BEAN IMPROVEMENT FOR LOW FERTILITY SOILS IN AFRICA

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PREFACE

This volume reports the proceedings of a working group meeting on genetic improvement of bean for tolerance to low soil fertility in Africa. Results achieved in recent years are reported of screening for tolerance to low soil availability of N, P and K, and to toxicities of Al, Mn and salt. Alternative methods are discussed and recommendations are given for Bean Improvement for Low Fertility in Africa (BILFA).

This document is the twenty fifth in a series of workshop documents that serves research on beans (*Phaseolus vulgaris*) in Africa. This publication was made possible through support provided by the Office of Agriculture, Bureau for Research and Development, U. S. Agency for International Development, under Grant No. LAG-4111-G-00-2026-00. The activities of the bean research networks in Africa are further supported by the Canadian International Development Agency (CIDA) and the Swiss Development Cooperation (SDC). The opinions expressed herein are those of the authors and do not necessarily reflect the views of these contributing donor organizations, nor of CIAT.

Further information on regional research activities on bean in Africa that are part of these projects is available from:

Pan-Africa Coordinator, CIAT, P.O. Box 23294, Dar es Salaam, Tanzania.

Coordinateur Regional, CIAT, Programme Regional pour l'Amelioration du Haricot dans la Region des Grands Lacs, B.P. 259, Butare, Rwanda.

PUBLICATIONS OF THE NETWORK ON BEAN RESEARCH IN AFRICA

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No. 6.	First SADCC/CIAT Regional Bean Research Workshop, Mbabane, Swaziland, 4-7 October, 1989.
No. 7.	Second Regional Workshop on Bean Research in Eastern Africa, Nairobi, Kenya, 5-8 March, 1990.
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No. 10.	National Research Planning for Bean Production in Uganda, Makerere University, Kampala, Uganda, 28 January - 1 February, 1991.
No. 11.	Proceedings of the First Meeting of the Pan-Africa Working Group on Bean Entomology, Nairobi, Kenya, 6-9 August, 1989.
No. 12.	Ninth SUA/CRSP Bean Research Workshop and Second SADCC/CIAT Regional Bean Research Workshop. Progress in Improvement of Common Beans in Eastern and Southern Africa, Sokoine University of Agriculture, Morogoro, Tanzania, 17-22 September, 1990.
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No. 15.	First Pan-Africa Working Group Meeting on Anthracnose of Beans, Ambo, Ethiopia, 17-23 February, 1991.
No. 16.	Cinquieme Seminaire Regional sur l'Amelioration du Haricot dans la Region des Grands Lacs, Bujumbura, Burundi, 13-17 Novembre, 1989.
No. 17.	Sixieme Seminaire Regional sur l'Amelioration du Haricot dans la Region des Grands Lacs, Kigali, Rwanda, 21-25 Janvier, 1991.
No. 18.	Conference sur Lancement des Varietes, la Production et la Distribution de Semaines de Haricot dans la Region des Grands Lacs, Goma, Zaire, 2-4 Novembre, 1989.

No. 19. Recommendations of Working Groups on Cropping Systems and Soil Fertility Research for Bean Production Systems, Nairobi, Kenya, 12-14 February, 1990.

No. 20. Proceedings of the First African Bean Pathology Workshop, Kigali, Rwanda, 14-16 November, 1987.

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No. 7. Bean Sieving, a Possible Control Measure for the Dried Bean Beetles, *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchidae). 1994. J. Stored Prod. Res. 30:65-69; and,An Additional Character for Sexing the Adults of the Dried Bean Beetle *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchidae). 1994. J. Stored Prod. Res. 30:61-64.

No. 8. *Crotalaria ochraleuca* as a Green Manure Crop in Uganda. 1994. African Crop Sci. J. 2:55-61.

