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Trader acceptability of African eggplant (*Solanum aethiopicum* Shum) genotypes and effect of bio-control treatments on consumer sensory acceptability

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Summary Application of advanced agronomic practices may affect the sensory attributes of plant products. The study determined the trader physical acceptability of farmer preferred African eggplant (*nakati*) genotypes (E11, E15 and E16); and later studied the impact of bio-control treatments; *Trichoderma* spp (TRI). and Arbuscular Mycorrhizal Fungi (AMF) on consumer sensory appeal of genotypes using standard sensory evaluation methods. The trader acceptability of genotypes based on leaf number, succulence, smoothness, colour, and shininess were significantly different; except for the hard-textured leaves of E11 ($P \leq 0.05$). Leaf appearance (E11) and stalk-leaf quantity (E15 and E16) were preferred by high-end and low-end markets, respectively. Consumer sensory acceptability of bio-control-treated samples, above 85% of E15 and E16 was liked based on reduced bitterness ($P \leq 0.05$). Using descriptive sensory tastes, results showed that soil bio-control treatment with TRI during the light rain season significantly improved the palatability of E15 and E16. Therefore, use of TRI during light or dry season improves sensory appeal of *nakati*.

Keywords Arbuscular Mycorrhizal Fungi, consumer acceptability, *nakati*, rain seasons, *Trichoderma* spp., vegetable.

Introduction

Uganda is home to many highly nutritious vegetables; among which the most preferred, produced and traded on the Ugandan market is African eggplant (*Solanum aethopicum* L., chum) also locally known as *nakati* (Musinguzi *et al.*, 2006; Kasharu *et al.*, 2019). The crop is traditionally grown mixed with seeds of other vegetables such as *Amaranthus blitum* L. (locally known as *bugga*) and *Gynadropsis gynandra* L. (locally known as *jobyo*) using the broadcasting method of planting as opposed to the recommended individual type planting in lines (Semalulu *et al.*, 2020).

African eggplant (*nakati*) is a light branched plant with hairless leaves and shoots that are plucked for use as green leafy vegetables while its fruits (about 1.5 cm diameter) are very bitter and considered inedible (Plazas *et al.*, 2014; Han *et al.*, 2021). The leaves possess antibiotic, and prebiotic properties (Park & Zeikus, 2002; Erasto *et al.*, 2004; Veluri *et al.*, 2004) and phytochemicals that protect against non-communicable diseases (Uusiku *et al.*, 2010; Han *et al.*, 2021). They serve as an affordable source of micronutrients and phytochemicals thus playing an important role in improving household nutrition (Forestell & Mennella, 2007; Onyango, 2007; Gotor & Irungu, 2010). In Uganda, *nakati* is an important component of traditional dishes such as matooke cake in steamed form (Musinguzi *et al.*, 2006).

In Uganda, *nakati* is produced year-round and thrives well in humid areas (Schippers, 2000; Nyadanu & Lowor, 2015; Han *et al.*, 2021) which receive bimodal rainfall patterns between 800–1200 mm per year (rainy seasons are March to May-light rains and September to November-heavy rains; Bernard, 2018); and also planted in swampy areas during the dry season (Schippers, 2000; Nyadanu & Lowor, 2015; Han *et al.*, 2021). The main production zones are; Lake Victoria Crescent and Western Savannah grasslands

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(Luwero). Western Savannah grasslands are characterised by less precipitation and poor soil fertility (Musinguzi *et al*., 2006; Jagwe *et al*., 2016). These conditions pose a challenge to the year-round productivity of *nakati*. The use of bio-control treatments is proposed as one of the recent advancements in agronomic practices for improved production of vegetables in water-stressed environments (Aggarwal *et al*., 2011; Molla *et al*., 2012).

The most popular bio-control treatments used in vegetable production include; *Trichoderma* spp. (TRI) and Arbuscular Mycorrhizal Fungi (AMF; Aggarwal *et al*., 2011; Molla *et al*., 2012). These are filamentous fungi that are opportunistic, virulent symbionts that are used as biopesticides, biofertilisers, or fertility promoters worldwide. Application of such bio-control treatments has been reported to result in the promotion of plant growth vigour, yield and increased adaptability to environmental stress as well as increased nutrient availability (Begum *et al*., 2019; Halifu *et al*., 2019). Some species of TRI and AMF are well-known producers of specific secondary metabolites that are important for plant growth regulation. Some strains may also be able to colonise root surfaces and cause substantial changes in plant metabolism (Diagne *et al*., 2020). The effect of TRI and AMF on plant growth and productivity has been studied for a large number of plant species mainly vegetables grown in a greenhouse or in pot experiments but with limited research on their impact on sensory quality.

According to Lado *et al*. (2019), the manipulation of agronomic practices reportedly has drastic impacts on nutritional quality and contributes to the inherent sensory variability of resultant plant products (Kader, 2008; Lado *et al*., 2019). The characteristics that define quality are described by four (Begum *et al*., 2019) different attributes namely; appearance (colour), flavour as a factor of taste and aroma, texture and nutritional value (Kader, 2008). The freshness, taste (sweetness/bitterness), and other flavour attributes are critical to the eating pleasure. The consumption of vegetables particularly African eggplant is greatly influenced by consumers' degree of physical appeal and sensory acceptability (Dinehart *et al*., 2006). The majority of the vegetable consumers are less likely to eat vegetables with a bitter taste (Drewnowski & Rock, 1995; Drewnowski & Gomez-Carneros, 2000; Singh-Ackbarali & Maharaj, 2014).

Therefore, the study aimed at determining the trader physical acceptability of African eggplant (*nakati*) genotypes (E11, E15 and E16), grown during heavy rains (main season) in non bio-control-treated soils. These genotypes were previously referred to as farmer preferred by Nakyewa *et al*. (2021) because of their distinctiveness for pest and disease resistance and growth vigour. The study also aimed at determining the impact of two soil bio-control treatments (TRI and AMF) on the consumer sensory appeal of the three farmers preferred genotypes. Using descriptive sensory analysis, the study further determined the impact of soil bio-control treatments under two growth seasons (light and heavy rains) on sensory appeal. Acceptable sensory attributes alongside better productivity of *nakati* grown under bio-control-treated soils will likely improve the livelihoods of farmers and traders dealing in *nakati*. The final consumers will benefit from nutritional benefits as a result of increased vegetable consumption.

Materials and methods

Selection of study materials and experimental design

The experimental site was located in Luwero district (Western Savannah Grassland). A split-plot randomised complete block design with three replications was used. The main plot factor was the bio-control treatment with three levels [either *Trichoderma* spp (TRI) or Arbscular Trichoderma mycorrhizal fungi (AMF) treatments and control (Ctrl) with no application of either TRI or AMF] while the subplot factor was genotype with three levels (E11, E15 and E16). The experiment was repeated over two seasons (light; and heavy seasons). The test genotypes used for this study were the ones preferred by farmers based on perceived resilience to field diseases and pests as well as superior growth vigour traits (Nakyewa *et al*., 2021).

Collection of samples

Two hundred grams (200 g) sample of each genotype were picked from each treatment. The samples with their roots were randomly picked from the experimental field in Luwero, soil was shaken off the roots (to reduce incidences of leaf soiling), labelled and packed in polystyrene bags before transportation to Makerere University, Department of Food Technology and Nutrition (DFTN). On delivery to the sample preparation laboratory, the roots were immersed in a 10-litre bucket with portable water (with 4 L of water) at room temperature overnight to prevent wilting of leaves.

Trader physical quality acceptability analysis

For trader acceptability analysis, four markets in Kampala were purposively selected based on being the main destination for the majority of the farmers and consumers (Kasubi, Kalerwe and Busega market) while Nakasero market was selected because it represents the main destination for elite-class consumers within Kampala (Jagwe *et al*., 2016). From each market, 30 respondents were randomly selected and three control (no bio-control treatment) samples of *nakati* genotypes (E11, E15 and E16) grown during heavy rains, were presented to each of them for physical quality scoring. Rootstock was cut off the samples and bundled to represent the form in which *nakati* is sold on the Uganda market. The aspects scored against were; leaf number, leaf colour, leaf size, leaf hardness, leaf smoothness, succulence and shininess. These attributes were scored using a five-point hedonic rating where; 1 = dislike a lot and 5 = like a lot (Lawless & Heymann, 2010).

