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Review

Breeding in bambara groundnut (*Vigna subterranea* (L.) Verdc.): strategic considerations

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Bambara groundnut (*Vigna subterranea* (L.) Verdc.) has a large number of landraces throughout Africa where small-scale farmers have preserved its genetic diversity on-farm. To date, the full genetic diversity of the crop remains largely unexploited. Until recently bambara groundnut never received any appreciable research effort, especially for its genetic improvement. Until then, only selection breeding was practised in which existing landraces were evaluated and their seeds multiplied. However, no new combinations resulting from hybridisation had ever been produced. Recently, collaborative research efforts involving partners from Africa and Europe have produced the first crosses of bambara groundnut. The creation of these crosses is a significant scientific and practical achievement and opens up the possibility of breeding true varieties of this crop. This paper shows how different strategies have been combined to establish the basis of a strategic breeding programme in bambara groundnut. The paper also illustrates the use of landraces in the bambara groundnut breeding programme, as an example of the contribution that landraces can make to increasing productivity in marginal environments and the conservation of a crop's genetic resources on-farm.

Key words: *Vigna subterranea*, underutilised, breeding, molecular technologies, landraces, bambara groundnut

INTRODUCTION

Grain legumes serve as a cheap source of protein to a large proportion of the population in poor countries of the tropics. Bambara groundnut (*Vigna subterranea* (L.) Verdc), an indigenous African legume, plays an important socio-economic role in the semi-arid regions of Africa. It is a rich source of protein and along with other local sources of protein could help to alleviate nutritional problems in these areas. As an under-utilised crop, bambara groundnut has not received sustained research input largely because most funding agencies are not willing to support research on crops of unproved potential and unknown commercial value. Nevertheless, despite the ambivalence of research sponsors, in recent years there has been a growing awareness of the potential of bambara groundnut to contribute to increased food production in Africa and the need to improve the crop (Anonymous, 1997; 2004). The crop is grown by subsistence farmers in Africa under traditional low input agricultural systems. It is grown mainly for its edible protein which has high lysine content and therefore has a beneficial complementary effect when consumed with cereals that are low in lysine.

Bambara groundnut seeds can be used to produce vegetable milk that is comparable with soy milk. Protein functionality tests on the ground seed indicate that it can compete with or replace other conventional flours in a range of processed products (Brough, Taylor and Azam-Ali, 1993). The seed makes a complete food, as it contains sufficient quantities of proteins, carbohydrates and lipid (Brough and Azam-Ali, 1992; Brough et al., 1993).

Bambara groundnut is a drought resistant crop grown in marginal, low-input, environments. Despite the

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absence of dedicated research efforts, it remains one of the most important legume crops in Africa. All cultivated bambara groundnut genotypes are landraces that have evolved directly from their wild relatives. They have adapted to hostile environments and are popular among farmers for their yield stability under different environmental conditions. In their study of the evolution of bambara groundnut as a crop, Doku and Karikari (1971) concluded that the domesticated bambara groundnut (*Vigna subterranea* var. *subterranea*) originated from its wild relative (*Vigna subterranea* var. *spontanea*). These domesticated forms of bambara groundnut were developed from their wild relatives in response to selection under cultivation through a series of gradual changes that are still taking place. One example of such adaptation is a change from a spreading/trailing to bunch growth habit. Doku and Karikari (1971) also reported reductions in leaflet area, shell thickness and days to flowering as a result of domestication.

The major germplasm collection of bambara groundnut is held by the International Institute of Tropical Agriculture (IITA) in Nigeria. Although a number of scientists have collected bambara groundnut landraces from different parts of Africa and beyond, these valuable genetic resources have not been exploited fully. It is clear that bambara groundnut landraces have been grown continuously in unfavourable and stressful environments since domestication without agronomic inputs such as fertilisers, irrigation or pest and disease control. The ability of these landraces to survive in the most resource-poor environments is a clear demonstration of how adapted they are to stressful conditions. To improve yield and nutritive value in bambara groundnut and select appropriate genotypes for distinct agroecological regions, breeders need to find sources of genetic variation. The existing genetic variation in bambara groundnut provides breeders with sources of genes for biotic and abiotic resistances, adaptability to different environments, nutritional characteristics and yield potential.