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INTRODUCTION

Bean (*Phaseolus vulgaris* L.) is a major source of protein and calories in Eastern and Southern Africa. Productivity of the crop is often constrained by problems of low soil fertility. Low soil availability of N and P are major constraints, while low K availability and toxicities of Al and Mn are of intermediate importance, and Na toxicity of localized importance. Bean production in Africa is primarily by small-scale farmers who use little fertilizer or soil amendments. Cultivars that are efficient in uptake and use of available nutrients are needed to give good performance in cases of low nutrient supplies and to use applied nutrients efficiently.

The Africa Network for Screening for Edaphic Stresses (ANSES, but later renamed Bean Improvement for Low Fertility in Africa, BILFA) is pan-Africa effort initiated by the Network on Bean Research in Africa in 1990 to screen for tolerance to several soil fertility related constraints. Scientists from several national programs have been involved in this effort to identify or develop cultivars and parents with tolerance to one or more edaphic stresses. The first cycle of screening evaluated 280 entries identified as agronomically promising by national and regional bean breeders in Africa, and the results are reported in these proceedings.

The Network on Bean Research in Africa organized this working group meeting to compile the results of the germplasm evaluations, to reconsider the research strategy and methods, and to make recommendations for future activities. The working group consisted of agronomists, breeders, plant nutritionists and soil scientists from national bean research programs and CIAT.

This document is compilation of the papers presented during the working group meeting and the results of the discussions.

THE AFRICA NETWORK FOR SCREENING BEANS FOR TOLERANCE TO EDAPHIC STRESSES -- AN OVERVIEW

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INTRODUCTION

The Africa Network for Screening for Edaphic Stresses (ANSES) emerged from a recommendation for a pan-African screening program for tolerance in beans (*Phaseolus vulgaris* L.) to various soil fertility related problems (Anon, 1988). The idea was further developed at a working group meeting on issues of soil fertility research (Anon., 1990). Subsequently, Dr. J. Lynch and I visited several of the proposed screening sites, discussed the work with interested parties and developed a strategy for implementation.

The strategy had a number of features.

1. It called for a pan-African effort to screen for tolerance to low soil N and P availability, and Al and Mn toxicity. Screening for tolerance was to be done independently for each of the four stresses rather than screening for tolerance to complexes of stresses.

2. Entries of good agronomic type and/or known reaction to soil fertility problems were to be collected from national and regional programs, and from CIAT.

3. Screening was to be done at primary sites for two seasons, rejecting 50% of the entries based on the first season results and another 35-40% based on the second season results. The primary sites identified were:

   Melkassa (Ethiopia) Research Station for low soil N (this work was shifted to Uganda because of temporarily self-imposed restrictions on importation of bean germplasm to Ethiopia from other African countries);

   Lyamungu (Tanzania) and Kawanda (Uganda) Research Stations for low P;

   Mulungu (Zaire) Research Station for Al toxicity; and

   Makerere (Uganda) University of Mn toxicity.

4. Secondary sites were identified for multi-location testing of the most promising varieties.

5. Screening was to be done at moderate stress levels that would allow 40-50% of the yield of non-stress conditions. This was to allow adequate expression of yield potential and good adaptation, as well as tolerance.

6. The primary selection criterion was yield under stress.

Once tolerant varieties were identified, the physiological and genetic mechanisms of tolerance would be determined. National programs would be encouraged to evaluate the tolerant materials under stress and non-stress conditions to identify acceptable cultivars, as well as parents to be used in breeding.

Implementation of the ANSES activities began in 1990 when 280 entries were collected, multiplied in Uganda, and distributed in 1991 to the primary evaluation sites. Promising materials were distributed for multi-location testing in 1992-3. Results from the secondary testing sites have not yet been returned. A second cycle of the ANSES consisting of 350 entries was started in 1993. The first cycle contained many I-gene protected (but susceptible to the necrosis inducing strain of BCMV, NL3) varieties, but in the second cycle, I-gene materials were generally excluded. Mechanism studies are underway for tolerance to low N, low P, low K and high Mn.

