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AGROMORPHOLOGICAL CHARACTERISATION OF *GBOMA* EGGPLANT, AN INDIGENOUS FRUIT AND LEAFY VEGETABLE IN GHANA

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ABSTRACT

Gboma (*Solanum macrocarpon* L.) is an important leafy and fruit vegetable in Ghana. Despite its nutritional and medicinal properties, and consumption by many ethnic groups in the country, the crop is underdeveloped. The objective of this study was to characterise diversity among local landraces of *Solanum macrocarpon* in Ghana using agro-morphological descriptors in order to identify outstanding accessions which could be involved in further breeding programmes. A total of 23 accessions collected from different agro-ecological zones in Ghana were characterised using morphological descriptors. The accessions varied significantly in days to 50% flowering, days to fruiting, stem girth, fruit weight, number of seeds per fruit, weight of leaves per plant and plant height. Principal components analysis based on the morphological traits showed that PC1 for 99% of the total variation was mainly defined by number of leaves, number of branches, plant height, stem girth and number of leaves per plant. The accessions evaluated were grouped under five clusters. The clustering pattern indicated that inter-cluster distance was higher than intra-cluster, indicating wide genetic diversity among the accessions. Correlation analyses between morphological traits revealed positive and negative relationships, indicating predictable success for eventual breeding activities. Accessions CAGRICW3, CAGRICW4, CAGRICN2 and CAGRICA4 had more leaves and fruits, and could be used as potential donors for hybridisation programme to develop variety with higher yield potential.

Key Words: Inter-cluster distance, *Solanum macrocarpon*

RÉSUMÉ

L'aubergine *Gboma* (*Solanum macrocarpon* L.) est un important légume feuille et fruit au Ghana. En dépit de ses propriétés nutritionnelle et médicinale, et de sa consommation par plusieurs ethnies du pays, cette culture est sous développée. L'objectif de cette étude était d'évaluer la diversité entre les cultivars traditionnels de *Solanum macrocarpon* au Ghana en se servant des descripteurs agro morphologiques, dans le but d'identifier des cultivars à bonne performances agro-morphologiques pouvant être introduits dans des programmes ultérieurs d'amélioration variétale. Au total 23 cultivars traditionnels collectés dans différentes zones agro-écologiques au Ghana ont été caractérisés. Les cultivars ont montré une différence significative en ce qui concerne la date de floraison, la date de fructification, la circonférence de la tige, le poids du fruit, le nombre de pépin par fruit, le poids des feuilles par plante et la hauteur des plantes. L'analyse en composantes principales basée sur les traits morphologiques montre que le premier axe PC1 comportant 99% de la variation totale était essentiellement défini par le nombre de feuilles par plante, le nombre de branches, la hauteur des plantes et la circonférence de la tige. Les accessions évaluées ont été groupées en cinq typologies. La répartition typologique a montré que la distance intergroupes était plus importante que la distante au sein des groupes, cela suggère une grande diversité génétique entre les accessions. L'analyse des corrélations entre traits morphologiques révèle des corrélations positives et négatives, ceci indique qu'on peut aboutir à de bons résultats en amélioration variétale. Les cultivars CAGRICW3, CAGRICW4, CAGRICN2 et CAGRICA4 avaient plus de feuilles et de fruits, et de ce fait pourraient être utilisés comme potentiel parents dans des programmes d'amélioration variétale pour développer des variétés à haut rendement.

Mots Clés: distance intergroupes, *Solanum macrocarpon*

INTRODUCTION

Gboma (*Solanum macrocarpon* L.), of the family Solanaceae, is one of the horticulturally important eggplant species with an African ancestry. It is found throughout the warmer and non-arid parts of Africa, where it is an important fruit or leafy vegetable (Schippers, 2000). *Gboma* eggplant is rich in protein, fibre, calcium, iron, potassium, magnesium, phosphorus and sodium (Agoreyo *et al*., 2012; Nyadanu and Lowor, 2014). The quality of protein in *Gboma* leaf and fruit is of high quality and, therefore, represents affordable but quality nutrition for many families (Adeyeye and Adanlawo, 2011). It is used in traditional medicine for treatment of various ailments, ranging from weight reduction, asthma, skin infections, rheumatic disease, gastro-oesophageal reflux diseases, to constipation and diabetes (Nwodo *et al*., 2011). The fruits are said to represent blessings and fruitfulness and are offered as tokens of goodwill during visits, marriages and other social events in Ghana and Nigeria (Schippers, 2000).