Sensory evaluation

Preparation of samples for steaming
A total of nine samples comprising three genotypes (E11, E15 and E16) under two bio-control treatments (AMF and TRI) and control (Ctrl); were prepared for steaming and further sensory analysis. The roots were cut off from the shoot to avoid soiling leaves before being plucked off the stalk. Samples were washed twice to remove soil and adhering dirt and water drained off the *nakati* leaves. The *nakati* weight to potable water volume used was; 100 g of *nakati* leaves in 1 litre of potable water. Using a chopping board and stainless-steel knife, the *nakati* was chopped into smaller sizes of approximately 10 mm and immediately steamed in a perforated stainless-steel pan seated over a saucepan with steaming water. Steaming was done for 12 min at 100°C. To maintain heat stability, a gas cylinder (from Total Energies) of 16 kg was used at a regulated constant gas flow, in a closed room to avoid wind disturbance. The samples were assigned codes and served at room temperature on plastic disposable plates.

Consumer acceptability analysis
Twenty-five consumer panellists were recruited among farmers in Luwero where the experimental fields were located. Samples grown during the heavy rain season were prepared on-site following the procedure (Preparation of samples for steaming) above. Panellists were briefed before the start of the session. Steamed *nakati* samples were presented to each panellist and they were requested to evaluate them in the order of appearance on the ballot. Panellists were asked to eat crackers and rinse their mouths with water between samples. The samples were ranked by panellists for appearance (Colour), flavour, bitterness, mouth-feel, and taste using a five-point hedonic scale; where 1 = dislike a lot and five like a lot. A modified five-point hedonic scale was adopted because it generates both intensity and acceptability at the same time (Lawless & Heymann, 2010).

Descriptive sensory analysis

Training of expert panel for scaling and scoring. The sensory acceptability of food is determined by a number of factors including consumer attitude. The attitude is a personal judgement, preference, or intuition. Therefore, the guidance of sensory evaluation is paramount.

The choice of sensory analysis method in the current study was informed by the need to assess: (a) consumer information which focused on preference, acceptance and liking through the ranking of samples using a hedonic scale; (b) descriptive information of samples (Singh-Ackbarali & Maharaj, 2014).

Ten experienced panellists from the DFTN, which included six females and four males were selected and recruited. Criteria for selection based on ability to provide similar responses on similar vegetable samples on repeated occasions and availability for the period of study. Panellists were trained half-day in preparation for the sensory profiling of *nakati* genotypes using descriptive analysis. Each panellist received a representative specimen and training to increase their sensitivity and ability to discriminate between the sensory attributes and intensity of the bitter vegetables. Due to time limitations as a result of COVID-19, training was cut short and free choice profiling of *nakati* was done by the assessors prior to sensory analysis as recommended by Singh-Ackbarali & Maharaj (2014), and Marques *et al*. (2022). A five-point category ranging from 1 to 5 was used to measure the intensity of each sensory attribute, where 1 denoted the least appealing or palatable and five denoted the most appealing or palatable.

Sensory analysis. The samples were purposively analysed for two seasons: light rains (March to May) and heavy rains (September to November) because the trained panellists could potentially identify changes in sensory attributes as a result of variations in the rain season. The trained panellists were requested to profile the sensory appeal of the *nakati* products by; appearance (bright colour or pale colour), bitterness, aroma, flavour and texture. One sample was served at a time to each of the panellists, and a score sheet for evaluation accompanied the sample. Samples were evaluated under a well-balanced light and each panellist sat in an individual booth. The attributes were ranked by appeal or palatability as was perceived by the panellists. The panellists were requested to eat crackers and rinse their mouths between samples to reduce fatigue.

Data analysis

Data was entered in an Excel sheet and subjected to descriptive analyses using Pivot chart and ANOVA in Genstat (12th Edition). The means were separated using LSD ($P < 0.05$) to determine significant differences.

Results

Trader acceptability of *nakati* genotypes

Generally, the results showed that there were significant differences in the trader acceptability of genotypes (E11, E15 and E16) in the different markets. Table 1 also indicates that throughout the four markets tested for trader acceptability of *nakati* genotypes, gender (male or female) of the traders did not significantly ($P > 0.05$) contribute to the likeability of any of the *nakati* physical qualities that determine the decision to purchase.

Ranks of the quality attributes generated during the market study to assess the physical acceptability of different *nakati* genotypes are indicated in Table 2. The results showed that in the four markets, all genotypes had highly acceptable leaf number with an average rank/score of 4.0. In the four markets, genotypes E11 and E15 had highly acceptable leaf Colour, smoothness and shininess. All three *nakati* genotypes were highly acceptable in Busega and Kasubi markets, especially for succulence, shininess and leaf hardness.

The leaf size of genotype E16 was disliked in the three markets (Busega, Kalerwe and Kasubi) except for Nakasero market where the majority of customer's appeal to buy *nakati* was not majorly determined by the leaf size thus being expressed as neutral (neither like nor dislike). Overall, the *nakati* genotypes were acceptable across the markets except for small leaves (genotype E16) and leaf hardness (genotype E11; Fig. 1).

Observation from the pivot charts (Fig. 1) further indicates the overall physical acceptability of the genotypes (E11, E15 and E16) in the 4 markets, with exception of leaf size for genotype E16 (score range 2.5–3.0). The leaf smoothness of E16 was also marginally accepted in Kalerwe market. In high-end markets (Case of Nakasero), Ell was generally disliked most for physical quality aspects such as leaf hardness with an average score of 2.8 and leaf succulence (an average score of 2.5) which majorly determine the acceptability of any leafy vegetable. A negative trend was observed between leaf size and leaf hardness. The preference for leaf hardness (texture) increased with dislike for leaf size, thus could imply that small-sized leaves have better texture.

Sensory acceptability of *nakati* genotypes

Consumer panel

Generally, results indicate that E15 and E16 were more preferred compared with E11 regardless of the treatment. Results further indicate that the consumer

Table 1 Probability values for rejecting a null hypothesis (Ho: no differences among genotypes at α = 5%) for physical attributes acceptability in study markets

SoV	Leaf number	Colour	Leaf hardness	Leaf size	Leaf smoothness	Succulence	Leaf shininess
Market	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Genotype	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Gender	0.675	0.659	0.869	0.790	0.086	0.509	0.880
Market*Genotype	<0.001	<0.001	<0.0010	<0.001	<0.001	<0.001	<0.001
Market*Gender	0.779	0.641	0.500	0.181	0.701	0.843	0.112
Genotype*Gender	0.102	0.736	0.116	0.862	0.944	0.669	0.063
Market*Genotype*Gender	0.031	0.666	0.184	0.693	0.869	0.133	0.679
% CV	17.2	18.8	17.6	17.7	16.6	21.9	17.3

If $P \leq 0.05$, there is significant difference.