There are no improved varieties of bambara groundnut and therefore yields, usually under low input farming systems, are low and unpredictable. The low yields have been associated with poor germination percentage and variable germination rates which lead to poor crop establishment in the dry regions where the crop is grown (Linnemann and Azam-Ali, 1993). However, there is also evidence that the crop can produced high yields (up to 3 t ha^{-1}) both in the field and glasshouse environments (Collinson et al., 1996; 1999; 2000), suggesting that there is high yield potential that can be exploited in breeding programmes. There is great variability in the growth and development characteristics of individual plants within a landrace (Squire et al., 1997; Massawe, 2000). Populations of seed are also heterogeneous - different landraces show different germination responses to factors such as temperature, dryness and pre-sowing hydration (Zulu, 1989; Kocabas et al., 1999; Massawe et al., 1999). Biochemical and molecular analyses of selected bambara groundnut landraces have also revealed great genetic diversity between and within landraces (Pasquet et al., 1999; Amadou et al., 2001; Massawe et al., 2002; 2003).

In marginal hostile environments, variation between and within landraces may be advantageous especially when considering yield stability between sites and seasons. In such circumstances, at least part of the population will survive and yield under any particular set of environmental conditions. However, the same reasons may limit the maximum yield of a crop because a community of plants does not produce the integral of the yield of its most productive individuals. Conventional agronomy seeks to achieve a combination of uniformly high yielding individuals of a homogeneous variety growing at a high population density. However, in unpredictable and resource-poor environments, such uniformity may not be an advantage. Whether the contrasting variability displayed by heterogeneous landraces is a desired quality is complex and remains to be resolved.

Landraces as breeding material

Bambara groundnut landraces have recognisable morphological features, such as seed testa colour, that can be used to identify them. Commonly, landraces have names based on the colour of the testa and the place where they are grown or from where they have been collected. Such informal methods of classification may lead to one landrace having more than a single name as a consequence of seed introductions to or from other places or the historical movement of people and their crops across the African continent without documentation. The most recent description by Zeven (1998) defines a landrace as 'a variety with a high capacity to tolerate biotic and abiotic stress, resulting in high yield stability and an intermediate yield level under a low input agricultural system'. From the definitions given by other researchers (see Zeven (1998) and references therein), landraces can be described as a mixture of genotypes with highly diverse populations both between and within them. This is clearly the case with bambara groundnut landraces where growers either save their own seed for the next season or buy seed from the market and the mixing of seeds (of similar or different testa colour) results in a completely different population. The very fact that individuals within a population vary in their yield performance, depending on the vagaries of each season, means that the overall genetic composition of a `landrace' changes each year when farmers grow crops from their own stored seeds.

Although crop improvement work on bambara groundnut has been negligible so far, the conservation of its genetic resources for such work in future is appreciable. Apart from the resources conserved by farmers throughout the sub-Saharan Africa, there are also seed accessions in gene banks such as the collection of about 2,000 and 972 accessions kept by the IITA in Nigeria and the national gene banks of the Southern Africa Development Community (SADC) member countries, respectively. With good characterisation of the gene bank accessions and encouragement of on-farm conservation, there should be a reasonable range of genetic variation to support any breeding programme. Research to improve bambara groundnut should consider the fact that growing conditions in tropical regions can be diverse and both high productivity and yield stability at any level would require equal attention in breeding programmes. Of course, the ideal cultivar would be one that produces both high and stable yields. Although the likelihood of developing such a cultivar is rather low, a solution would lie in releasing a range of cultivars composed of both the high and stable yielding types.

