# Using economic selection index for trait prioritization in sweetpotato target product profiles in Eastern Africa

Julius J. Okello, Robert O.M. Mwanga, Bernard Yada, Reuben Ssali, Guy G. Hareau, Hugo Campos

## Abstract

This brief reports an approach that relies on market intelligence gathered from a broad spectrum of breeding program customers, taking market forces into account when computing trait economic selection indexes (ESI). The ESIs generated are then used to prioritize the traits pursued in the breeding program. The pilot study targeted the white-, orange-, and purple-fleshed market segments in the Lake Victoria crescent in Eastern Africa—a region that faces high virus pressure. Along with virus protection, target product profiles (TPPs) designed for these segments emphasize agronomic traits and nutritional enhancement (with vitamin A and anthocyanins). The ESI findings stress the heterogeneity of actors with divergent needs, underscoring the importance of trait prioritization in TPPs based on market forces and employing systematic market intelligence to understand trait preferences of market segment actors/participants.

## Key Points

- Sweet potato breeding in Eastern Africa targets three market segments with diverse actors/customers, including farmers, consumers, traders, and processors.
- The TPPs designed for the market segments of white-fleshed sweet potato, orange-fleshed sweet potato, and purple-fleshed sweet potato embody a wide range of essential and desirable traits.
- An ESI approach systematically crowdsources trait preferences from value chain actors to prioritize traits included in the TPPs.
- Prioritization of traits in sweet potato using the ESI approach revealed strong heterogeneity of requirements for sweet potato seed products—notably, yield for farmers, root shape for traders, and shelf life for consumers.
- The ESI approach highlights under-emphasized traits to monitor and prioritize in the future.

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## Introduction

This brief presents a pilot study that focused on traits that should comprise the target product profile (TPP) for sweet potato breeding targeting Central Uganda and the Lake Victoria Crescent region. Breeding for this area targets all three market segments in which sweet potato farmers and other value chain actors in the region take part: (1) white-fleshed sweet potato (WFSP) for home consumption and fresh markets; (2) orange-fleshed sweet potato (OFSP) (Vitamin A biofortified) for home consumption, fresh markets, and local processing; and (3) purple-fleshed sweet potato (PFSP) for home consumption and fresh markets.

The major production constraint in the region is sweet potato virus disease (SPVD) which causes up to 80 percent yield losses. Breeding in the region for these segments thus prioritizes SPVD resistance. The TPPs linked to these segments also focus on yield and resistance to sweet potato weevil among 18 essential traits, besides other desirable traits such as ease of peeling, skin color, and growth habits. The current WFSP TPP prioritizes yield maintenance and quality traits (taste, sweetness, mealiness) that consumers in this market segment want and abiotic as well as biotic traits (pest and disease resistance, drought tolerance), agronomic traits (germination/establishment, root storage) that farmers want, and postharvest traits (shelf life) that farmers and traders/processors in the segment want. The OFSP and PFSP TPPs have greater focus on nutritional traits (vitamin A and anthocyanin enrichment) that vulnerable farm and non-farm households participating in these segments need/should have, while maintaining yield, agronomic, and other quality traits.

To date, the selection of traits that constitute sweet potato TPPs in the three market segments has relied on subjective judgement of which traits are essential and desirable. The approach used in the pilot study uses economic forces of supply and demand to prioritize the selection of traits to include in the TPPs. We report the findings of that pilot drawing from a study implemented in Central Uganda by a cross-disciplinary team, including socio-economists, seed systems specialists, and breeders. Uganda hosts the Eastern Africa sweet potato breeding platform, which influences breeding decisions and activities in the entire region. Design of the Uganda breeding program thus reflects the trait selection decisions prioritized in the rest of Eastern Africa's three market segments. In the following sections, we briefly describe the approach, summarize findings, and draw lessons.