Table 2 Physical quality acceptability of *nakati* genotypes within the major markets of Kampala

	Leaf number			Colour			Leaf hardness			Leaf size			Leaf smoothness			Succulence			Shininess		
Market	E11	E15	E16	E11	E15	E16	E11	E15	E16	E11	E15	E16	E11	E15	E16	E11	E15	E16	E11	E15	E16
Busega	4.00	4.53	4.83	4.73	4.80	4.47	3.69	4.47	4.93	5.00	4.93	2.87	4.90	4.60	4.13	4.36	4.30	3.87	4.63	4.58	4.40
Kalerwe	3.09	4.58	4.06	4.03	4.15	3.24	3.00	3.88	4.46	4.82	3.91	2.70	4.46	4.33	2.88	3.97	4.41	3.06	4.37	4.22	2.82
Kasubi	4.23	4.30	4.69	4.73	4.50	4.10	3.45	3.90	4.97	4.90	4.61	2.94	4.77	4.49	4.03	4.61	4.19	3.77	4.90	4.20	3.94
Nakasero	4.04	4.07	3.83	3.53	4.10	4.20	2.89	4.47	4.33	4.43	3.72	3.23	4.23	3.90	3.53	2.61	4.23	3.97	4.41	3.33	3.37
Mean	3.83	4.37	4.35	4.26	4.38	3.99	3.25	4.17	4.67	4.79	4.29	2.93	4.59	4.33	3.63	3.89	4.29	3.65	4.58	4.09	3.61
l.s.d (α = 5%)	0.3688			0.3886			0.3541			0.3497			0.3428			0.4275			0.3529		
c.v%	17.2			18.8			17.6			17.7			16.6			21.9			17.3		

Like a lot = 5, like a little = 4, Neutral = 3, dislike a little = 2, Dislike a lot = 1.

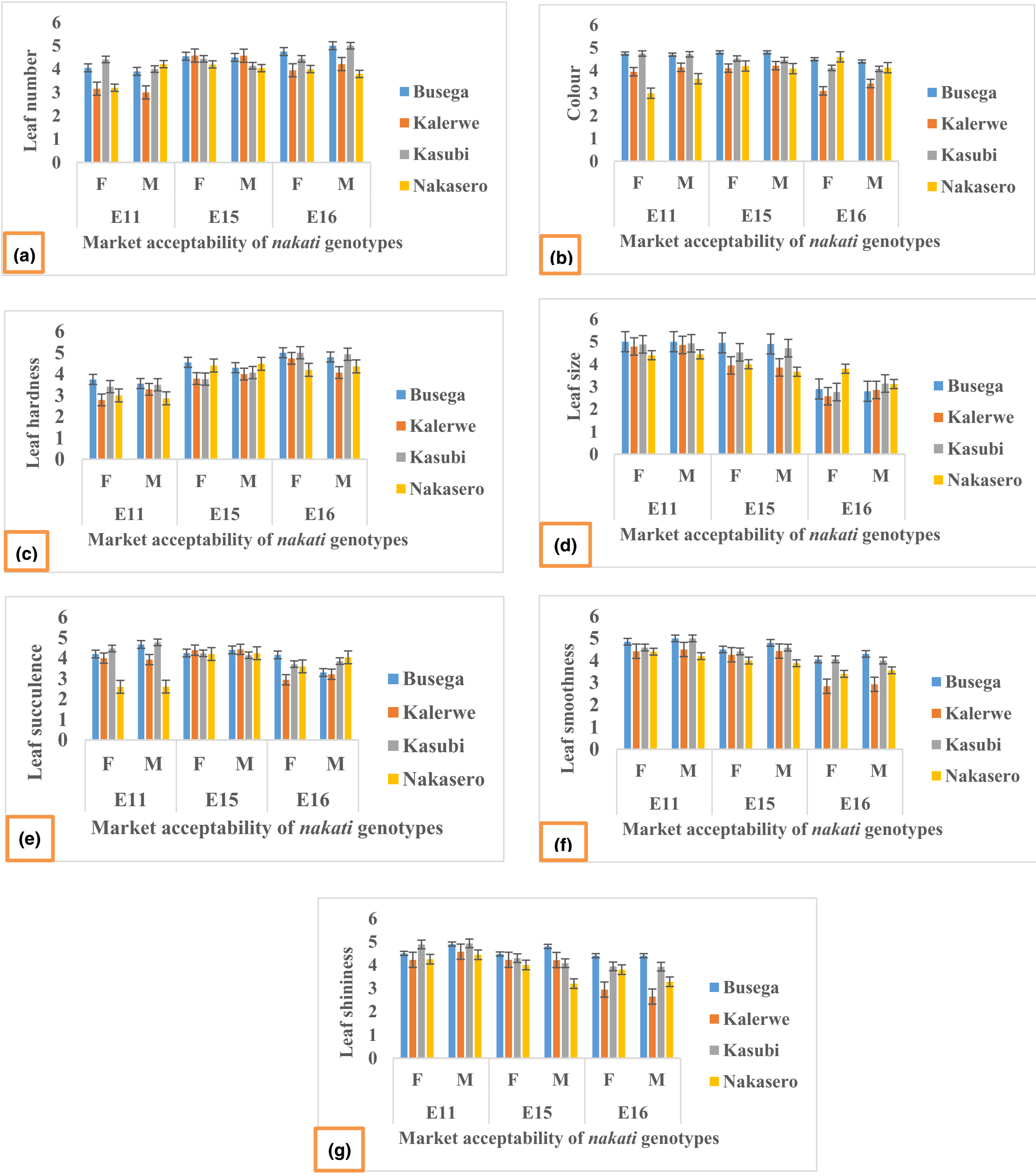

Figure 1 (a–g): Physical market acceptability of the *nakati* genotypes. Error bars represent standard error (SE).

acceptability of *nakati* genotypes was not significantly different in terms of appearance and flavour ($P > 0.05$) except the gender, bio-control treatment and genotype interaction which was slightly significant for appearance ($P < 0.047$; Table 3). The results in Table 4 and Fig. 2 also show that female rejected taste, bitterness and mouth-feel of genotype E11 for both control and TRI-treated samples with scores

Table 3 Probability values for rejecting a null hypothesis (Ho: no differences among genotypes and treatments at α = 5%) for consumer sensory acceptability of *nakati*

SoV	Appearance	Bitterness	Mouth_feel	Flavour	Taste
Gender	0.140	0.319	0.204	0.172	0.255
Treat	0.178	0.352	0.116	0.063	0.629
Genotype	0.207	0.120	<0.001	0.199	<0.001
Gender*Treat	0.231	0.489	0.448	0.459	0.081
Gender*Genotype	0.457	<0.001	0.162	0.374	0.001
Treat*Genotype	0.339	0.172	0.076	0.219	<0.001
Gender*Treat*Genotype	0.047	0.141	0.160	0.300	0.388
% CV	25.6	42.5	33.9	33.5	30.0

If $P \leq 0.05$, there is significant difference.

Table 4 Consumer sensory acceptability of *nakati* genotypes under different treatment

		Appearance			Bitterness			Mouth-feel			Flavour			Taste		
Gender	Treatment	E11	E15	E16	E11	E15	E16	E11	E15	E16	E11	E15	E16	E11	E15	E16
F	AMF	4.000	4.273	4.000	3.000	3.364	3.364	3.545	4.000	3.182	3.727	3.182	3.727	4.000	3.818	4.000
	Ctrl	4.091	4.455	4.727	2.455	3.273	3.455	2.455	3.545	3.818	2.727	3.455	3.182	2.273	4.364	3.909
	TRI	3.636	3.727	3.727	2.182	3.818	2.727	2.545	4.091	3.000	2.364	3.455	3.091	2.727	4.182	3.000
M	AMF	4.583	3.833	4.600	3.917	2.667	2.100	3.583	4.250	3.000	4.000	3.667	3.100	4.083	3.333	3.300
	Ctrl	4.400	4.400	3.700	2.600	3.100	2.400	2.600	3.500	3.400	2.900	3.400	3.200	3.100	4.000	3.500
	TRI	3.417	4.417	4.500	3.000	3.000	3.500	3.250	3.583	3.500	3.364	3.500	3.750	3.500	4.167	3.917
l.s.d (α = 5%)		0.868			1.061			0.952			0.924			0.888		
c.v%		25.6			42.5			33.9			33.5			30.0		

Key: like extremely = 5, like moderately = 4, neither like nor dislike = 3, dislike moderately = 2, dislike extremely = 1.
AMF = Arbuscular Mycorrhizal fungi; Ctrl = No bio-control treatment; TRI = *Trichoderma* spp.

ranging between 2.2 and 2.7, while the male accepted the genotypes. A negative response was noted among male as genotype E15 and E16 under AMF treatment was rejected.

