Contributed paper

TRAIT PRIORITISATION METHODS USED IN ANIMALS ALSO WORK IN PLANTS

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SUMMARY

We applied methods used successfully in prioritising trait improvements in animal breeding to cassava, to demonstrate that they are also relevant to plant breeding. Preference survey methodology based on 1000minds® was adapted and utilised to assess cassava trait improvement preferences of smallholder cassava farmers and other actors in the cassava value chain. We then establish how preference surveys can be employed to quantify and translate preferences into terms (trait units and scale) that align with estimated breeding values in plant breeding. Trait economic values were calculated according to the preference for each trait, relative to the preference for a monetary value included in the survey. Typologies of preferences were identified according to cassava traits preferences, and the resultant economic values differed between the typologies. This presents the potential for plant breeders to consider economic gains and cluster groups based on traits preferences in the development of breeding objectives.

INTRODUCTION

Trait selection and breeding goal establishment are important when developing breeding objectives in crop and animal breeding. Animal breeding has made more advances than plant breeding in the use of economic values for index selection. This difficulty in crop breeders using economic theory to develop economic weights (Sölkner *et al.* 2008) is attributed to the absence of formal frameworks for derivation of economic weights. Participatory breeding, which involves including farmers and other value chain actors in the development of breeding objectives, has been employed in breeding programs for several crops; however, a challenge in participatory breeding has been an inability to transfer farmers' and other actors' descriptions of, and expressed preferences for, traits into quantitative terms that would allow them to be combined with estimated breeding values in a formal selection index. This challenge increases the risk of the breeding program releasing varieties that do not meet the requirements of the farmers and markets.

1000minds® (https://www.1000minds.com/) is a preference survey tool that employs an adaptive conjoint analysis methodology to minimise user burden. A detailed description of the algorithm of 1000minds can be found in Hansen and Ombler (2009). The 1000minds® method has been applied in the breeding of pasture plants (Smith and Fennessy 2011), sheep (Byrne *et al.* 2012), and dairy cattle (Martin-Collado *et al.* 2015) to assess farmers' preferences for trait improvements. Analysis of the outputs from 1000minds surveys enables the derivation of economic values and provides insights into trait preference heterogeneity across farmers and other supply chain actors.

This paper describes the application of methods and tools used in animal breeding to crops and shows how survey approaches can be employed to assign economic values to traits for genetic improvement when developing breeding objectives.

MATERIALS AND METHODS

We applied the 1000minds® survey tool (https://www.1000minds.com/) to prioritise trait improvements for cassava in Nigeria. The 1000minds software asks a series of choice questions, where respondents are repeatedly required to select their preference between two trait improvement alternatives. The survey was conducted in four geopolitical zones in Nigeria: the north-central, south-east, south-south and south-west zones. The traits included in the survey were selected in consultation with experts and through literature research. Prior to the survey, focus group discussions (FGDs) were carried out with farmers and other cassava value chain actors, and in addition to discussing the traits to include in the surveys, they were used to establish benchmarks, units, and economic equivalents for cassava traits. Table 1 presents the parameters used to calculate equivalent levels for the traits in the 1000minds survey. Economic equivalents were calculated as the economic effect on increment per unit change in each of the traits independently.

The survey included 11 cassava traits and was administered to 792 smallholder cassava farmers and other actors in the cassava value chain. A demographic questionnaire was administered alongside the 1000minds® survey to explore the sociodemographic factors. The 1000minds output contains rankings of traits and preference percentage. These preference percentages were employed in the calculation of economic values.

Derivation of Economic values. An economic value is defined as the marginal impact of a one-unit change in a genetic trait. Trait economic values were calculated according to the preference (%) for each trait relative to the preference (%) for the trait expressed in monetary terms in the survey, 'price per 100kg bag' (Byrne *et al.* 2012).

Table 1. Parameters used to calculate economic equivalence of levels for 1000minds preference survey traits

Inputs	Value
Average price per 100kg bag[1]	2,500
Average fresh roots yield (Number of100kg bags) per acre	40
Total crop value/acre	100,000
Average crop duration (days)	270
Average ground storage(days)	365
Price difference per change in root size	1,000
Price difference per change in root colour	1,000
Gari price per kg of gari	200
Gari price per 100 kg of gari	15,000
Average gari value (number of bags per acre)	13
Total gari value/acre[1]	200,000
Price difference across change in taste per 100kg[2]	1,000
Price difference across change in texture per 100kg[2]	1,000
Price difference across change in colour per 100kg[2]	1,000
Price difference across change in swelling per 100kg[2]	1,000

[1]Prices of cassava in Ibadan, Nigeria at the time of the survey
[2] Assumes NGN 1,000 (Nigerian currency) between lowest and highest score (i.e., NGN 250/ score change) for a 5-point scale.

Thus, the economic value per trait unit was calculated to reflect a unit change in the trait according to this equation:

$$\mathrm{pEV}_{qi} = \left[\frac{P_{iq}}{\alpha_i}\right] \times \beta_q, \quad (1)$$

where for trait i and individual respondent q, P is the preference (%) for each trait, α is the number of units represented in the trait level (to convert to the desired final trait unit), and β is the monetary value per preference (%) for individual q. Values for β were calculated as:

$$\beta_q = \left[\frac{\alpha mv}{Pmv_q}\right], \quad (2)$$

where αmv is the number of units represented in the level for the monetary trait and, for individual respondent q, Pmv is the preference (%) for the monetary trait.