## Methods

### *Economic selection index*

The ESI approach combines modelling of trait-specific economic values with the investigation of farmers' preferences for specific sweet potato traits and the sociodemographic characteristics to generate trait ESIs. Specifically, the method develops trait weightings presented in monetary units. These units infer a marginal economic value (profit) for a change in a specific trait unit. Such changes in the trait units can be driven by the associated costs and revenues. The method therefore integrates both economic (prices and values) and non-market (sociodemographic) drivers in ranking traits. The ESIs are then used to prioritize the traits or trait combinations that should be pursued by the breeding program. The approach was first applied to livestock (Martin-Collado 2015) and has recently been applied in sweet potato, cassava, and rice (Okello et al. 2022; Balogun et al. 2022; Tarjem et al. 2023).

### *Implementation of ESI*

ESI is data intensive given the need to gather market intelligence from across the entire value chain (from the lab to the table) and it relies on both qualitative and quantitative information-gathering techniques. The steps involved in gathering data used in the sweet potato case are illustrated in Figure 1 and subsequently described.

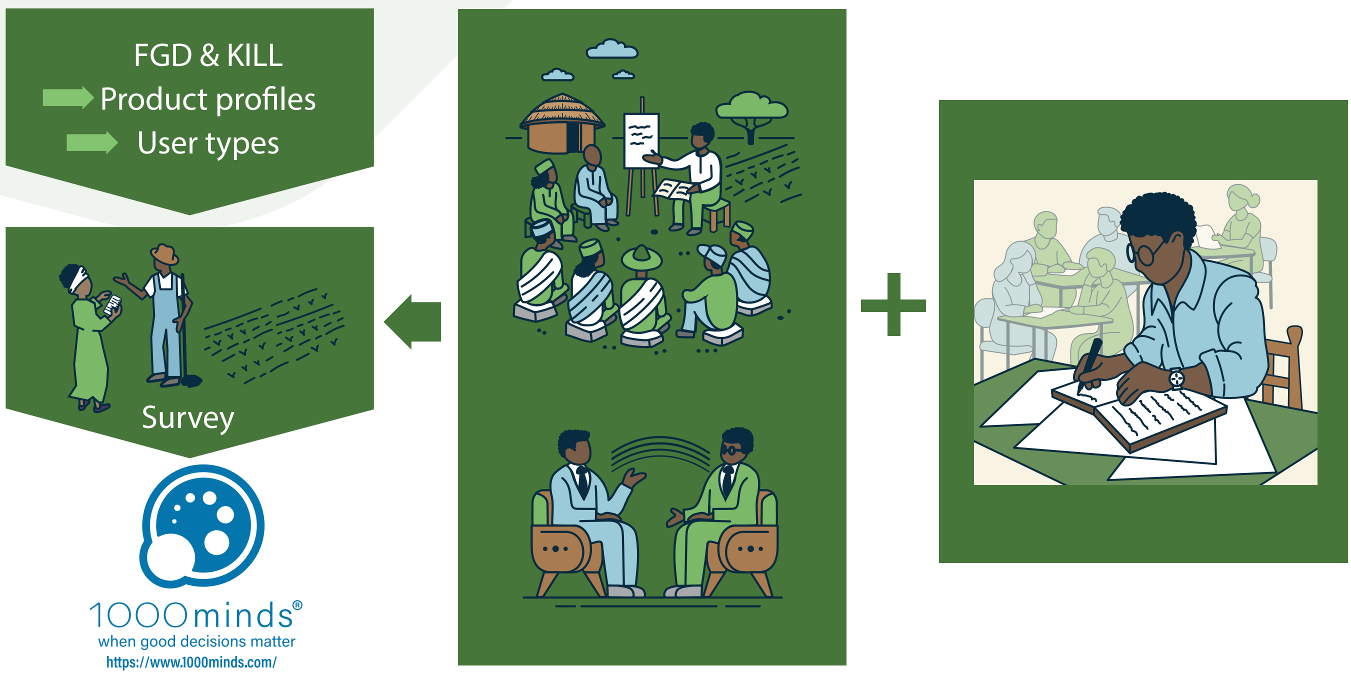


**Figure 1. Steps in the collection of data for economic valuation of varietal traits using ESI.**

**Step #1:** Preparatory. A research team conducted a literature review to gain a clear understanding of the breeding focus (objective, traits to pursue, customer focus) and actors in the value chain. The latter involves mapping the different actors that directly and/or indirectly benefit from the breeding program. A preliminary list of traits important to value chain actors was drawn based on the literature. Then a questionnaire/tool was drafted to elicit additional traits and trait preferences, desired levels of change, and economic equivalences and the needed/desired improvements.