Regarding leaf appearance; the results from the rating of the consumer acceptability (Fig. 2) showed that, the consumer perception of appearance for genotypes was generally high regardless of the bio-control treatment or gender. Scores ranged from 3.4 to 4.7 (Table 4) with the interaction between gender, bio-control treatments and genotypes being significant (Table 3). For TRI treatments, both male and female generally ranked E11 lower at 3.6 and 3.4 respectively, compared with E15 (3.7–4.4) and E16 (3.7–4.5). Treatment with AMF gave more appealing appearance for all genotypes with score values ranging from 3.8 to 4.6 by both gender (Table 4). Generally, all values for TRI-treated samples were less acceptable than the control while AMF treatments were generally more liked than the control with small differences due to gender (Fig. 2).

Regarding taste, significant differences were observed between genotypes ($P \leq 0.05$), gender–genotype interactions ($P \leq 0.05$) and genotype bio-control interactions ($P \leq 0.05$; Table 3). This collaborates to the observed significant differences in bitterness due to gender–genotype interactions. In terms of differences in genotypes, E11 was generally less liked, followed by E16 and E15 irrespective of bio-control treatments and gender (Fig. 2). Regarding gender–genotype interactions, females preferred E15 (3.8–4.4) and E16 (3.0–4.0) to E11 (2.3–4.0; Table 4), whereas males seemed to like all genotypes with E15 slightly more preferred irrespective of bio-control treatments (Fig. 2). Considering bio-control treatments, both TRI and AMF were generally preferred than the control, with E15 and E16 treated with TRI more liked. Generally, the level of bitterness for both E15 and E16 was more preferred to that of E11 unrelatedly, with females liking E15 and E16 more than E11, while males slightly preferred E11 to E15 and E16 (Fig. 2).

As far as mouth feel is concerned, genotypes E11 and E15 under AMF-treatment were generally acceptable with score ranges of 3.5–4.3 except for E16 which was marginally acceptable with an average score of 3.1 (Table 4). Although the mouth-feel, taste and flavour for E11 was acceptable when soils were treated, E11 grown under the control soils was not acceptable

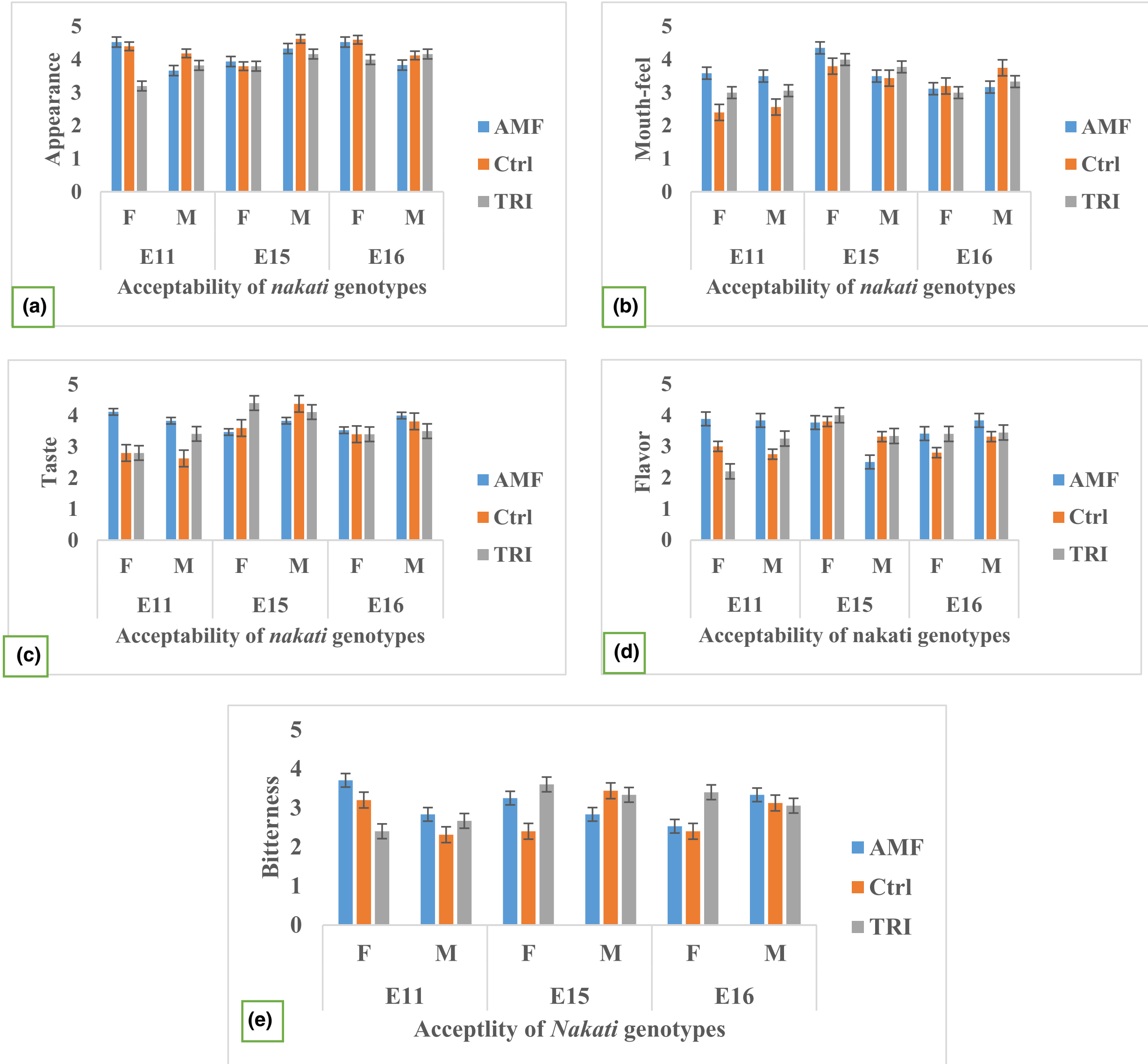

Figure 2 (a–e): Farmers sensory acceptability of *nakati* genotypes grown under different bio-control soil treatments. Error bars represent standard error (SE).

(scoring below 3.0; Table 4). Notably, the only significant differences ($P \leq 0.05$) in mouth-feel were due to genotypic differences, not related to gender and bio-control treatments (Table 3).

Trained panel

Appearance. There was no significant difference ($P > 0.05$) observed in the appearance appeal as a result of the different bio-control treatments during the light rain season; regardless of gender and genotype (Table 5), with TRI-treated samples of E15 and E16 generally appealing to both gender except E16 in males which was less appealing (Fig. 3b). The results also showed that TRI-treated E11 was appealing to both female and male with score an average score of 4.2 (Table 6).

In the heavy rains season, significant differences ($P \leq 0.05$) in appearance appeal were due to genotypes and gender–genotype interactions irrespective of bio-control treatments (Table 5). Regarding genotypic differences, the overall appeal score ranges for E11, E15 and E16 were 3.2–4.4, 2.6–4.0 and 3.2–4.4, respectively with E11 and E16 more appealing with respect to

Table 5 Probability values for rejecting a null hypothesis (Ho: no differences among genotypes and treatments at α = 5%) for sensory appeal of *nakati* grown during two growth seasons

	Light rain season (*March to May*)					Heavy rain season (*August to November*)				
SoV	Appearance	Aroma	Bitterness	Flavour	Texture	Appearance	Aroma	Bitterness	Flavour	Texture
Gender	0.473	0.298	<0.001	0.089	0.152	0.870	0.655	0.197	0.023	0.010
Treat	0.003	0.074	0.010	0.495	0.250	0.453	0.353	0.050	0.752	0.707
Genotype	0.749	0.080	<0.001	0.641	0.785	0.013	0.004	<0.001	<0.001	<0.001
Gender*Treat	0.350	0.024	0.423	0.251	0.591	0.521	0.951	0.138	0.991	0.998
Gender*Genotype	0.287	0.121	0.005	0.094	0.141	0.017	0.945	0.607	0.467	0.931
Treat*Genotype	0.075	0.828	0.568	0.952	0.034	0.898	0.999	0.998	0.756	0.466
Gender*Treat*Genotype	0.375	0.363	0.423	0.566	0.104	0.698	0.940	0.696	0.930	0.868
% CV	21.4	23.4	30.1	29.6	29.4	31.1	29.0	34.8	35.6	26.0

If $P \leq 0.05$, there is significant difference.