The variation available within bambara groundnut landraces is of great value to a breeding programme for stressful environments and low-input farming systems. To exploit this large reservoir of genetic variation for bambara groundnut improvement, six strategic points have been followed, although not always systematically structured.

IMPLEMENTATION OF THE BREEDING STRATEGY

i. Evaluation of genetic diversity of bambara groundnut landraces using molecular markers.
ii. Development of pure lines from landraces after testing their stability in different environments (first under controlled environment glasshouses, then in field and on-farm experiments).
iii. Development of multi-lines (genotype mixtures or blends), constructed with a variable number of pure lines properly characterised for a set of traits to fit defined growing conditions and other farmer/consumer preferences.
iv. Multi-locational field trials of selected bambara groundnut landraces to evaluate genetic and agronomic traits across a range of environments.
v. Utilisation of pure lines in a crossing programme to introduce additional desirable characters in an adapted genetic background.
vi. Generation of genetic maps from F2 and Recombinant Inbred Lines (RILs) populations in order to locate important Quantitative Trait Loci (QTLs).

Whereas the development of pure lines is a short term approach, the use of mixtures and hybridisation both represent a long term approach to crop improvement. In all these crucial stages, there are cross-cutting studies of physiological and agronomic performance of the materials within the breeding programme. This paper gives an insight into the current state in respect of crop improvement in bambara groundnut using both the short and long term approaches.

Evaluation of genetic diversity using molecular techniques

Between 1997 and 2003 experiments were conducted at the University of Nottingham, UK and Technical University of Munich, Germany to lay the groundwork for genetic improvement of bambara groundnut by improving the understanding of the diversity between and within accessions and to further the rational exploitation of these resources in improvement programmes. Studies conducted using Randomly Amplified Polymorphic DNA (RAPD) and Amplified Fragment Length Polymorphism (AFLP) markers have revealed high levels of polymorphism among bambara groundnut landraces (Massawe et al., 2002; 2003; Singrün and Schenkel, 2004). Using RAPDs data, AMOVA (Analysis of Molecular Variance) was used to partition variation into between- and within- landrace components. Results indicated that there is variation both between and within landraces although the variation within a landrace was lower than that between them. Recent studies by Singrün and Schenkel (2004) also showed variations within individual landraces and they reported that each of the 263 landraces they analysed contained three to eight distinct genotypes. The molecular studies of both Massawe et al. (2002; 2003) and Singrün and Schenkel (2004) suggest that genetic relationships observed among bambara groundnut landraces from different regions of Africa were related to their place of collection rather than to their phenotypic similarities. AFLP results suggest that there is a possibility to develop location- or landrace-specific markers for identification purposes and there is potential for association of AFLP markers and agronomic traits.

Development of pure lines

Between 1993 and 1995 experiments were carried out at Sebele, near Gaborone in Botswana to isolate single plants with high pod and seed numbers for the generation of pure lines. These lines were then used to estimate coefficients of phenotypic and genotypic variation and heritability values for yield related characters. From this work, Wigglesworth (1997) reported that of the six landraces used in the study, there were no major differences in phenotype or performance between landraces. However, there was great variation within landraces. Tables 1 and 2 show the descriptive statistics for single plant selections and line performance of six bambara groundnut landraces, respectively. Results from

Table 1. Descriptive statistics for single plant selections of bambara groundnut (Wigglesworth, 1997).

Variable	Mean	Std Dev	Minimum	Maximum	No. of observations	CV%
Total seed weight (g)	176.6	83.8	29	352	65	47
Pod weight (g)	229.3	110.3	31	441	65	48
Pod number	334.8	151.0	61	540	17	45
100 - seed weight (g)	53.6	10.5	43	72	10	20
Number of seeds per pod	1.03	0.06	0.99	1.16	10	0.06

Table 2. Performance of six bambara groundnut landraces (Wigglesworth, 1997).