**Step #2:** Stakeholder workshop. Stakeholders from the entire value chain were invited to a one-day workshop convened in a central location. Care was taken to ensure representation of all relevant actors in the value chain. For sweet potatoes, these included: sweet potato breeders, early generation seed producers, seed inspectors, community seed producers/multipliers, industry (seed/root traders) association representatives, root producers, rural assemblers/aggregators, traders (wholesalers, retailers, exporters), processors, and consumers. Providers of services that facilitate transportation of roots to the market were also invited. After an explanation of the purpose of the workshop, the actors were grouped by category. Breakout groups identified traits of relevance, desired levels, desired improvement, and rank of each relevant trait relative to others (Table 1).

The elicitation process was structured as focus group discussions, each led by one research team member. Notes were recorded into predesigned templates for ease of capture. The consumer group included all participants involved in various value-chain-actor groups, thus extending beyond root producers. Moreover, consumption as boiled roots and intermediate and processed products were identified, and data gathered for respective consumer types. The workshop participants were then split by gender, and traits preferred by women and men were noted/identified, discussed, and ranked (Figure 2). Overall, the discussions in each group were designed to capture trait preference and ranking by value chain actors at different nodes and by consumer and gender types.

**Step #3:** Root processing and market trader consultations. Processing and value addition takes place mostly for OFSP and can be at group level or industrial level, with the latter still nascent. During this step, a consultant consulted a community group that processed OFSP roots into an assortment of baked products (Figure 3) and traits desired by the group for processing were identified and defined/described. Since traders, especially retailers, are "consumer-facing" value chain intermediaries, informant interviews held with individual market traders focused on traits that facilitate trade, i.e., making a variety marketable and profitable.

**Step #4:** Trait identification to finalization of data collection protocol. The research team synthesized information from the stakeholder workshop, focus group discussions, and informant interviews. All traits were listed by various actor groups to generate a full list of breeding traits. Trait definitions, equivalences, and direction of desired improvement were discussed with the breeders and socio-economists. The final list of traits for the survey was limited

**Table 1. Trait elicitation, definition, and performance measure.**

| Trait | Most Common measure of change | Desired direction of change | Average Performance | Very good performance | Very bad performance |
|---|---|---|---|---|---|
| Yield | Tonnes | More | 4 t/ha | 20 t/ha | 0 t/ha |
| Maturity | Time to maturity | Less | 5 months | 4 months | 7 months |
| SPVD | Score | Less | Mildly infected | Not infected | Very sick |
| Mouth feel | Score | More | Moderately dry mouth feel | Dry mouth feel | Moist mouth feel |
| Flesh color | Color intensity | N/A | N/A | N/A | N/A |
| SP W | Score | Less | Mildly infected | Not infected | Very sick |
| Uniformity in shape | Percentage uniformity | Oval to oblong | Less number of irregular | Regular and uniform shape | Irregular shape |
| Size | Appearance | medium | Medium | Medium | Too small/too large |
| Number of marketable roots per plant | Count | More | 2 roots | 5 roots | 0 roots |
| Vine vigor | Number of bags per acre | More | X number of bags | X umber of bags | X number of bags |
| Shelf life | Time to decay | More | 4 days | 7 days | 2 days |
| Number of stems per plant | Count | More | 2 stems per plant | 4 stems per plant | 1 stem per plant |