In addition to the originally planned activities, 140 entries of the first cycle of the ANSES are being evaluated for K use efficiency in Uganda. National collections and introductions are being evaluated for low P and the low P/high Al complex in Kenya and Madagascar, respectively. In Sudan, some varieties have been evaluated for tolerance to excess salinity in the Nile Valley.

Much experience has been gained with the implementation of the ANSES. Several issues have arisen which deserve further consideration.

ISSUES

Issues have arisen concerning difficulties in implementation and possibilities for improvement of the screening process.

Site identification and management. Stress levels were inadequate for effective screening at some sites, and some sites had other stresses associated with them which often prevailed over the stress of interest. Often, on-farm sites are used because of inadequate stress on research station. In some cases, earlier screening may have been inefficient while management of the stress of interest and to alleviation of other stresses was improved.

Exchange of germplasm. Quarantine restrictions or difficulties in implementation of the services has hindered the exchange of germplasm as required for the ANSES in a few countries. A self-imposed quarantine to prevent the introduction of the necrosis-inducing strain of BCMV (NL3) has prevented Ethiopia from participation in the ANSES.

Single stresses versus complexes of stresses. The original approach of the ANSES was to screen for tolerance to single stresses. Complexes of stresses are highly variable, and genotype by environment (stress complex) interactions are likely to be problematic in screening for tolerance to a complex. It appeared likely that screening for tolerance to single stresses would be most efficient. This has not been proven nor disproven, though an exception may be the high Al/low P/low Ca complex as these three stresses are closely associated.

Optimal level of stress for screening. If our aim is to identify potential cultivars to be released by National Programmes, tolerant varieties should perform well in the absence of stress. The varieties must respond well to the available nutrient supply, whether it be low or adequate. The screening process, therefore, should allow expression and consideration of good agronomic characteristics and yield potential. Screening only at severe stress levels does not allow this expression, and selected genotypes may be those of high tolerance but little yield potential. There are two options:

1. the materials can be evaluated under severe stress and non-stress conditions, selecting those that do well in both situations; or,

2. the materials can be evaluated under moderately severe stress conditions (where 40-50% of non-stress yields are produced) during the primary screening stage, and then at severe stress and non-stress levels at the advanced stage.

If our aim is primarily to identify parents with high levels of tolerance *per se*, it may be most efficient to screen at severe levels of stress.

Rapid screening. The use of effective rapid screening approaches is expected to be more cost-effective than evaluating large numbers of entries in the field. Experience with other crops indicates that rapid screening techniques can be useful to eliminate the most susceptible entries (Gerloff, 1987 and Jones *et al.*, 1992). Seedling root growth in soil of high Al saturation relative to growth at low Al saturation appears to relate well to field tolerance to Al toxicity (Lunze, pers. comm.). A method developed for cowpeas of testing for tolerance to Mn toxicity by floating disks of leaf tissue on a $MnSO_4$ solution (Wissemeier and Horst, 1991) did not give reliable results for beans in our tests.

Tolerance and adaptation. Tolerance to soil fertility related problems appears to be much affected by a variety's adaptation to the environment. It may be that entries rejected at the primary screening site may be tolerant in another environment. If so, the approach of using primary screening sites to identify promising materials for the rest of Africa may be inefficient. We found that our low P sites were not suitable for screening for tolerance to high altitude materials identified in Latin America (pers. comm., S. Beebe). Climbing bean varieties, when tested at intermediate altitudes, tend to be eliminated, probably partly due to poor adaptation. The results of the multi-location trials are needed to test the validity of this approach of using one or a few primary sites for the first stage of evaluation. In the meantime, additional primary sites have been added to the ANSES to include a high altitude site at Bembeki (Malawi) for the low P/high Al complex and a high altitude site at Rubona (Rwanda) for low P at moderate soil pH.

Accounting for variability within sites. Often the screening sites are quite variable for intensity of the soil fertility related stress. Such heterogeneity might be accounted for in several different ways.