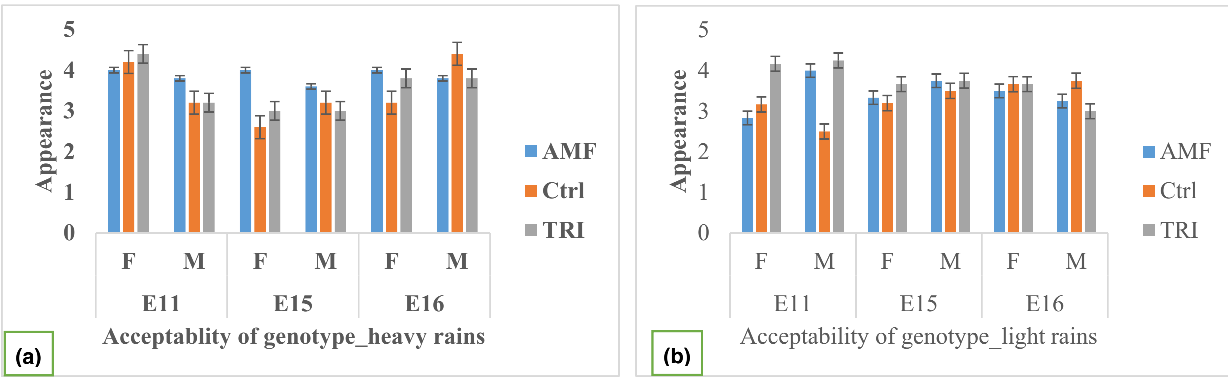

Figure 3 Appearance appeal of *nakati* grown in bio-control-treated soils under different seasons. Error bars represent standard error (SE).

Table 6 Sensory attributes appeal scores of *nakati* genotypes under different treatments, light rain season

		Appearance			Aroma			Bitterness			Flavour			Texture		
Gender	Treat	E11	E15	E16	E11	E15	E16	E11	E15	E16	E11	E15	E16	E11	E15	E16
F	AMF	2.833	3.333	3.500	2.833	3.167	3.500	1.833	3.667	3.167	2.667	3.333	3.000	3.000	3.833	3.000
	Ctrl	3.167	3.333	3.667	2.667	3.500	3.833	2.167	3.000	3.500	2.500	3.000	3.333	2.500	3.667	3.333
	TRI	4.167	3.667	3.667	3.333	4.167	3.833	2.500	3.833	3.833	2.833	3.333	3.833	3.500	3.000	3.500
M	AMF	4.000	3.750	3.250	4.250	4.000	4.250	3.750	3.750	4.500	4.500	3.500	3.500	4.750	2.750	4.250
	Ctrl	2.500	3.500	3.750	3.250	3.500	3.500	2.750	3.500	3.500	3.500	3.500	3.000	3.500	3.500	3.750
	TRI	4.250	3.750	3.000	3.750	3.750	3.500	4.250	3.500	3.750	3.750	3.500	3.250	4.000	2.250	3.250
l.s.d (α = 5%)		0.995			0.632			1.224			1.224			1.258		
c.v %		21.4			23.4			30.1			29.6			29.4		

Key: 1 = very unappealing, 2 = unappealing, 3 = ok, 4 = appealing, 5 = very appealing.
AMF = Arbuscular Mycorrhizal fungi; Ctrl = No bio-control treatment; TRI = *Trichoderma* spp.

appearance (Table 7). E15 was the least appealing to both male and female.

Aroma. Regarding aroma appeal, significant differences ($P \leq 0.05$) were noted for gender bio-control treatment interactions in the light rain season and genotypes in the heavy rain season (Table 5). During light rains, all bio-control treatments were rated higher than the controls. However, AMF-treated samples generally scored lower than TRI-treated samples among males and *vice versa* in females (Table 6; Fig. 4b). Females' appeal was inclined to E15 and E16 compared with E11 with TRI-treated samples more preferred. Males seemed to generally be indifferent in their appeal for all three genotypes (Table 6).

In the heavy rain season irrespective of gender and bio-control treatments (Table 7), genotypes were liked in the order; E16 (mean = 3.8) followed by E15 (mean = 3.5),

Table 7 Sensory attributes appeal scores of *nakati* genotypes under different treatments, heavy rain season

		Appearance			Aroma			Bitterness			Flavour			Texture		
Gender	Treat	E11	E15	E16	E11	E15	E16	E11	E15	E16	E11	E15	E16	E11	E15	E16
F	AMF	4.000	4.000	4.000	2.600	3.200	3.600	1.600	2.600	2.800	2.200	2.600	3.400	2.800	3.200	3.800
	Ctrl	4.200	2.600	3.200	3.200	3.800	4.000	2.800	3.800	4.200	2.000	3.600	3.200	2.400	3.800	3.800
	TRI	4.400	3.000	3.800	3.200	3.400	3.600	1.600	3.800	3.200	2.000	3.000	3.400	2.600	3.200	3.400
M	AMF	3.800	3.600	3.800	3.000	3.600	3.600	2.400	3.600	3.800	2.800	3.200	3.400	3.600	4.000	3.600
	Ctrl	3.200	3.200	4.400	3.400	3.600	4.000	2.600	3.600	4.000	2.400	3.800	3.400	2.800	4.000	4.400
	TRI	3.200	3.000	3.800	2.800	3.400	4.200	3.200	3.200	3.800	2.400	3.600	3.800	3.000	3.800	3.800
l.s.d (α = 5%)		0.995			0.632			1.224			1.224			1.258		
c.v %		21.4			23.4			30.1			29.6			29.4		

Key: 1 = very unappealing, 2 = unappealing, 3 = ok, 4 = appealing, 5 = very appealing.
AMF = Arbuscular Mycorrhizal fungi; Ctrl = No bio-control treatment; TRI = *Trichoderma* spp.

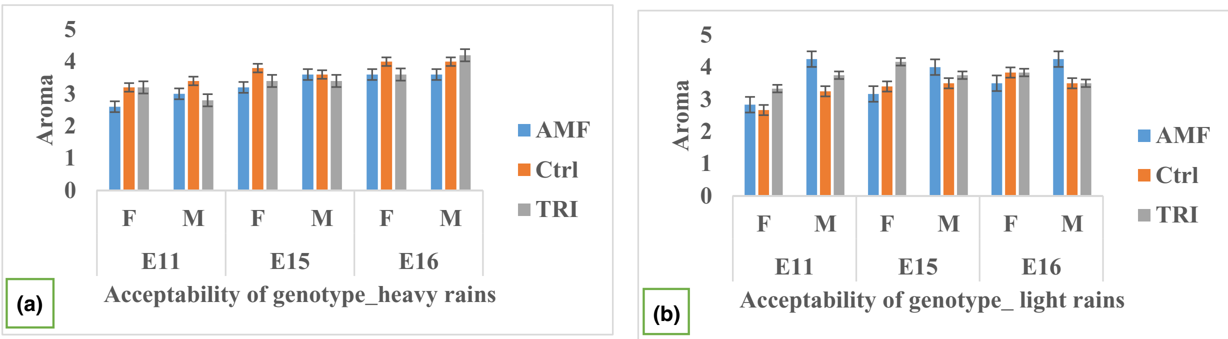

Figure 4 Aroma appeal of *nakati* grown in bio-control-treated soils under two rain seasons. Error bars represent standard error (SE).

and lastly E11 (3.1). A similar trend was observed in Fig. 4a. Results of aroma preference were not significant for gender and bio-control treatments (Table 5).