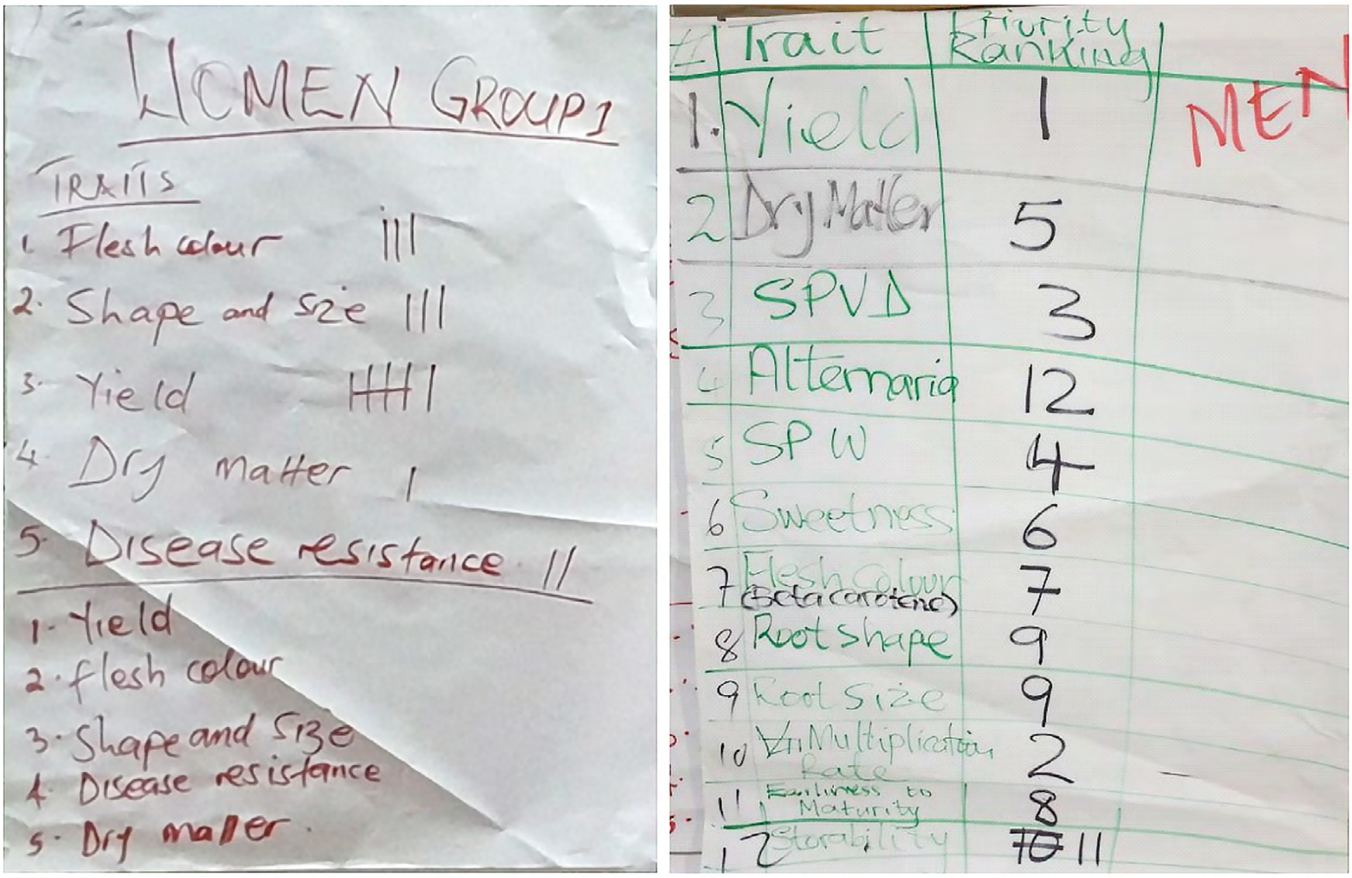


Figure 2. Gendered sweet potato trait preference ranking.