Despite the importance of *Gboma* eggplant, in most African countries, the crop is neglected and underutilised. Virtually, no research has been done to enhance the germplasm potential or to study its agronomic requirements. Consequently, cultivated varieties are still landraces and their cultivation is in drastic decline due to pest and disease pressures, poor yield and small fruit sizes. Breeding for improved varieties is no longer an option, but a dire need to meet the requirements of both farmers and consumers in Africa. The knowledge of diversity and characteristics of existing landraces, and farmers' selection criterion are a pre-requisite for designing a concrete breeding programme (Adoukonou-Sagbadja *et al*., 2006). Lack of this information places *Gboma* eggplant in danger of continued genetic erosion and disappearance.

The objective of this study was to characterise diversity among local landraces of *Solanum macrocarpon* in Ghana, using agro-morphological descriptors, in order to identify outstanding accessions which could be involved in further breeding programmes to develop improved varieties for farmers and consumers.

MATERIALS AND METHODS

The experiment was carried out at the research station of the College of Agriculture Education, University of Education, Winneba, Ashanti Mapong campus, located within longitudes 0.05 degrees and 1.30 degrees west and latitudes 6.55 degrees and 7.30 degrees north in Ghana.

Twenty three accessions (Table 1) of local landraces of *Gboma* egg plant were collected from Volta, Ashanti, Eastern, Brong Ahafo, Western and Northern regions of Ghana. Seeds extracted from the fruits were first nursed at the research station of College of Agriculture Education, University of Education, Winneba, Mampong Campus, Ghana. Seedlings were transplanted at four-leaf stage to 3 m x 2 m beds, in a randomised complete block design, with four replicates, at a spacing of 40 cm between rows and 30 cm within rows.

Quantitative and qualitative characters of vegetative development, leaf, floral and seed production were studied using descriptors for eggplant (IBPGR, 1990). These parameters included number of leaves, number of branches per stem, days to 50% flowering, number of flowers per plant, plant height, petal colour, fruit colour, leaf blade width, leaf length, sepal colour, number of leaf lobes, fruit shape, fruit apex shape, number of flowers per inflorescence, leaf blade shape, leaf apex shape, leaf base shape, girth of stem, fruit length, fruit width, fruit colour at physiological maturity, measured using a colour

TABLE 1. Status, collection sites and regions of Gboma eggplant accessions collected in Ghana

Accessions	Status	Collection sites	Region
CAGRIC V1	Cultivated	Keta	Volta
CAGRIC V2	Cultivated	Keta	Volta
CAGRIC V3	Cultivated	Anloga	Volta
CAGRIC V4	Cultivated	Anloga	Volta
CAGRIC V5	Cultivated	Denu	Volta
CAGRIC V6	Cultivated	Denu	Volta
CAGRIC W1	Wild	Wiawso	Western
CAGRIC W2	Wild	Wiawso	Western
CAGRIC W3	Cultivated	Wiawso	Western
CAGRIC W4	Cultivated	Wiawso	Western
CAGRIC A1	Cultivated	Ejura	Ashanti
CAGRIC A2	Cultivated	Ejura	Ashanti
CAGRIC A3	Wild	Ejura	Ashanti
CAGRIC A4	Wild	Mampong	Ashanti
CAGRIC E1	Wild	Begoro	Eastern
CAGRIC E2	Cultivated	Konongo	Eastern
CAGRIC E3	Wild	Konongo	Eastern
CAGRIC E4	Wild	Koforidua	Eastern
CAGRIC E5	Cultivated	Nkawkaw	Eastern
CAGRIC N1	Cultivated	Tamale	Northern
CAGRIC N2	Cultivated	Tamale	Northern
CAGRIC N3	Cultivated	Tamale	Northern
CAGRIC N4	Cultivated	Tamale	Northern

chart, fruit taste, number of fruits per plant, fresh leaf weight, stem weight and fruit weight.