Line	Mean pod number per plant	100-seed weight (g)	Total seed weight per plant (g)
DipC93-L38/94	278.6	41.9	121.8
JacB(1)93-L97/94	231.3	32.2	90.0
GooB93-L67/94	206.9	43.9	92.0
RamR93-L75/94	252.5	30.7	84.1
NTSR92-L85/94	312.0	35.9	112.7
GooB93-L68/94	220.8	49.0	112.0
Entire population	250.3	38.9	102.1
F ratio; p	2.8; 0.056	13.7; 0.000	2.4; 0.091
C.V. (Error)	18.8	9.9	19.5

Table 3. Estimates of genetic parameters in bambara groundnut (Wigglesworth, 1997).

Trait	Coefficient of phenotypic variation (%)	Coefficient of genotypic variation (%)	Heritability (h^2)
Pod number	20.2	12.6	0.39
100-seed weight	18.3	17.7	0.94
Total seed weight	22.9	11.4	0.25

this work show that single plants can yield up to 540 mature pods and a seed weight of 352 g (Table 1). Performance of the six bambara groundnut landraces in this study showed that there were significant differences in 100-seed weight (Table 2), which may serve as criteria for selection for seed size and grain yield. Wigglesworth (1997) also reported that there was high heritability for 100-seed weight indicating that significant increases in yield could be obtained by selecting for this trait (Table 3).

Between 1997 and 2000 experiments were carried out at the Tropical Crops Research Unit (TCRU) of University of Nottingham, UK to establish the degree of variability in vegetative and reproductive traits between and within landraces. These studies revealed that there was no strong correlation between vegetative and reproductive development in the bambara groundnut landraces studied (Massawe, 2000). Phenotypic traits indicated that there was variability both between and within bambara groundnut landraces. However, the degree of phenotypic variation could not be associated with the collection sites for these landraces

Studies were also carried out at Nottingham to explore the degree of variation that exists between and within landraces of bambara groundnut and to isolate single plants with superior qualitative and quantitative traits from the landraces with the aim of developing pure lines. Results from descriptive characterisation of DodR1995 and LunT1995 based on individual plant measurements are summarised in Table 4. In each landrace there were plants with no flowers and hence no pods at harvest while other individual plants had as many as 132 and 103 cumulative flowers for DodR1995 and LunT1995, respectively, by the end of the season. Table 5 presents the descriptive statistics for yield parameters in DodR1995 and LunT1995. The above studies represent examples of preliminary work done on bambara groundnut aimed at improving landrace performance through selection of superior individuals from within the landraces. The most important lesson from these studies

Table 4. Descriptive characterisation of DodR1995 and LunT1995 landraces based on individual plant measurements (Massawe, 2000).

Character	Min	Max	Mean	Count (N)	SD	SE	%CV
DodR1995							
Days to emergence	7	53	13.6	189	7.4	0.5	54.4
Leaf number per plant	9	216	126.3	44	39.9	6.0	31.6
Days to first flower	43	80	60.2	123	9.8	0.9	16.3
Flower number per plant	0	132	75.0	45	33.1	4.9	44.1
Pod number per plant	0	182	51.1	133	37.5	3.2	73.4
Pod weight per plant (g)	15.8	44.6	29.0	10	9.0	3.0	31.0
Seed weight per plant (g)	12.5	27.5	21.2	10	6.1	2.0	28.8
100-seed weight per plant (g)	25.5	56.5	38.2	10	10.5	3.5	27.5
Shelling percentage	45.6	82.8	74.5	10	11.7	3.9	15.7
Green leaf area per plant	104	6686	3225	44	1474	222	45.7
Shoot dry weight (g)	0.8	82.2	35.5	134	18.1	1.6	51.0
LunT1995							
Days to emergence	7	32	12.4	180	4.1	0.3	33.1
Leaf number per plant	51	171	86.9	44	28.4	4.2	32.7
Days to first flower	42	80	57.0	126	9.4	0.8	16.5
Flower number per plant	0	103	52.0	47	26.9	3.9	51.7
Pod number per plant	0	61	18.0	136	14.1	1.2	78.3
Pod weight per plant (g)	0.14	21.5	8.2	10	7.8	2.5	95.1
Seed weight per plant (g)	0.11	14.2	5.6	10	5.2	1.6	92.8
100-seed weight per plant (g)	11	30.9	23.4	10	6.4	2.3	27.3
Shelling percentage	62.3	78.6	70.6	10	5.5	1.9	7.8
Green leaf area per plant	34.5	5577	1791	44	1364	206	76.1
Shoot dry weight (g)	3	93.4	28.7	140	16.8	1.4	58.5