1. Use of check varieties is an obvious option. Variability across the screening site implies that the checks need to occur frequently, considerably increasing the size of the trial. Many find difficulty in the use of checks in adjustment of plot values at the time of data analysis.

2. Adjustment of the plot values by the mean of the nearest neighbors has worked well. Use of the mean of the four nearest neighbors (two on each side) as a covariate in the analysis of variance is generally most effective with single row plots.

3. Mapping of variation across the sites might be useful. Two approaches can be used:

    a) using yield performance data from a trial of single row plots where the main determinant of performance is the stress of interest; or,

    b) sampling and testing the soil of the site on a grid-basis to determine the stress intensity throughout the field (nutrient availability should be estimated considering its soil test value as well as soil organic carbon and soil pH (Jannsen et al., 1989)).

Each grid might have a value which can be used as a covariate to adjust plot values. Such maps can also be used to improve blocking.

Poor nutrition and susceptibility to pathogens. Increased susceptibility to some pathogens, especially root rots, and possibly bean stem maggot, is commonly associated with poor nutrition of the bean crop. In the low K screening site, stem rots were a serious problem. Should the stem rots be treated as part of the low K complex, or should the pathogens be controlled to screen for low K tolerance independently? Maybe only stem/root rot resistant varieties should be screened for low K tolerance?

Multi-location testing. While this is probably essential, implementation has not gone well. In some cases, trials were not received because of quarantine problems. In others, the trials were received but not planted, or maybe planted and not reported. In other cases, the site is inadequate.

CONCLUSION

Considerable progress has been made in identification of varieties tolerant to various soil fertility related problems. Minor or major changes may be needed in the approach to make the process more effective. Other papers to be presented may enlightened us further on the opportunities for improving this work.

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GENETICS AND BREEDING FOR TOLERANCE IN BEANS TO SOIL FERTILITY RELATED CONSTRAINTS - A REVIEW

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INTRODUCTION

Cultivation of beans in Eastern and Southern Africa on poor soils is increasing in order to meet demand for more production, but the crop is constrained by inadequate availability of key elements such as N, P and K, and toxicities of Al and Mn. Development of tolerant varieties requires a good understanding of the problem and the mechanisms of tolerance, presence of genetic variation and adequate heritability, and use of good screening techniques and facilities. Identification of sites and preliminary screening of germplasm has been initiated in some countries and the results reported in this workshop are encouraging (Rachier, 1994; Ochwoh and Wortmann, 1994; and Wortmann, 1994). This screening has been limited to field conditions where separation of factors is difficult.

Information on genetic studies on beans for various edaphic constraints is limited and are reviewed in this paper. Possible mechanisms of tolerance are described. Implications of this information in a breeding program are discussed.

GENETIC STUDIES

Phosphorous

P deficiency often constrains bean yields. Several studies in Africa (Rachier, 1994) and elsewhere (Urrea and Singh, 1989) have demonstrated the existence of sufficient genetic variability in bean germplasm for low P tolerance to further improve tolerance. CIAT started work in the early 1980's but made little progress until 1987 due to lack of adequate selection criteria. Now several morphological (root and shoot dry weight) and physiological (P acquisition and utilization) characters have been identified as important to low P tolerance (CIAT 1987; Gerloff, 1987; Whitaeker *et al.* 1976).

Lindgren *et al.* (1977) used excised roots to identify lines of beans with different capacities for P absorption. They found high variance due to environment and the heritability estimates derived from parent offspring regression in families of efficient x inefficient lines were about 40%. Data on P uptake by excised roots, however, could not be used to predict P uptake and translocation in plants. Fawole *et al.* (1982b) found root development, as an indicator of efficiency of P utilization, to be controlled by quantitative inheritance patterns. Dominance variance was more important than additive variance in four out of six families. Broad sense heritability estimates were high (0.69-0.89). In another study using the same six families derived from crosses between efficient, moderately efficient and inefficient lines, and using total dry plant weight as an index of efficiency, Fawole *et al.* (1982a) found that epistasis, notably additive x additive and dominance x dominance, played a major role in efficiency of P utilization. Additive and dominance gene effects were also significant. Narrow sense heritability estimates of 0.45-0.76 indicated total plant dry weight to be highly heritable.