Figure 3. OFSP processed products produced by a community group in Uganda.

to 13—dictated by the capacity of ESI software. This list of traits was fed into the final tool, programmed in 1000minds software, used for field data collection. This step ended with a discussion of sampling procedure and the generation of sampling frame.[1] The sweet potato study interviewed 1,000 farmers, 147 consumers, 134 traders, and 52 vine multipliers. Traders and consumers were recruited in the market, with consumers randomly selected at the point of purchase.

**Step #5:** Field data collection. Data were collected, in real time, by a team of trained enumerators from each major value-chain-actor group. The 1000minds software required an active internet connection, which necessitated stationing data collection points in locations with internet signals. Separate trained teams collected data from farmers and market-based actors (traders and consumers). Trait preference elicitation was based on the conjoint analysis principle (Martin-Collado et al. 2015). The respondent chooses, each time, between two traits, with an option of "they are equal" (Figure 4). Pairwise comparison of traits has the advantage of substantially reducing the cognitive burden on the respondents (Okello et al. 2022).

**Step #6:** Data analysis. Principal component analysis (PCA) and cluster analysis (CA) were used to create homogeneous groups (i.e., clusters) of respondents based on trait preferences. The clusters were defined for each actor type. Trait economic values were calculated according to the preference (percent) for each trait relative to the preference (percent) for the trait expressed in monetary terms in the survey the price per 100 kg bag.[2] In this sweet potato study, the economic value per trait unit was calculated to reflect a unit change in the trait. Economic value of a trait in breeding program units ($EV_{BP}$) was then calculated by multiplying the economic value of a trait in survey units ($EV_S$) by the unit transformation (*ut*), i.e., $EV_{BP} = EV_s \times ut$. Details of the computations are in Okello et al. (2022).

## Findings of the pilot study

### *Trait preferences*

Figure 4 presents preferences for varietal traits based on simple subjective ranking for the full sample of respondents. The three most preferred traits are vine survival, weevil resistance, and sweet-potato-virus disease resistance. Vine survival was especially highlighted in the context of the establishment of seed vine under drought conditions. Its relevance arises from the current rainfall variability due to climate change that is expected to worsen. Notably, this trait still does not feature in the current white-, orange-, and purple-fleshed market segment's TPPs as an essential trait and was not prioritized in the breeding program. It is currently "monitored in the clone selection given increasing importance" (Reuben Ssali, sweet potato breeder, pers com; 26 October 2023; Email – r.ssali@cgiar.org). The distribution of responses (grey dots) highlights the variation in preferences among respondents within traits. The wide variation indicates that trait preferences are strongly heterogenous: actors in the respective market segments have different trait preferences. For instance, producers, as expected, prioritized root yield, virus-resistance vine survival, weevil resistance, and root storage shelf life. Interestingly, though the breeding program placed much emphasis on yield, it was prioritized below the other traits mentioned. For consumers, some of known quality traits such as root color (proxy for vitamin A enhancement), hardness, and sweetness were ranked low, contrary to expectations and the literature (Mwanga et al. 2020). This could be because of study design issues discussed in Okello et al. (2021). The study also found that traders had a strong preference for root shape. While included in the current TPPs as an essential trait, roots shape has been seen from the perspective of the consumer and in relation to ease of peeling. For the traders, root shape relates to packing and filling of the bags. Traders,


**Figure 4. Pairwise presentation of varietal traits during elicitation trait preferences using the 1000minds software.**

[1] This was only possible for farmers. Traders and consumers were sampled using systematic random sampling, while all processors and vine multipliers were interviewed because of their small numbers.

[2] Byrne et al. (2012). A preference-based approach to deriving breeding objectives: Applied to sheep breeding. Animal 6(5):778–788.

including transporters, play key roles as intermediaries in the value chain and in moving produce through it. Root storage shelf life is especially critical, under commercial processing, to ensure that quality and integrity of the roots do not deteriorate rapidly in holding/storage conditions and therefore smooth inventory over the seasons.