Table 5. Descriptive characterisation of yield parameters of DodR1995 and LunT1995 based on mean values (Massawe, 2000).

Landrace	Mean pod number per plant	Mean pod weight per plant (g)	Mean seed weight per plant (g)	Shelling percentage (%)	Mean 100-seed weight per plant (g)
DodR1995	51.1	29.0	21.2	74.5	38.2
LunT1995	18.0	8.2	5.6	70.6	23.4
Mean	34.5	18.6	13.4	72.5	30.8
Standard Deviation	23.3	14.7	11.0	2.7	10.5
% CV	67.5	79.0	82.1	3.7	34.1
Significance	Significant**	Highly significant***	Highly significant***	Not significant	Significant**

** = P<0.01; *** = P<0.001

is that significant phenotypic and genotypic variation was found both between and within bambara groundnut landraces. One unique feature of these landraces is that their populations harbour a huge variability as evidenced by both the agronomic and molecular marker studies. Taking advantage of the existing variability, a number of pure lines have been developed using Single Seed Descent method. These pure lines have been evaluated under controlled environments and are ready to be tested and evaluated in the field. It is envisaged that these pure lines will be grown under typical farmers' conditions and farmers will be invited to assess and make their own selection of desired lines. Some of the desirable traits are already known from the survey studies conducted in Botswana, Namibia and Swaziland (Magagula et al., 2001; Manthe et al., 2001; Fleissner, 2001). Overall, the

Table 6. Bambara groundnut characteristics preferred by farmers in Botswana, Namibia and Swaziland.

Country	Large seeds	White cream	Sweet taste	Early maturing	High yield	Fast cooking	Strong pegs
Botswana	+	+	+	+		+	
Namibia	+	+	+	+	+	+	
Swaziland	+			+	+	+	+

most important traits and selection criteria for bambara groundnut landraces, as identified by growers and consumers during the surveys, are: early maturity, high yield, large pods, sweet taste, fast cooking, spreading growth habit and cream coloured seeds (Table 6).

The pure lines developed so far have a wide range of traits, some of which match what growers and consumers identified as the most important traits and selection criteria for their bambara groundnut ideotype. These include pure lines that are early maturing with large seeds and some that are high yielding with stable and predictable yield among individual plants. The exploitation of the variability available within landraces is a simple and efficient way to improve the productivity of crops for which landraces are still available. Because of its potential for increasing crop production, however, using landraces as breeding material may lead to the replacement of landraces with improved pure lines. It is therefore vital that *in situ* conservation programmes for maintaining the landraces are established. For a crop like bambara groundnut, this provides a mechanism of maintaining the genetic diversity of the crop while making strides in the provision of improved cultivars/varieties.