Aluminium

The adverse effect of Al on plant growth and development is caused by toxic effects in low pH soils. Varietal differences for Al tolerance have been reported for several crop species, including wheat and barley (Foy *et al.*, 1965 and 1967a), and beans (Foy *et al.*, 1967b and 1972; CIAT, 1985, 1987; and CIAT Malawi, 1993). In several of these studies, varieties tolerant to high Al have been reported to produce significantly more top and root growth than the susceptible ones. Foy *et al.* (1972) reported less Ca uptake in the tops of the Al sensitive variety, Romano, than those of the Al tolerant Dade. Al tolerance appears to be simply inherited.

Manganese

Like Al, presence of high Mn concentration in soil can adversely affect plant growth, especially if reducing conditions occur in the rooting zone. Morris and Pierre (1948) found a widely varying response in five leguminous species i.e. lespedeza, sweetclover, cowpea, peanuts and soybeans for tolerance to Mn. Lespedeza and sweetclover were the most sensitive, cowpeas and soybeans intermediate, and peanuts the most tolerant. Peanuts were able to endure high concentrations of Mn within the plant. Carter *et al.* (1975) found variation in susceptibility to Mn toxicity in 30 soybean lines. Heenan and Carter (1976) found differences in tolerance to Mn in four soybean varieties and observed leaf crinkle to be the most prominent visual symptom associated with Mn toxicity. Little difference in Mn uptake and distribution in root and shoot was found in the varieties. Field observations at Chitedze Research Station in Malawi during the 1993-94 crop season showed a wide range in tolerance of beans to Mn toxicity.

Nitrogen

Genetic diversity exists in beans for response to soil N (CIAT, Malawi, 1993). The tolerance identified elsewhere was confirmed for some varieties in Malawi (Aggarwal *et al.*, 1994). The genetic and physiological mechanisms involved in N use efficiency need to be studied.

In beans, the capacity to fix atmospheric nitrogen is relatively low as compared to other grain legumes, particularly cowpeas and soybeans. This low N fixation in beans is attributed to difficulty of establishing effective symbiosis in the field. Differences in N fixing capacity have been observed where bush types fix less than indeterminate and climbing types (Graham, 1981; Rennie and Kemp, 1983). It will be useful to identify germplasm that can tolerate low N soils, make better use of existing soil N, and efficiently fix atmospheric N.

Mechanisms of Resistance

Knowledge of mechanisms of tolerance, e.g. whether it is a mechanical barrier, a chemical reaction, etc., can help to identify the main character(s) associated with tolerance, how it is inherited, and how tolerance can be combined with other desirable traits. Physiological and morphological plant factors that could be responsible for genotypic adaptation to nutrient deficiency have been divided into four categories by Gerloff (1987). They are (1) nutrient acquisition from the environment, (2) nutrient movement across the root to the xylem, (3) nutrient distribution and remobilization in the shoot, and (4) nutrient utilization in metabolism and growth.

IMPLICATIONS FOR BREEDING

Success in breeding for tolerance to soil fertility related disorders have been achieved for maize (Magnavaca and Filho, 1993), sorghum (Gourley, 1993), rice (De Datta, 1993), wheat (Briggs and Taylor, 1993) and forages (Caradus, 1993). Presence of genetic variability in beans exists for tolerance to low as well as high levels of nutrients, indicating that the crop can be improved genetically both for the deficiencies, such as low P and low N, and Al and Mn toxicities. P use efficiency has been transferred from an exotic germplasm to an adapted variety by Schettini *et al.* (1987) using a backcross method, and several tolerant lines were derived from the efficient P donor parent (PI 206002) combined with the desirable recurrent parent 'Sanilac'.