Data collected were subjected to Analysis of Variance (ANOVA) using GenStat statistical software, Version 11. UPGMA Cluster Analysis (Sneath and Sokal, 1973; Swotford and Olsen, 1990) and Principal Components Analysis (PCA) were performed using Minitab statistical software. Computation of Pearson coefficients of correlation among the various agro-morphological traits was done using the same software.

RESULTS

There were significant differences ($P<0.05$) among accessions for the characters studied (Table 2). Accessions CAGRICW3 and CAGRICW4 registered the highest number of leaves; while CAGRICA4 and CAGRICN2 had the highest number of fruits per plant. The Phenogram generated using 26 morphological descriptors based on Euclidean Distance Coefficient and UPGMA clustering method (Fig. 1), clearly showed phenotypic diversity among *S. macrocarpon* accessions. The phenogram separated the 23 accessions studied into five distinct clusters by grouping accessions sharing close phenotypic similarities into distinct clusters. The clustering pattern indicated that the inter-cluster distance is higher than intra-cluster distance.

Colours of fruits, sepals and collora were variable, clearly revealing diversity among the accessions (Plates 1a-d; 2a-d). The most characteristic fruit shapes were round, oval or egg and oblong shaped. Fruit colour ranged from white, pale green to dark green. Some accessions produced fruits with shiny green fruits with dark green stripes; while others were uniformly green without stripes. The sepal colour ranged from pale green, green to purple black. Inflorescence characteristics varied considerably among *Gboma* eggplant accessions (Plates 2a-d). Flower (corolla) colour intensity also varied among the accessions. Pale violet, light violet, bluish violet and deep bluish violet colours were displayed by the accessions.

Multivariate PCA analysis revealed that the first two principal components cummulatively accounted for 100 percent of the total variance (Table 3). The first principal component which explained 99% of total variation was defined by number of leaves, number of branches, plant height, stem girth and number of fruits per plant (Table 3).

The second principal component was mainly defined by number of days to 50% flowering ad number of flowers per plant. Principal components analysis performed on the 26 morphological descriptors through score plot analysis (Fig. 2) displayed clustering patterns of the accessions, further suggesting their diversity and grouping.

As expected, there was a significant positive correlation ($r= 0.93$) between number of branches and number leaves. Days to 50% flowering was significant and inversely related to leaf number ($r =-40$) and number of branches ($r =-0.41$). Plant height was positively correlated with leaf number ($r=0.89$), number of branches ($r =0.87$) and number of flowers ($r = 0.46$). Stem girth was positively

TABLE 2. Variation among *Gboma* eggplant accessions for agro-morphological traits

Accessions	Morpho-agronomic traits								
	NL	PH	DF	LL	FL	WF	FW	NF	NB
CAGRICV1	15.5	26.7	99	206.8	3.4	4.7	46.4	4.8	2.5
CAGRICV2	26.3	34.6	90	212.7	3.8	5.0	53.6	3.4	3.5
CAGRICV3	38.4	42.6	84	235.4	3.6	4.8	349.3	8.2	5.9
CAGRICV4	36.9	44.8	89	299.3	4.0	5.5	75.3	7.4	5.5
CAGRICV5	16.1	23.5	93	218.7	3.7	5.1	193.6	3.1	2.2
CAGRICV6	12.4	21.1	92	230.5	3.3	4.4	54.0	2.9	1.9
CAGRICW1	32.0	41.1	90	241.9	3.9	5.2	215.3	6.0	4.9
CAGRICW2	43.9	48.1	88	237.3	3.9	3.8	583.3	10.8	6.0
CAGRICW3	60.0	49.2	87	257.7	3.8	4.7	426.0	11.9	6.6
CAGRICW4	60.0	50.5	84	243.7	3.6	5.1	256.9	10.6	5.2
CAGRICA1	39.1	48.4	88	279.7	3.7	4.8	175.3	10.9	5.6
CAGRICA2	46.6	49.4	87	242.1	3.3	4.8	154.3	6.8	4.5
CAGRICA3	28.5	37.8	91	243.9	3.8	4.9	312.1	10.3	6.2
CAGRICA4	47.6	47.8	91	237	4.2	5.3	96.2	12.5	5.9
CAGRICE1	42.6	49.1	97	268.6	3.8	4.9	245.3	10.3	5.8
CAGRICE2	45.9	43.8	91	247.4	3.6	5.0	205.6	10.4	4.6
CAGRICE3	43.9	37.1	94	269.7	3.7	5.1	252	11.3	5.5
CAGRICE4	45.5	44.1	91	230.1	3.6	5.1	89.3	9.0	6.9
CAGRICE5	51.2	40.6	89	260.3	7.3	5.4	126.9	10.1	6.5
CAGRICN1	54.5	50.1	92	298.5	4.0	5.4	718	11.9	6.1
CAGRICN2	47.4	45.9	85	230.6	4.0	5.4	106.7	12.3	5.6
CAGRICN3	31.9	42.9	100	220.1	3.7	5.1	118	11.6	5.1
CAGRICN4	45.7	37.7	91	215.8	3.7	5.3	121.8	11.4	6.5
LSD (0.05)	13.8	7.72	2.30	16.40	2.50	1.31	14.85	3.62	2.13