Cluster analysis revealed three cluster types of actors (CTAs): (1) CTA1—the "productive output" group—prioritizes root yield, vine yield, and storage shelf life; (2) CTA2—the "plant robustness" group—prioritizes virus resistance and weevil resistance; and (3) CTA3—the "root quality" group—prioritizes root flesh color , hardness/firmness of cooked roots, flesh sweetness, skin smoothness, and root size, providing further evidence of the heterogeneity of preferences.

The standard univariate analysis confirmed the distinct patterns of trait preference across clusters (Table 2). Respondents in CTA1 and CTA2 clusters had higher preference (relative to CTA3) for agronomic traits, while those in the CTA3 had greater preference for root-quality traits.

Table 3 presents economic values of individual traits computed using the ESI. Columns 1–3 present the economic values of traits in survey units ($EV_S$), unit transformation (*ut*) coefficients, and economic values of traits in breeding program units ($EV_{BP}$), respectively, for the full sample. The $EV_{BP}$ (columns 3– 6) are based on several assumptions, hence illustrative. They are, however, projected at a national level and no longer apply only for the central region. Thus, the computations are more reflective of the market segments at a country level and easily extrapolate to the Eastern Africa region.

They represent the weights that would be applied to estimates of genetic merit (i.e., breeding values or trait means) to rank varieties on the index. Thus, in column 3, the economic value of flesh sweetness in breeding program units ($EV_{BP}$) equals Uganda shillings (UGX) 4,738 (approximately US $1.3: 1 UGX = 0.00027 USD) per score.