To develop a typical breeding program, the important steps involved are (1) identification of lines tolerant to different nutrient stresses, (2) determination of characters associated to tolerance for which selection in populations is easy, and (3) determination of the mechanisms of inheritance, and (4) development of a suitable breeding scheme. Screening techniques are needed that are reliable, simple enough to permit evaluation of thousands of plants, and cost effective. Several common culture media procedures are available especially for P (Gerloff, 1987). Techniques are needed to detect morphological and physiological factors under field conditions.

A question worth discussing concerns the approach to screening for tolerance. Should selections be for an individual stress or combination of stresses? What are the advantages of each? Which will be most effective and efficient? Whatever the approach, the ultimate objective is to combine many desired characters in improved genotypes. Since facilities in Africa are limited, it will be quite desirable, in my opinion, to select, if possible, the best tolerant genotypes under poor soil conditions even if the tolerant factors are not clearly identified. Such genotypes can be further tested for specific tolerances, and studied for mechanisms and inheritance of tolerance.

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SCREENING BEANS FOR TOLERANCE TO LOW N AVAILABILITY

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INTRODUCTION

The N requirement of beans *(Phaseolus vulgaris L.)* can be met by both mineral N assimilation and symbiotic N_2 fixation. The economic benefits of improving legume N_2 fixation include reduced reliance on soil N, leading to more sustainable agricultural systems and reduced requirements for fertilizer N inputs, enhanced residual benefits to subsequent crops, and increased harvest yields under low soil N conditions. Presence of an active, efficient symbiosis is necessary if N_2 fixation is to positively influence yield and crop N, but beans do not fix N as a matter of course. Nodulation requires the presence of sufficient numbers of the appropriate rhizobia in the root zone, and because of the specificity of the bean-rhizobia symbiosis, rhizobia are often lacking. Even where suitable rhizobia are present, other factors such as soil fertility or water availability may interfere with processes of nodulation and N_2 fixation. Research with beans has also shown the cultivars vary in their capacity to fix N both under stress-free and stress conditions (Attewell and Bliss, 1985; Piha and Munns, 1987).

The interaction between genetic yield potential and environment determines the N requirement of a legume. Mineral N availability, the availability of effective rhizobia and the bean N requirement will together determine the contributions of symbiotic and mineral N sources to total plant N. When mineral N uptake is less than the N requirement, N_2 fixation is promoted. Assuming a well-nodulated plant, N_2 fixation potential may therefore be considered to be equal to the aggregate of per day deficits in mineral N uptake during the bean growth cycle. Taken together, plant growth stage, N requirement, and efficiency of mineral N uptake regulate N_2 fixation of effectively nodulated bean. Understanding these characteristics may provide useful diagnostic tools to identify genotypes with a high capacity to fix nitrogen.

Because of the generally low soil N fertility present in most of Africa and the N requirements of other non-N fixing crops in prevalent farming systems, it is probably wise to select for improved N_2 fixation in beans regardless of the difficulties. There are two possible strategies for improving bean N_2 fixation: management of the crop to minimize stresses and optimize nodulation, fixation, and yield; and selection/breeding bean with enhanced capacity for nodulation and N_2 fixation. The former is probably impractical under African conditions. It is more likely that, varietal selection for N_2 fixation traits, separately and in combination with tolerance to low P and other stresses, will result in improved bean yield with less negative effects on soil N availability for subsequent crops.

Rhizobium effects on bean N_2 fixation and productivity

The most obvious benefits of N_2 fixation research can be found in inoculation experiments where nodulation by selected strains results in increased yields of dry matter and N in the crop, and in increased grain yields. These results, however. are limited to situations where native soil rhizobia are present in low numbers and where a strain selection program has been carefully carried out for the specific conditions present. Significant improvements in fixation often depend on minimizing the effects of "incompetent" native rhizobia populations. The factors influencing the success of introduced rhizobia in soil, including their ability to nodulate in competition with indigenous rhizobia, are poorly understood. Unless a focused interest in microbiology and adequate facilities (clean lab, greenhouse) are present, strain selection and inoculant development are not recommended. Work in advanced labs to develop competitive effective strains should be relied upon for advances in this area.