Where: NL = leaf number, NB = Number of branches per plant, DF = Days to 50% flowering, NFF = Number of flowers per plant, LBW = leaf blade width, L L = leaf length, NPI = number of flowers per inflorescence, GS = Girth of stem, FL = fruit length, WF= Fruit width, NF = number of fruits per plant, LW = leaf weight, SW = Stem weight, FW = Fruit weight, PH = Plant height

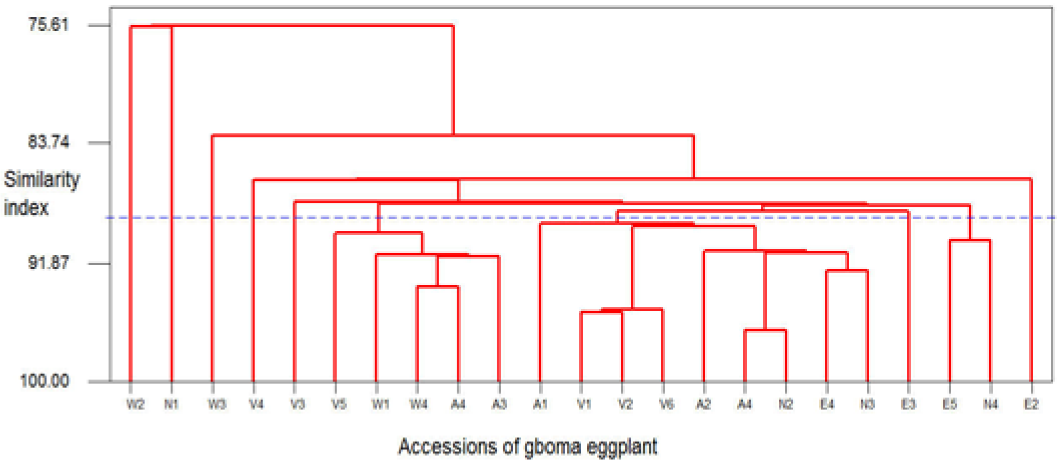

Figure 1. Phenogram showing phenotypic diversity between *Solanum macrocarpon* accessions.

Plate 1. Diversity in fruit shape and colour and sepal colour among the *Solanum macrocarpon* accessions.

Plate 2. Diversity in corolla shape and colour among the *Solanum macrocarpon* accessions.

correlated with leaf number (r= 0.66), number of branches (r =0.57), plant height (r = 0.64), leaf blade width (r =0.71) and leaf length (r = 0.75). Number of fruits per plant was positively correlated with leaf number (r= 0.84), number of branches (r = 0.82), plant height (r= 0.77) and stem girth (r= 0.54). However, number of fruits per plant and number of lobes on leaves were negatively correlated (r= -0.55) (Table 4).

TABLE 3. Principal components analysis of agro-morphological traits of the 23 accessions of *Solanum macrocarpon*