Development of mixtures

Creation of pure lines selected from landraces is potentially risky because it tends to replace genetically heterogeneous populations such as landraces with genetically uniform populations such as varieties. Genetic uniformity contrasts with the genetic diversity characteristic of the agricultural systems of low input farmers in marginal areas. In these systems, diversity is maintained at one or more levels by using different '*varieties*' of the same crop, different crops on the same farm and heterogeneous populations such as landraces. To growers in low input marginal farming systems, diversity reduces the risk of crop failure due to biotic or abiotic factors, while monocultures maximise such risks. Despite constant human and natural selection operating in marginal environments on a crop such as bambara groundnut, landraces are still made up of heterogeneous populations rather than a single or a few genotypes. For example, bambara groundnut landraces in use in Southern Africa are composed of 3 to 8 different genotypes (Singrün and Schenkel, 2004). In this respect, it is the structure of the population, in addition to the genetic constitution of the individual components, which harbours the secret of adaptation to difficult and unpredictable environments.

The aim of our bambara groundnut improvement programme is to enhance the genetic potential of bambara groundnut and ensure that crop sustainability and reliability are prime objectives, alongside enhanced yields and quality. One way of achieving this is to create mixtures (multi-lines) of a number of superior but genetically different pure lines selected from the landraces. This approach provides a buffering mechanism to the adaptation of the individual components of the mixture (Simmonds and Smartt, 1999) and therefore provides an answer to the needs of low input farmers for stable yield. Bambara groundnut scientists consider this approach crucial in order to ensure that crop sustainability and reliability are achieved under different environmental conditions and circumstances. It is anticipated that from a number of pure lines already developed, some will be combined to produce genotype mixtures (multi-lines), analogous to existing landraces. It is envisaged that the ratios of the different genotypes will vary depending upon the ecological zone in which the crop is to be grown and consumer preferences. The actual choice of the lines that will form a mixture will be based on the qualities of each line in relation to the agro-ecological conditions where the specific mixture is intended to be grown.

Genetic and agronomic characterisation of landraces

Genetic and agronomic characterisation of selected bambara groundnut landraces indicates that there are significant differences with regard to morphological, physiological and agronomic traits. Flower number, days to maturity, leaf number, pod development and yield are among the important traits that vary significantly among the landraces. However, there was a large influence of environmental conditions on some of the parameters measured and this resulted in large variations from location to location. In glasshouse experiments soil moisture was found to have a significant effect on crop growth. Drought led to reduction in leaf number, plant dry weight, leaf area and leaf area index. However, the effect of drought on these parameters varied with the landrace. Glasshouse experiments indicated that soil moisture stress affected the yield components of the crop and this led to more than 50% reduction in the final yield from the droughted treatment (Mwale et al., 2004).

The results from these experiments have provided good information on the yield potential, genetic variation and agronomic performance (on-farm and on-station) of the various landraces used in the breeding programme. Some of the traits identified in some landraces match what growers and consumers listed as the most important traits that they would want to be incorporated in their ideotypes. Even more important is the fact that some landraces display traits that confer drought tolerance such as deep rooting, reduction in leaf area and osmotic adjustment. Others, such as S19-3, avoid drought by having a short life cycle and hence early maturing.

Crossbreeding

The potential of pure line selection breeding in self pollinated crops (of which bambara groundnut is one) is limited by the available genetic variability. In order to develop improved cultivars with a combination of desirable traits that cannot be found in a landrace or pure line, artificial hybridisation is essential. Crossbreeding of selected parental lines allows for the controlled combination of traits, which were previously distributed between the parents, into one new stable line. Additionally, new genetic variability is produced, possibly resulting in traits previously unknown in the parental lines.

Research activities involving collaborators from Africa and Europe have demonstrated that it is possible to hybridise bambara groundnut and a number of crosses have been performed (Massawe et al., 2004). These crosses involved contrasting cultivated and wild genotypes selected on the basis of yield potential, variation in molecular and morphological markers, maturity and growth habit. Before these new developments, no one had successfully produced crosses of bambara groundnut and therefore, for many centuries, bambara groundnut cultivation has been based on the use of landraces. The successful crossing in this crop is a significant achievement because it has opened up the possibility of breeding the first improved varieties of bambara groundnut. This also provides an opportunity to position QTL (Quantitative Trait Loci) for novel physiological traits related to resource capture and use.