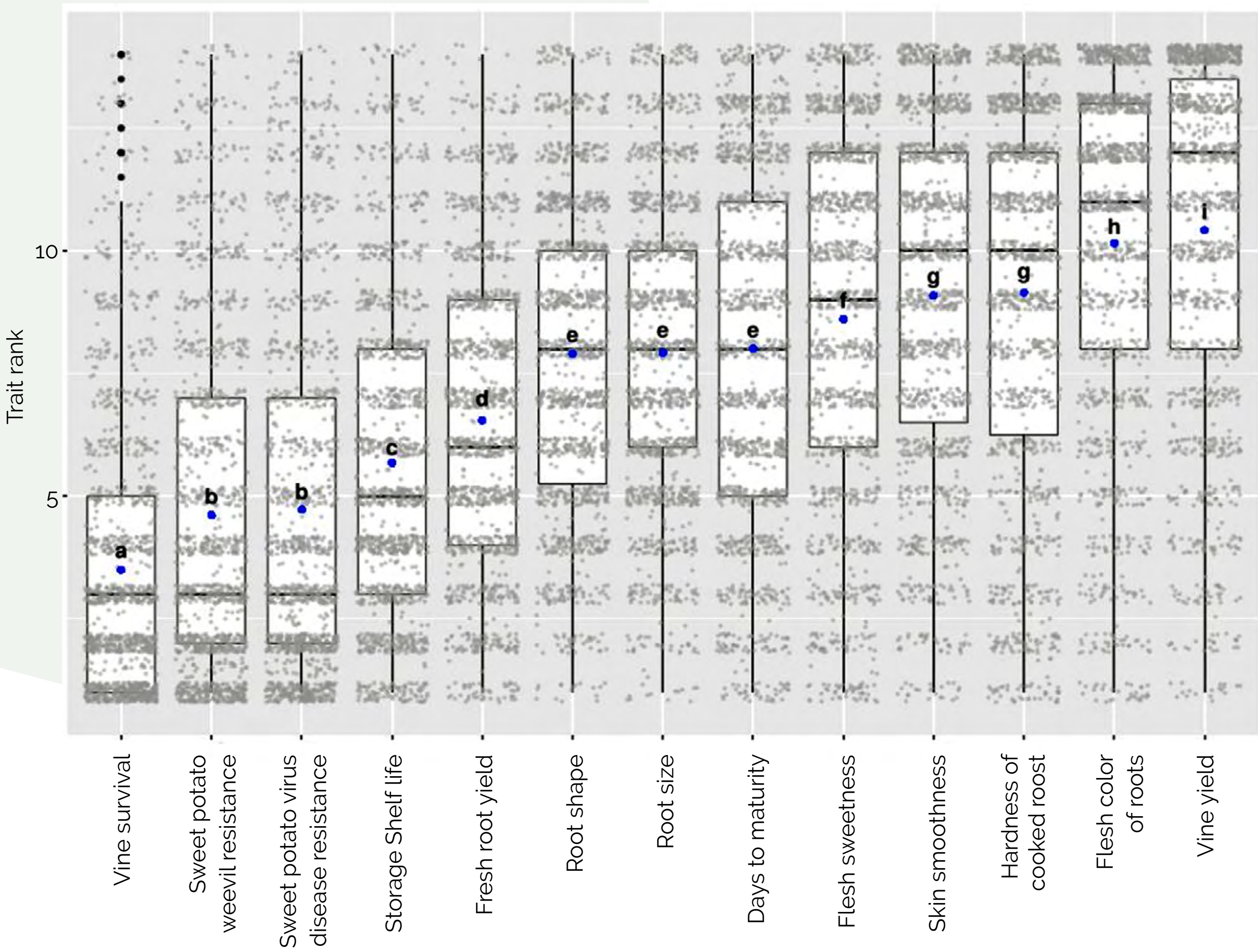


**Figure 4. Trait preference ranks of sweet potato traits based on subjective ranking;** *Source:* Okello et al. (2022).

**Table 2. Average trait preference ranks, by cluster.**

| Trait | Average preference rank[1] | | | | |
|---|---|---|---|---|---|
| | All CTA | CTA1 (n=686) | CTA2 (n=450) | CTA3 (n=187) | p-value |
| Vine survival | 3.50 | 2.99[a] | 3.06[a] | 6.48[b] | $<2x10^{-16}$ |
| Sweet potato weevil resistance | 4.61 | 4.31[a] | 3.15[b] | 9.23[c] | $<2x10^{-16}$ |
| Sweet potato virus disease resistance | 4.73 | 4.27[a] | 3.09[b] | 10.32[c] | $<2x10^{-16}$ |
| Storage shelf life | 5.67 | 5.06[a] | 6.56[b] | 5.85[c] | $6.1x10^{-14}$ |
| Fresh root yield | 6.54 | 5.61[a] | 7.81[b] | 6.91[c] | $<2x10^{-16}$ |
| Root shape | 7.90 | 8.38[a] | 7.53[b] | 7.02[b] | $7.4x10^{-9}$ |
| Root size | 7.92 | 8.22[a] | 7.98[a] | 6.76[b] | $6.3x10^{-8}$ |
| Days to maturity | 8.01 | 5.86[a] | 10.46[b] | 10.05[b] | $<2x10^{-16}$ |
| Flesh sweetness | 8.61 | 10.22[a] | 7.63[b] | 4.96[c] | $<2x10^{-16}$ |
| Skin smoothness | 9.09 | 10.51[a] | 8.29[b] | 5.83[c] | $<2x10^{-16}$ |
| Hardness of cooked roots | 9.15 | 10.87[a] | 8.28[b] | 4.90[c] | $<2x10^{-16}$ |
| Flesh color of roots | 10.14 | 11.43[a] | 10.08[b] | 5.57[c] | $<2x10^{-16}$ |
| Vine yield | 10.42 | 9.44[a] | 11.60[b] | 11.24[b] | $<2x10^{-16}$ |

[1] Preference ranks are sorted from most (first row) to least preferred across groups. Hence, a lower rank means the trait is more preferred. The traits that differ significantly between group(s) are either highlighted green (= most preferred) or red (= least preferred). Different letters indicate statistically significant (p-value<0.05) differences between the group(s).

*Source*: Okello et al. (2021).