RESULTS AND DISCUSSION

The Economic Values. Average economic values (NGN per trait unit) are presented in Table 2. The economic values presented are based on the cost of cassava at the time of the survey. Price of cassava varies greatly in Nigeria and so we used the current price of a bag of cassava at the time of the survey to derive economic values. Economic values are presented per trait unit, as defined in the survey. The calculation of economic values is based on equation (1) and equation (2). Given the preference for the trait 'maturity time' = 7.53% (P_{1q}), and the preference (%) for the (monetary) trait 'price per 100kg bag' (αmv) = 8.00% (Pmv_q), by way of example, applying equation (1) to the (non-monetary) trait, we deduce that 28 days (4 weeks) of maturity (α_1) (Table 2) is worth 7.5% and thus 1 day of maturity is worth 0.27% (7.5%/ 28 days). Similarly, for the (monetary) trait using equation (2), NGN 250 is worth 8.00% and thus 1% is worth NGN 31.22 (NGN 250/ 8.00%). Given 1-day maturity is worth 0.3% and 1% of monetary trait is worth NGN 31.22, then the economic value for maturity time can be calculated as NGN 8.40 per day (i.e., 0.27% × NGN 31.22).

Table 2. Trait economic values for all respondents

Traits	Surveyed Unit	Per unit	Mean Trait ranks^{+}	Average preference %	Economic value (NGN/ survey trait unit)
Yield	Per 4 bags	Per 1 bag	4.8	10.6	82
Ground storage	Per 5 weeks	Per 1 day	5.4	9.7	9
Gari colour	Per 1 score	Per 1 score	6.0	9.0	281
Dry matter content	Per 5%	Per 1%	6.2	8.8	55
Gari taste	Per 1 score	Per 1 score	6.5	8.3	259
Root size	Per 25%	Per 1%	6.7	8.1	10
Gari swelling	Per 1 score	Per 1 score	6.8	8.0	248
Gari texture	Per 1 score	Per 1 score	7.0	7.7	239
Root colour	Per 1 score	Per 1 score	7.1	7.6	236
Maturity	Per 4 weeks	Per 1 day	7.1	7.5	8
Disease resistance	Per 10 %	Per 1%	7.7	6.8	21

Order of trait ranks are from highest to lowest. $^{+}$Smaller numbers indicate higher ranks.

Economic values differed by cluster groups. While Table 2 shows the population level trait preferences, heterogeneity exists in preferences for improvements in cassava traits (e.g., Martin-Collado *et al.* 2015), further analysis of this heterogeneity showed that three typology cluster groups could be established based on preferences for different combinations of cassava traits. The cluster analysis highlights traits that are important for different groups. An example is in the preference for disease resistance. While disease resistance ranked as the least preferred for improvement by the overall population (Table 2), a group of farmers exist that ranked disease resistance very high compared to other traits (data not shown)

Breeding objective challenges in plant breeding. In this paper we show how animal breeding trait prioritisation tools can be applied in a plant breeding setting. However, it is important to highlight some of the challenges plant breeders may face in adapting animal breeding tools: (1) The units reported in this study may not reflect the units of the trait breeding values as they are evaluated in the breeding program. This is because units presented to survey participants were developed and presented in ways the respondents can relate to. Plant breeders often use scales (e.g., 0-9 scores for diseases score) that are abstract when considered in terms of the economic impact on farm and/ or are very different to what farmers use (e.g., farmers probably use % crop lost, or % of diseased plants). This makes it difficult to calculate economic values, because a 0-9 score, for example, bears no resemblance to a unit that has an economic impact attached. This is less common in animals. (2) Another difference between plant and animal breeding is in the interactions of genetic traits with environmental variables (G x E). These G x E interactions are more influential in plants than animals; thus, plant breeders need to accommodate critical G x E interactions when developing breeding objectives. (3) The cluster groups (typologies) of preferences identified can be applied in targeting different market segments for breeding, however, complex factors such as breeding costs/benefits, variety replacement targets, and investment priorities need to be considered and integrated into the tools for these tools to be adoption by plant breeders.

CONCLUSION

This study has shown that traits prioritisation methods that have been successful in animal breeding are also relevant and useful for plant breeding. Many of the challenges and nuances associated with index development are common between plants and animals, although for plants, there are some additional challenges created by the strong influence of G x E interactions, potentially exaggerating differences in trait preferences across different typology cluster groups.

ACKNOWLEDGEMENTS

This research was undertaken as part of the NextGen Cassava Breeding Project funded by the Bill and Melinda Gates Foundation and the UK Foreign, Commonwealth and Development Office as investment INV-007637. The work was also supported by a Callaghan innovation PhD Fellowship. We would like to appreciate the cassava breeding units at IITA and NRCRI Nigeria, as well as farmers and other cassava value chain actors that participated in the study.

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