Recombinant Inbred Lines (RILs) and genetic mapping

There are three types of markers that are potentially useful in the genetic improvement of bambara groundnut. These are: morphological (traits), biochemical (seed storage proteins and isozymes) and molecular (DNA-based) markers. Morphological traits represent the first markers to be used in genetic mapping and have been used extensively in other crop species (Gepts et al., 1993; Kelly and Miklas, 1999). DNA-based (molecular) markers represent the more recent group of markers that are used in genetic mapping. These markers can be linked to heritable traits and thus used for screening in early generations thereby accelerating breeding programmes. Bambara groundnut scientists are using two F_2 populations to establish a genetic linkage map of bambara groundnut, based on molecular and morphological markers and to develop RILs (Basu et al., 2004; Massawe et al., 2004).

Development of RILs is an essential output with respect to the current position of crop improvement work in bambara groundnut. The RILs will provide a resource for future work and will also be made freely available to other research groups. Once developed, the RILs will provide the necessary basic starting point for studying the genetics of growth habit, drought tolerance and maturity by QTL analysis and identify molecular markers linked to QTL conditioning root growth, water use efficiency (WUE), growth habit and maturity.

Conserving landraces for food security and breeding

In order to appreciate the importance of landraces for the present and future bambara groundnut improvement programmes, it is crucial to recognise that, because of their evolutionary history, landraces are useful as breeding material and for direct use to low input farmers. Under low input farming systems bambara groundnut landraces have maintained a considerable amount of genetic diversity (Massawe, 2000). In breeding bambara groundnut ideotypes for certain environmental conditions and farmers preferences, evaluation and selection should be conducted within the target environment and under the agronomic conditions of the local farmers. Participatory plant breeding has been used for bambara groundnut in Swaziland (Sesay et al., 2004) where growers and consumers selected their preferred ideotypes from a range of landraces grown at research stations and in the farmers' own fields. Farmers should be made aware of the fact that the landraces they have grown over long periods of time are capable of continuously generating new types which can contribute towards improving the living standards of the present and future generations. This is a crucial factor in promoting farmer's interest in conserving the original landraces while adopting the new improved lines.

The concurrent use of landraces, pure lines, mixtures and crosses in bambara groundnut breeding programme is a balanced approach and ensures that the long term food security of people who depend on landraces is enhanced through a broad approach to crop improvement. It also represents a strong foundation of maintaining a wide genetic base within the germplasm that farmers use, thereby contributing to on-farm conservation of genetic resources. The use of landraces, pure lines, mixtures and new cultivars is likely to be appealing to farmers because of their good performance with respect to productivity and adaptability. Good performance of germplasm within the farmers' farming systems is very critical in on-farm conservation as it gives farmers the impetus to cultivate, use and retain such germplasm in the farming system and food options at household level. This recognition of value for cultivation and use can give significant contribution to the self-sustenance of on-farm conservation of bambara groundnut germplasm. Maintaining the genes of landraces in breeding programmes and through farmers' own conservation programmes is an obligation that researchers and their sponsors have towards those many generations of farmers who have maintained landraces for many years despite the ignorance or hostility of scientists.

CONCLUDING REMARKS

Efforts to improve many other crops have demonstrated a preference for a limited number of modern, genetically uniform varieties suited to high input farming systems to the detriment of the farmers' own landraces that are adapted to low input farming. On the other hand, it is to the benefit of the farmers and those interested in conservation that breeding programmes should be aimed at strengthening (and enhancing) the genetic base of the local landraces. In this paper, we have demonstrated how different approaches can be combined to establish a strategic breeding programme on bambara groundnut. The combined approach helps in creating more genetic diversity, particularly for the most important agronomic traits. The breeding strategy described here has the unique advantages of being responsive to farmers' desires (consumer driven), multi-disciplinary in approach and capable of safeguarding the germplasm against genetic erosion.

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