Bitterness. Significant differences ($P \leq 0.05$) in bitterness appeal were observed due to gender, bio-control treatments, genotypic differences, and gender–genotype interactions during the light rain season (Table 5). During light rains, females preferred TRI-treated E15 (3.8) and E16 (3.8) while males preferred highly AMF-treated E16 (4.5) and TRI-treated E11 (4.3; Table 6). Generally, E15 and E16 were more appealing for both gender compared with E11 for both bio-control treatments during light rains. Generally, bitterness appeal for all bio-control-treated samples was higher than the control except TRI-treated E11 (Table 6).

In the heavy rain season, the only significant differences in the bitterness appeal are expressed by bio-control treatments and genotypes ($P \leq 0.05$; Table 5). Generally, E15 and E16 were more appealing than E11 for all bio-control treatments. Bio-control treatments generally did not show positive appeal for genotypes E11, E15 and E16 with respect to the control, with sensory effect due to AMF being more suppressed except for E11 in females (Fig. 5a). This could indicate that bio-control treatment of soils may not be prioritised during rainy seasons.

Flavour. Regarding flavour, significant differences in flavour appeal were only expressed during the heavy rains in terms of gender and genotype ($P \leq 0.05$; Table 5; Fig. 6a). For both bio-control treatments, samples E15 and E16 were more appealing, with E16 highly scored (Fig. 6a). In comparison with the control, E15 was preferred to E16. All bio-control treatments were scored either comparably or higher than the control with higher scores for TRI-treated samples, except AMF-treated E15 among females (Table 7). Generally, for both bio-control treatments, samples from both seasons scored comparably the same with samples from light rains slightly higher (Tables 6 and 7; Fig. 6a,b).

Texture. Significant differences were noted for genotypes, bio-control treatment interactions ($P \leq 0.05$) irrespective of gender during the light rains season (Table 5). Irrespective of the gender bio-control-treated samples, E11 (3–4.75) was the most appealing followed by E16 (3.0–4.3) and E15 (2.3–3.5) for AMF- and TRI-treated samples (Table 6; Fig. 7a). TRI-

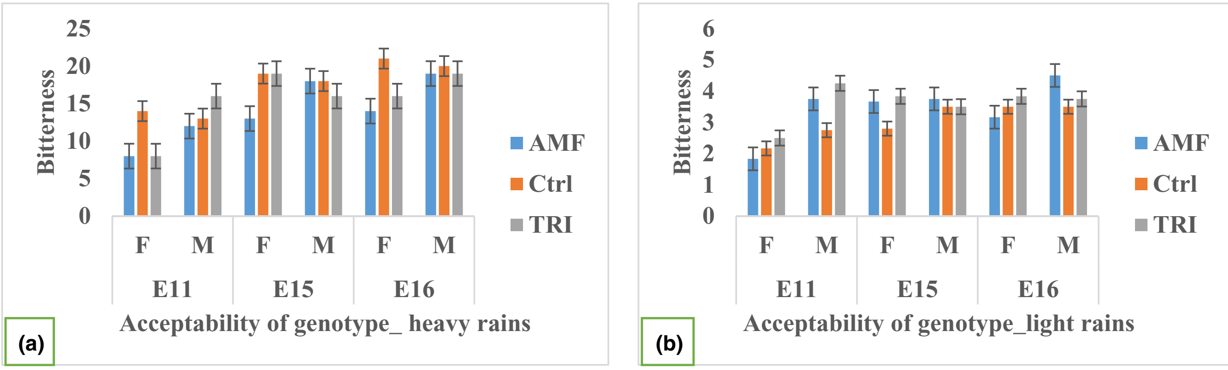

Figure 5 Bitterness appeal of *nakati* genotypes grown in bio-control-treated soils under 2 rain seasons. Error bars represent standard error (SE).

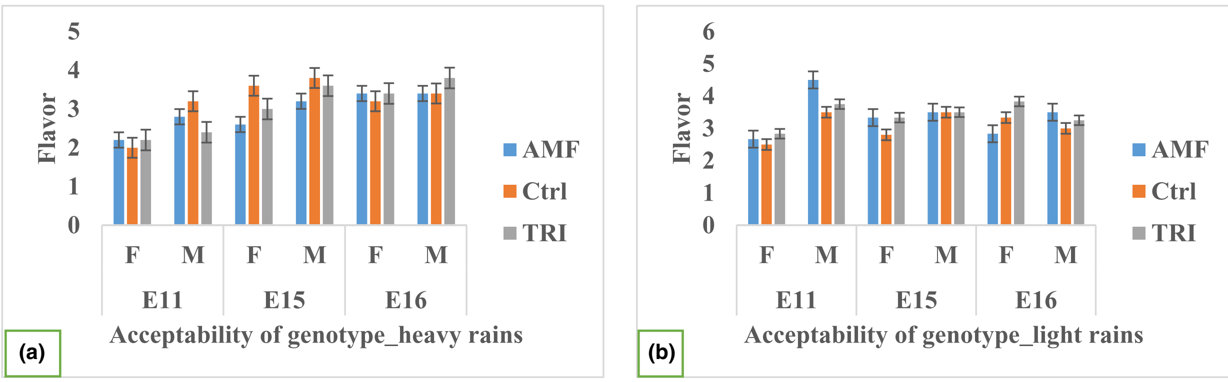

Figure 6 Flavour appeal of *nakati* genotypes grown in bio-control-treated soils under 2 rain seasons. Error bars represent standard error (SE).

treated samples generally scored lower than AMF treated (Table 6; Fig. 7b). It was also observed that the general appeal for the control sample was slightly higher than TRI-treated samples (Fig. 7b).

In the heavy rain season, significant differences ($P \leq 0.05$) were due to gender and genotypes (Table 5), irrespective of bio-control treatments. With respect to gender, among all genotype samples (bio-control treated and control), females generally expressed lower appeal compared with males (Table 7, Fig. 7a). Overall means of genotype sensory preference with respect to texture revealed that E16 (3.8) was most preferred followed by E15 (3.7) and E11 (2.9; Table 7). The results further indicated that TRI reduced the sensory appeal of E15 and E16 with respect to the control for both genders though the relationship was not significant.

Discussion of results

The paper discusses the sensory acceptability results of three *nakati* genotypes (E11, E15 and E16). Results of trader physical acceptability of *nakati* genotypes (control samples) grown in untreated soils during the heavy rainy season (September to November) are discussed. Furthermore, consumer panel sensory results of the three genotypes grown in bio-control-treated soils during the heavy rain period is discussed. Lastly, the manuscript discusses sensory differences expressed by the trained panel for the three *nakati* genotypes (E11, E15 and E16) planted in bio-control-treated soils across two seasons (heavy *versus* light rains).

Trader acceptability of *nakati* genotypes

The genotypes E11, E15 and E16 represented the farmer preferred genotypes due to perceived environmental resilience (Nakyewa *et al.*, 2021). For trader physical acceptability, they were grown in control soils. Familiarity of a food product influences consumer sensory perception and intention to purchase due to judgement based on prior knowledge and experiences about the same product (Tan *et al.*, 2015; Sinesio *et al.*, 2018). Trader judgements about familiar products can therefore be relied upon to predict purchasing decisions due to prior knowledge about their

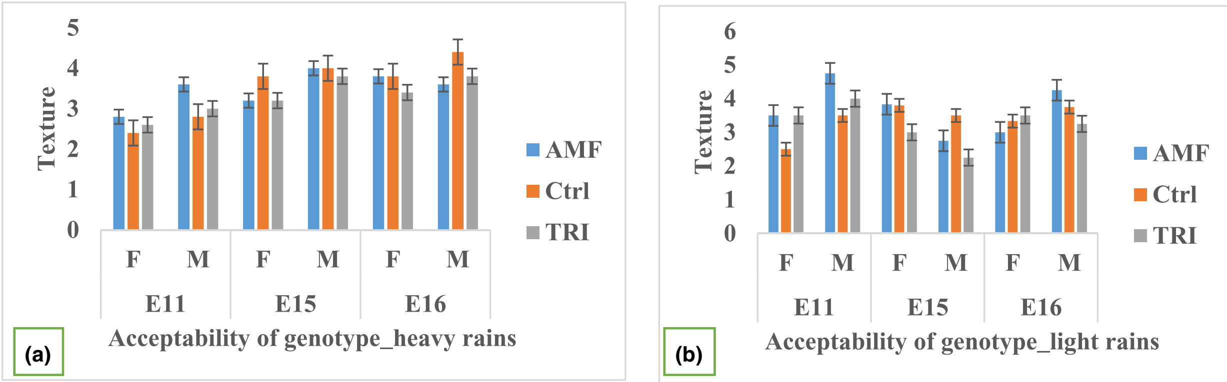

Figure 7 Texture appeal of *nakati* genotypes grown in bio-control-treated soils under two rain seasons. Error bars represent standard error (SE).

own preferences and attributes their customers prefer. Visual cues can be used by consumers to judge the eating quality of food (Endrizzi *et al.*, 2015).