Variable	PC1	PC2	PC3	PC4
Leaf number	-0.341	0.020	-0.014	-0.123
Number of branches	-0.313	-0.012	-0.077	-0.163
Days to flowering	0.133	-0.362	0.143	0.079
Number of flowers	-0.155	0.388	-0.159	-0.065
Plant height	-0.323	0.002	-0.179	0.001
Petal colour	-0.215	-0.088	0.231	0.139
Fruit colour	-0.107	0.237	0.116	-0.223
Leaf blade width	-0.202	0.192	-0.058	0.348
Leaf length	-0.261	0.207	-0.010	0.276
Sepal colour	0.060	-0.251	-0.265	0.228
Number of lobes	0.090	0.312	0.076	0.284
Fruit shape	0.034	0.104	0.348	0.280
Fruit apex shape	-0.082	-0.009	-0.382	0.011
Number of flowers per inflo.	0.019	0.105	-0.321	0.386
Leaf blade shape	-0.073	-0.237	-0.164	0.208
Leaf apex shape	0.048	-0.124	-0.319	-0.061
Leaf base shape	-0.023	-0.134	-0.345	-0.101
Girth of stem	-0.304	0.024	0.000	0.172
Fruit length	-0.168	-0.240	0.064	0.254
Fruit width	-0.107	-0.157	0.025	0.268
Fruit colour at maturity	-0.197	-0.163	0.334	-0.021
Fruit taste	-0.119	0.046	0.148	0.135
Number of fruit per plant	-0.314	-0.107	-0.001	-0.193
Leaf weight	-0.277	-0.148	0.099	-0.147
Stem weight	-0.233	-0.307	0.013	-0.019
Fruit weight	-0.178	0.252	-0.065	-0.143
Cumulative proportion	0.997	0.999	1.000	1.000

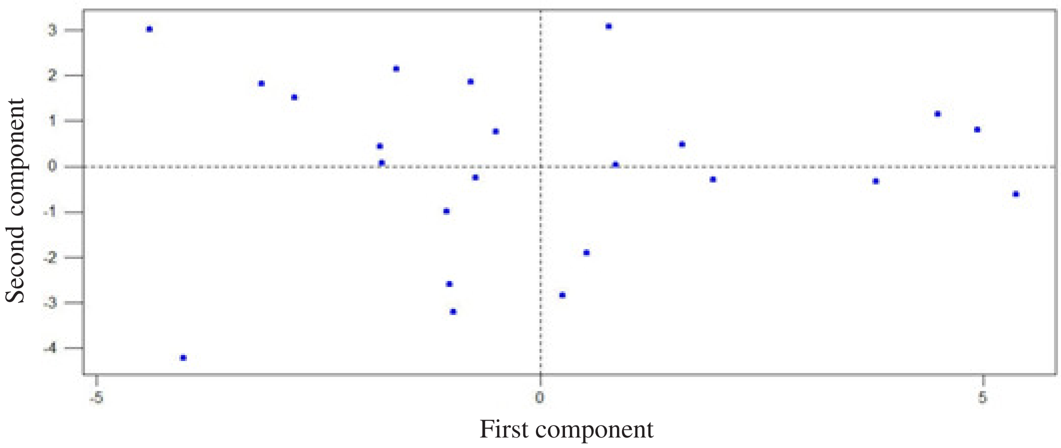

Figure 2. Score plot showing the clustering pattern of the accessions.

TABLE 4. Correlation among some of the agro-morphological traits

	LN	NB	DF	NF	PH	LBW	LL	NL	NPI	GS	FL	FW	NFP	LW	SW	FW
LN	1															
NB	0.93***	1														
DF	-0.40*	-0.41*	1													
NF	0.44**	0.39ns	-0.74***	1												
PH	0.89***	0.87***	-0.34ns	0.46**	1											
LBW	0.33ns	0.23ns	-0.36ns	0.50**	0.44**	1										
LL	0.53**	0.43**	-0.42*	0.59**	0.58**	0.88***	1									
NL	-0.23ns	-0.38ns	-0.31ns	0.26ns	-0.27ns	0.26ns	0.19ns	1								
NPI	-0.11ns	-0.05ns	-0.18ns	0.18ns	0.25ns	0.38ns	0.32ns	0.33ns	1							
GS	0.66**	0.57**	-0.33ns	0.34ns	0.64**	0.71***	0.75***	-0.05ns	0.05ns	1						
FL	0.37ns	0.34ns	0.10ns	-0.26	0.39ns	0.18ns	0.23ns	-0.06ns	0.08ns	0.52**	1					
FW	0.22ns	0.24ns	0.19ns	-0.10ns	0.16ns	0.29ns	0.25ns	0.01ns	0.15ns	0.32ns	0.34ns	1				
NFP	0.84***	0.82***	-0.13ns	0.22ns	0.77***	0.21ns	0.38ns	-0.55**	-0.23ns	0.54**	0.21ns	0.20ns	1			
LW	0.73***	0.61**	-0.12ns	0.08ns	0.60**	0.12ns	0.25ns	-0.31ns	-0.31ns	0.52**	0.36ns	0.21ns	0.76***	1		
SW	0.51**	0.53**	0.13ns	-0.16ns	0.44**	0.16ns	0.23ns	-0.53**	-0.23ns	0.50**	0.54**	0.39ns	0.65**	0.62**	1	
FW	0.50**	0.38ns	-0.59***	0.54**	0.44**	0.31ns	0.43*	-0.02ns	-0.08ns	0.34ns	-0.03ns	-0.29ns	0.39ns	0.14ns	0.01ns	1

