi.org/10.1080/09709274.2014.11906704

Ngidi, M.S.C., Hendriks, S.L. (2014) Coping with food insecurity in rural South Africa: The case of Jozini, KwaZulu-Natal. Mediterranean Journal of Social Sciences, 5, 278-289. DOI: https://doi.org/10.5901/mjss.2014.v5n25p278

Ngobese, N.Z., Workneh, T.S. (2017) Development of the frozen French fry industry in South Africa. American Journal of Potato Research, 94(1), 1-13. DOI: https://doi.org/10.1002/jsfa.7104

Prasad, B., Dutt, B.L. (1980) Reaction of *Solanum* spp. against early blight of potatoes. Journal of Indian Phytopathological Association, 7, 68-72. Available at: https://www.fabinet.up.ac.za/publication/pdfs/1475-a_review_of_early_blight_of_potato.pdf [Accessed 23 June 2022].

Šimková, D., Lachman, J., Hamouz, K., Vokál, B. (2013) Effect of cultivar, location and year on total starch, amylose, phosphorous content and starch grain size of high starch potato cultivars for food and industrial processing. Food Chemistry, 141, 3872-3880. DOI: https://doi.org/10.1016/j.foodchem.2013.06.080

Speiser, B., Tamm, L., Amsler, T., Lambion, J., Bertrand, C., Hermansen, A., Ruissen, M.A., Haaland, P., Zarb, J., Santos, J., Shotton, P. (2006) Improvement of late blight management in organic potato production systems in Europe: field tests with more resistant potato varieties and copper-based fungicides. Biological Agriculture & Horticulture, 23(4), 393-412. DOI: https://doi.org/10.1080/01448765.2006.9755339

Steyn, J.M., Geremew, E.B., Annandale, J.G., Steyn, P.J. (2009) Frodo and Darius: South African potato cultivars with good processing quality. South African Journal of Plant and Soil, 26, 24-30. DOI: https://doi.org/10.1080/02571862.2009.10639928

USDA (2015) Potatoes for processing: Inspection instructions. Available at: https://www.ams.usda.gov/sites/default/files/media/Potatoes_for_Processing_Inspection_Instructions%5B1%5D.pdf [Accessed 20 November 2021].

Wekesa, M.N., Okoth, M.W., Abong, G.O., Muthoni, J., Kabira, J.N. (2014) Effect of soil characteristics on potato tuber minerals composition of selected Kenyan varieties. Journal of Agricultural Science, 6, 163-171. DOI: http://dx.doi.org/10.5539/jas.v6n12p163

Yang, Y., Achaerandio, I., Pujolà, M. (2016) Classification of potato cultivars to establish their processing aptitude. Journal of the Science of Food and Agriculture, 96 (2), 413-421. DOI: https://doi.org/10.1002/jsfa.7104