**Table 3. Economic values of traits in survey units ($EV_S$), unit transformation factors (*ut*), and in breeding program units ($EV_{BP}$) for sweet potato traits.**

| Trait | | | Economic selection index | | | |
|---|---|---|---|---|---|---|
| | $EV_S$ | *ut* | $EV_{BP}$ | $EV_{BP}$ CTA1 index | $EV_{BP}$ CTA2 index | $EV_{BP}$ CTA3 index |
| Vine survival (%) | +2,285 | +1.00 | +2,285 | +19,183 | +26,196 | +22,371 |
| Sweet potato weevil resistance (1–9 score) | -2,078 | +12.50 | -25,975 | -5,687 | -8,842 | -6,015 |
| Sweet potato virus disease resistance (%) | -2,043 | +1.00 | -2,043 | -1,901 | -2,912 | -1,435 |
| Storage shelf life (week) | +1,111 | +7.00 | +7,777 | +6,594 | +8,008 | +11,480 |
| Fresh root yield (tons/ha) | +5,748 | +4.05 | +23,261 | +64,157 | +71,658 | +105,394 |
| Root shape (1–9 score) | +419 | -12.50 | -5,238 | -2,384 | -3,674 | -5,573 |
| Root size (1–9 score) | +427 | -12.50 | -5,338 | -2,631 | -3,955 | -6,408 |
| Days to maturity (days) | -1,165 | +1.00 | -1,165 | -3,737 | -2,734 | -3,194 |
| Flesh sweetness (1–9 score) | +10,661 | +0.44 | +4,738 | +3,570 | +7,702 | +14,495 |
| Skin smoothness[1] | +9,595 | - | - | - | - | - |
| Hardness of cooked roots (1–9 score) | +10,143 | +0.50 | +5,072 | +3,111 | +6,999 | +15,305 |
| Flesh color of roots (1–30 score) | +8,578 | +0.14 | +1,183 | +4,160 | +8,245 | +21,492 |

[1] Breeding program trait definition/unit was not available, hence not included in the calculations.

## Conclusions

The ESI approach presents a new and non-subjective approach for prioritizing traits to include in the TPPs. It demonstrates that breeding for customers across the value chain has different rankings of the traits than subjective ranking, which elevates yield above all other traits in the TPPs. Uganda, as the host of the Eastern Africa sweet potato breeding platform, continues to influence breeding program decisions and activities for the three market segments serving the region. The region's breeding programs focus on virus resistance as the main constraint, with 18 additional essential traits and three desirable traits in the TPPs. Screening clones for these traits have resource (financial and time) implications and it can be easy to ignore (or underinvest in) some traits. This pilot study shows a subjective ranking of traits in TPPs not only ignores market forces but is also non-comprehensive and can be erroneous. For instance, subjective ranking prioritizes root shape over yield for traders, key value chain actors who determine whether roots ever reach the off-farm consumers. It also gives precedence to root storage over yield for consumers, with clear implications.

Four key messages arise from the ESI approach and this pilot study: first, to be successful in understanding actors' trait preferences in the three market segments, it is important to ask them what they want in sweet potatoes (i.e., the bundle of traits to embody in sweet potatoes). Second, trait preferences are not homogenous within the market segments—there are distinct actor groups with preference for specific combination or a basket of traits, which can be niche markets. Third, subjective ranking of traits masks the real trade-offs breeders must make when comparing traits with market insights in mind. Fourth, hitherto underemphasized traits—notably vine survival, root storage shelf life, and root shape—are traits to monitor in the future.

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**Julius Okello** is an agricultural economist and impact assessment specialist at the International Potato Center.

**Robert O.M. Mwanga** is a plant breeder, formerly with International Potato Center, and a World Food Prize Laureate.

**Benard Yada** is a plant breeder-geneticist and senior research officer at the National Crops Research Institute, NARO, Namulonge, Uganda.

**Reuben Ssali** is a plant breeder and associate scientist at the International Potato Center.

**Guy Hareau** is an agricultural economist and principal scientist with the International Potato Center.

**Hugo Campos** is a plant breeder and deputy director general for science and innovation at the International Potato Center.

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