Where: LN= leaf number, NB= Number of branches per plant, DF = Days to 50% flowering, NFF= Number of flowers per plant, PH = Plant height, LBW = leaf blade width, LL= leaf length, NL= number of lobes, NPI= number of flowers per inflorescence, GS= Girth of Stem, FL = fruit length, FW= Fruit width, NFP= number of fruits per plant, LW= leaf weight, SW= Stem weight, FW = Fruit weight

DISCUSSION

The significant variation among accessions for the various agronomic traits suggests that these traits are under genetic control and should, therefore, be liable to genetic improvement. This provides opportunity to improve desirable morphological traits of *Gboma* eggplant. This result agrees with findings of Chowdhury *et al.* (2007) and Kumar *et al.* (2008), who also reported genetic variation in eggplant.

Even though the 23 *S. macrocarpon* accessions in the present study differed greatly in vegetative, inflorescence and fruit traits; their overall close morphology allowed them to be grouped in a distinct cluster. Accessions in a cluster are more genetically similar than the counterparts in other cluster groups. The higher inter-cluster distance than intra-cluster distance further suggest diversity among the accessions of *S. macrocarpon* evaluated. Similar results were reported by Furini and Wunder (2004) who worked on morphology and AFLP phylogenetic diversity in *Solanum melongena*.

The diversity noted in crop performance and fruit characters in this study could be explained by differences in agro-climatic conditions and farmer selection practices prevailing in areas where they were collected. Adaptation to local climatic conditions and farmers selections for certain desirable plant traits over years, generally directed at fruit morphology, across many generations appear to have generated a significant degree of differentiation in eggplant landraces and, thus giving rise to a significant number of local variants with interesting features among them. Similar observations were reported by Naujeer (2009) and Portis *et al.* (2006) in Mauritius egg plants and Italian pepper landraces, respectively. This has important implications for germplasm management and breeding of improved varieties. The grouping of the accessions into specific cultivar groups based on key morphological descriptors will allow a quick and easy discrimination between them. Furthermore, it will enhance the assessment of *Gboma* eggplant varietal diversity structure in relation to *in-situ* conservation at specific locations. Moreover, duplications and redundancies present in *Gboma* eggplant accessions in Ghana could be eliminated, while facilitating the establishment of core collections. For instance, very close phenotypic similarities for all the morphological descriptors characterised were observed between V1, V2 and V6, accessions collected from Keta and Denu areas in the Volta Region of Ghana. This indicates a high probability of duplication of gene bank collections from these accessions.

According to Furini and Wunder (2004), diverse geographical origin of two accessions may not necessarily reflect in genetically diverse plant materials. Frary *et al.* (2003) explained this observation by the fact that the phenotypes for certain traits are controlled by a limited number of genes with major effects on phenotypic traits and their quantitative trait loci are conserved during domestication and plant evolution. The close similarity and morphological ties between accessions from different agro-ecological zones in this study implies that they have conserved their gene functions linked to the successful expression of morphological traits over geographical space isolation and time.

The number of leaves, number of branches, plant height, stem girth and number of fruits per plant were indicated by principal components analysis to be the most reliable morphological characters that contribute to total variation. These factors could be used as useful marker traits that most effectively discriminate between *Gboma* eggplant accessions. Other useful marker traits were fruit colour, sepal colour and corolla colour.

Correlation analysis revealed significant correlation among some of the morphological traits suggesting that some traits could be used to predict the other. Traits that show significant positive correlation could be improved simultaneously. However, traits that exhibited significant inverse relationships could be improved independently.

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