The attributes used in the current study to define the physical quality of *nakati* genotypes encompassed leaf appearance, colour, hardness, size, smoothness, succulence and shininess. Related quality attributes descriptors have been used by Apolot (2018). According to Barrett *et al.* (2010), the aforementioned attributes are considered as the most important descriptors since they define the wholesomeness of most leafy vegetables.

Generally, all *nakati* genotypes were acceptable. The observed significant differences ($P \leq 0.05$) in physical acceptability between the three genotypes (Table 1) could be explained by differences in genetic composition. Although there is limited research about the acceptability of different *nakati* genotypes, differences due to genetics were concluded for vegetables and fruits. For instance, consumers could detect differences in the acceptability of sensory attributes for different strawberry cultivars (Lado *et al.*, 2010; Lado *et al.*, 2019). According to Oliveira *et al.* (2013), physical attributes such as leaf appearance, colour, hardness, size, smoothness, succulence and shininess can further be explained by differences in the water holding capacity of the different genotypes. Therefore, sensory aspects need to be considered in future plant breeding programs for *nakati* to maintain the desirable sensory qualities.

Colour of the three *nakati* genotypes (Table 2) was generally highly scored (4.0–4.4). This could have influenced the acceptance of other quality parameters. According to Hussin *et al.* (2010), over 90% of consumers regard colour as the most important attribute of vegetables. Furthermore, colour of leafy vegetables is an important attribute used to describe aging, mechanical damage, insect damage or any form of stress to the plant (Oliveira *et al.*, 2013). Therefore, traders and farmers should strive to maintain colour quality of fresh leafy vegetables to improve market value.

With regards to leaf size, genotype E11 and E15 was preferred to E11 due to their large leaf size (Fig. 1d). As leaf size increased, there was a noticeable decrease in leaf hardness and *vice versa* (Fig. 1c,d). This could be explained by the firmness exhibited by smaller leaves. Leaf texture could be an important contributor to the mouth-feel of leafy vegetables upon cooking (Leighton *et al.*, 2010). This could therefore explain the moderately high sensory acceptability of E15 and E16 compared with E11 as was expressed by the consumer panel. Therefore, physical quality evaluation is a valuable tool in assessing food acceptability.

Generally all *nakati* genotypes were liked by the traders, with differences in preferences between high-end and low-end markets. Traders in high-end markets like Nakasero were not influenced by the leaf number on the stalk but rather considered other factors that are key in defining *nakati* quality and market value. This could be explained by differences in customers who visit the markets. The type of customers in high-end markets are willing to pay a higher price for quality when compared with those who visit low-end markets (Jagwe *et al.*, 2016). High-end markets are mainly visited by middle to high income and educated customers who value vegetable quality aspects as opposed to the low-end markets (Jagwe *et al.*, 2016). According to Ugur *et al.* (2014), the more income people have, the higher the willingness to pay a high price for quality when compared with quantity. Therefore, quality is more important in high-end markets than low-end markets where quantity is more valued.

While the physical perception of traders has been discussed; it could have been based on their experiences as point of sales contacts, experiences of their customers or their own consumer experiences. The trader physical scores therefore needed to be validated with consumer acceptance. Therefore, there was need to evaluate consumer acceptability of the *nakati* genotypes.

Sensory acceptability of bio-control-treated *nakati* genotypes

Bio-control treatments have increasingly gained importance in agriculture. *Trichoderma* spp. (TRI) and AMF, both soil fungi are natural plant growth stimulators (biostimulants), applied as plant protection practices against adverse growth conditions such as drought, pests and diseases (Szczałba *et al*., 2019). However, there is a need to investigate their effects on sensory aspects of food.

Consumer panel

In this section, the three *nakati* genotypes planted in the heavy rain season in bio-control-treated soil (TRI and AMF) were compared with a control for each genotype.

Generally, results indicate that all genotypes were desirable with E15 and E16 more preferred. The slight difference in acceptability of E15 and E16 could be due to the interaction of genetic and agronomic manipulation (Lado *et al*., 2010; Lado *et al*., 2019). Although consumers could not detect significant differences for the three bio-control-treated *nakati* genotypes in terms of flavour and appearance, there appears to be a slightly significant interaction between gender, appearance and the use of bio-control treatments. This could be as a result of differences in gene expression among the three genotypes due to the bio-control treatments, with AMF appearing to confer a more preferred leaf appearance. With bio-control treatments regulating genes involved in different plant physiological mechanisms such as anti-pathogenicity (Pandit *et al*., 2022), resilience and nutrient availability (Begum *et al*., 2019; Halifu *et al*., 2019), it is not inconceivable that AMF and TRI could affect sensory aspects despite the limited research in this area. Regarding gender differences for leaf appearance, females are reportedly 3.5% more susceptible to visual illusions than males (Shaqiri *et al*., 2018); which partly explains the gender differences. Therefore, there is a need for plant breeders to study the inherent genetic behaviour of plant genes in relation to sensory characteristics.

Bio-control treatments did not separately influence gender sensory perceptions; however, the observed differences in taste of the three genotypes could have been influenced by genetic differences and their interactions with bio-control treatments, which conferred better taste in all genotypes with TRI more preferred (Lado *et al*., 2010; Lado *et al*., 2019) as well as gender differences in taste perception. For instance, it is reported that male and female exhibit differences in brain activation in response to taste stimuli during different physiological states of hunger and satiety (Haase *et al*., 2011). However, this study did not consider differences in physiological states of the panellists. Therefore, TRI treatment can be recommended due to its desirable effects on taste of E15 and E16.

Notably, the only significant differences ($P \leq 0.05$) in mouth-feel could be due to genotypic differences (Lado *et al*., 2019), not related to gender and bio-control treatments (Table 3). Both TRI and AMF had a similarly positive impact on E11 probably due to differences in gene expression (Lado *et al*., 2010; Lado *et al*., 2019; Szczałba *et al*., 2019). Therefore, as far as mouth-feel is concerned, farmers could only need bio-control treatments for E11.

According to Piqueras-Fiszman & Spence (2015), sensory characteristics of food such as taste, texture, aroma and appearance have distinct and influential effects on acceptability. In a variety of ways, sensory characteristics of food are considered key areas in which food introduction on market can be successfully used to differentiate the quality. Generally, TRI-treated genotypes of E15 and E16 were more preferred by consumers. Both bio-control treatments enhance water uptake by the plants and stimulate growth, however, having planted the *nakati* genotypes during the heavy rain season, other factors such as pathogen resistance conferred by TRI could also explain why TRI-treated genotypes were preferred (Szczałba *et al*., 2019). Therefore, there was a need to investigate further the effect of different rain seasons.

Trained panel

Leaf appearance. As far as leaf appearance (light rains) is concerned, bio-control treatments (TRI and AMF) improved acceptability of all samples, with TRI-treated E15 and E16 generally more preferred, however males did not like E16. Females are known to be 3.5% more susceptible to visual illusions when compared with males (Shaqiri *et al*., 2018), hence male dislike of E16 due to leaf size cannot be ignored. Bio-control treatments are known to exhibit bio-stimulatory effects during adverse growth conditions such as water stress (Szczałba *et al*., 2019). Such effects include better water and nutrient uptake (Begum *et al*., 2019; Halifu *et al*., 2019) which could have increased leaf succulence. Additionally, TRI confers anti-pathogenicity (Pandit *et al*., 2022), which could have provided healthier growth conditions resulting in a better appearance than AMF-treated samples.

In the heavy rain season, bio-control treatments did not have significant effects on acceptance; while the gender-related deviation has been discussed (Shaqiri *et al*., 2018), with some differences attributed to differences in gene-specific interactions with the bio-control treatments (Szczałba *et al*., 2019).

Aroma. Regarding aroma, females have better taste and flavour sensitivity (Michon *et al*., 2009) which contributes to better aroma perception. It is also been reported that males and females exhibit differences in brain activation in response to taste stimuli during different physiological states of hunger and satiety (Haase *et al*., 2011). However, this study did not consider differences in the physiological states of the panellists.

During light rains, all bio-control treatments proved effective at reducing the production of water stress-induced phenolic aroma compounds (Fellman *et al*., 2000; Fellman *et al*., 2003), the level of which was also influenced by differences in genotype bio-control treatment associations (Szczałba *et al*., 2019); with genotypes E15 and E16 treated with TRI generally preferred. Bio-control treatments may not be needed during the heavy rains season since no significant effects on aroma were observed.

Bitterness. Regarding bitterness, females reportedly have a higher sensitivity to bitterness and sweetness than males (Michon *et al*., 2009; Koubaa & Eleuch, 2020). The results of the bio-control treatments generally imply that the female panellists could have found AMF-treated E15 and E16 more bitter and less desirable during light rains; hence their low scores when compared with the male.

Despite *nakati* being expected to be bitter, extreme bitterness could be related to poisonous foods significantly reducing palatability (Sharif *et al*., 2017). During light rains, water stress could have led to the production of bitter phytochemicals to develop resilience against environmental stress (Dinehart *et al*., 2006) which is also influenced by genotypic differences (Szczałba *et al*., 2019). Results also imply that TRI conferred better protection against water stress than AMF during the light rains season.

Bio-control treatments performed negatively during the heavy rains, with AMF-treated samples more affected. Effects of TRI and AMF are still unpredictable in different environmental conditions (Szczałba *et al*., 2019), however, AMF suppression could be attributed to antagonistic bacteria that suppresses its growth and root colonisation; for instance, *Acidobacteria* are known to be putative fungal antagonists (Svenningsen *et al*., 2018); while the absence of water stress favoured the growth of the control samples. More research is needed regarding the effect of bio-control treatments on taste under different conditions such as amount of bio-control treatment inoculant.

Generally, genotypes E15 and E16 were preferred to E11. For panellists who chose E11 despite extreme bitterness, their choice could probably be explained by natural personal/individual differences in the sense of taste or personal preferences developed over time (Cho *et al*., 2016; Wanjiru, 2018). However, E11 treated with bio-control treatments had better taste than the controls. Hence a change in taste of food can have a relatively large effect on its acceptability (Romagny *et al*., 2017) due to the effect on palatability. This explains why E11 when grown in soils treated with TRI and AMF during the light rain seasons was highly acceptable compared with *nakati* grown in non-treated soils.

Flavour. Regarding flavour, females have a high odour reaction than males (Michon *et al*., 2009; Koubaa & Eleuch, 2020); while differences in genetic composition (Szczałba *et al*., 2019) were also evident in terms of flavour explaining why E15 and E16 were more preferred. The influences of genotype and growing conditions (bio-control treatments) on compounds that serve as precursors for phenolic production are critical factors that determine the ultimate levels of bitterness, aroma and flavour in agricultural produce (Fellman *et al*., 2000; Fellman *et al*., 2003, Szczałba *et al*., 2019). It is therefore possible that both TRI and AMF were effective at reducing the production of water-stress related bad flavour, hence the reason why results in both heavy and light rain seasons were comparable with TRI-treated samples generally having better flavour in E15 and E16.

Texture. Texture is expressed in form of food attributes such as crunchiness, firmness, and smoothness (Tauferova *et al*., 2015). Regarding texture (light rains), genotypic differences influenced the effect of bio-control treatments on texture (Szczałba *et al*., 2019); with AMF-treated samples more preferred than TRI-treated samples. While TRI-treated E16 and E15 were most preferred for most parameters, light rain grown E11 treated with AMF had the most preferred texture irrespective of gender. Generally, consumers prefer cooked vegetables that are chewy due to a more fulfilling effect (de Barros & Cardoso, 2016), but not woody. Consistent with appearance, TRI made *nakati* samples more succulent and less chewy when compared with AMF. It is not clear why TRI (E16 and E15) and AMF (E15) were less liked than the controls, hence there is a need to optimise TRI and AMF soil inoculation for better texture, during light rains.

Furthermore, irrespective of gender/personal differences; food texture affects orosensory exposure time of food. The harder the texture, the more chewy and hence the longer the orosensory exposure time of food.

Longer orosensory exposure time combined with perceived fullness/satiety reduces eating rate and food intake (Bolhuis *et al.*, 2011; de Barros & Cardoso, 2016). This could be an important aspect of nutrition for the prevention of diabetes and cardiovascular diseases since vegetables are normally eaten with other foods.

On the other hand, during heavy rains, the level of liking for texture was influenced by gender differences (Michon *et al.*, 2009) and *nakati* genotypic differences (Szczałba *et al.*, 2019) with E16 and E15 preferred. Oral stereognosis tests performed by Michon *et al.* (2009) revealed that females perform better than males as far as sensitivity to different oral textures is concerned, despite males having a higher chewing ability. While effects of bio-control treatments were not significant during heavy rains, similarly TRI-treated samples were liked less than the controls.

Conclusion

Trader acceptability of *nakati* in high-end and low-end markets as reflected in this study indicated that Nakasero market was very strict on quality regardless of the number of leaves on the stalk thus rating E11 as quality *nakati*. However, the low-end markets like Busega and Kasubi were not much strict on quality but preferred quantity as they demanded *nakati* with the highest number of leaves on the stalk thus choosing genotypes E15 and E16.

Regarding consumer sensory acceptability, men are less sensitive to the bitterness of *nakati*, whereas women are highly sensitive to the bitterness which also influences their perception to flavour and aroma. E11 was therefore rejected on basis of bitterness by women. Treatment with TRI seemed to enhance the sensory acceptability of *nakati* genotypes when compared with AMF. It is therefore important to optimise treatment with TRI for enhanced quality *nakati* with less expression of bitterness. The use of bio-control treatment during the heavy rain season does not have a significant impact on the quality of *nakati*, it could therefore be economical to use bio-control treatments during dry seasons or light rains to enhance the sensory acceptability of *nakati*.

Providing physically appealing *nakati* to markets and palatable *nakati* to consumers is likely to increase consumption of these healthy vegetables and uptake for commercialisation. To achieve this goal, future research and development efforts should focus on addressing the drivers of trader and consumer acceptability.

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Author contributions

Mulindwa Joseph: Conceptualization (lead); data curation (equal); formal analysis (lead); methodology (lead); visualization (lead); writing – original draft (lead). **Sseremba Geoffrey:** Data curation (equal); formal analysis (equal); supervision (lead); writing – original draft (supporting). **Bbosa Tom:** Data curation (supporting); validation (supporting); writing – review and editing (equal). **Nakanwagi Mildred Julian:** Data curation (supporting); writing – original draft (supporting). **Musubire Brian Justus:** Data curation (supporting); methodology (supporting); writing – original draft (supporting). **Nahamya Pamela Kabod:** Data curation (supporting); writing – review and editing (equal). **Gerard James Bishop:** Investigation (lead); project administration (lead); resources (lead); supervision (equal). **Kizito Elizabeth Balyejusa:** Funding acquisition (lead); project administration (lead); resources (equal); supervision (lead); writing – review and editing (lead).

Conflict of interest

The authors have no conflict of interest to declare.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethical considerations

Ethical approval was not required for this research.

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