Screening techniques

Each of the four most widely-used methods for measurement of N_2 fixation has advantages and limitations (Beck et al, 1993). Some are more reliable than others.

N difference. The simplest estimates of N_2 fixation are obtained by measuring the amount of N in the legume biomass and are based on the assumption that the legume derives all of its N from N_2 fixation. In the case of bean, the contribution of soil N to plant growth can be considerable, so fixation will be overestimated. A true measure of N_2 fixation based on legume yield can only be obtained when the contribution of soil N to total biomass N is determined. This is usually achieved by growing a non N_2 fixing crop concurrently in the same soil. The difference in total N accumulated by the legume (N_{leg}) and non-fixing control (N_{nonfix}) is regarded as the amount of N_2 fixed. Thus:

$$N_2 \text{ fixed} = N_{leg} - N_{nonfix}$$

The major assumption of the method is that the legume and non-fixing control take up identical amounts of N from the soil. Because of this, the choice of the control is of utmost importance. Ideally, the legume and control should explore the same rooting volume, have the same ability to extract and utilize soil N, and have similar patterns of N uptake. For these reasons the non-fixing crop of choice is a non-nodulating bean isoline, but errors in estimates of fixation are possible even with this "best" control plant where large differences in root morphologies exist. A non-legume such as sorghum can, however, be used as a reference plant with accuracy in some situations.

^{15}N enrichment method. This method is generally regarded as the standard method for estimating legume N_2 fixation. However, the high cost of instrumentation to measure ^{15}N plus the expense of the ^{15}N-labeled fertilizer materials are real constraints to the use of this method. Its main advantage is that it provides a time-averaged estimate of Pfix (the proportion of legume N derived from N_2 fixation), integrated for the period of plant growth. The major assumption of both the ^{15}N enrichment and natural abundance methods is that the legume and the non N_2 fixing reference crop utilize soil N with the same isotopic composition. Because the enriched ^{15}N is generally applied to a small volume of soil as a cost saving measure, roots from the fixing and/or non-fixing crop may extend out of the zone of enrichment; this is the major weakness of the method. For this effect to be minimized, legume and reference plants should have identical patterns of soil N use; in practice this is difficult to accomplish. Together with the cost of the method, it is unlikely to be used in a screening program.

Natural ^{15}N abundance. Because most soil N transformations result in isotopic fractionation the abundance of ^{15}N in soil is higher than in the atmosphere. The natural abundance method gives an integrated estimate of Pfix over time and has the advantage of being able to be used in already established experiments (provided non-fixing reference plants are also growing in the experimental plots) because no application of ^{15}N is necessary. The differences in ^{15}N are small and the sensitive instrumentation required is very expensive, but once available, samples can be routinely run at relatively low cost. For soils that are regularly cultivated, natural ^{15}N abundance levels are relatively constant with time and depth, and are high enough so that the method can be used with confidence. Therefore, the major limitation of ^{15}N enrichment and difference methods, i.e. choice of a non-fixing reference plant, is much less critical.

Xylem solutes (ureides). In recent years, the ureide assay of N_2 fixation has developed into an assay with application over a wide range of species and field environments. The principle is that the composition of N solutes in xylem sap changes from one dominated by nitrate and amino-N in plants utilizing soil N to ureides during N_2 fixation. Beans export fixed N as ureides during fixation, and if calibrated for N_2 fixation with different varieties under varying environmental conditions, measurement of ureides in bleeding sap would be a simple, non-destructive method to indicated fixation levels at critical times during bean development. A current effort between Australian institutes and CIAT to calibrate the method for bean could make the technique usable by African scientists.

BREEDING AND SELECTION STRATEGIES

There is a general consensus that enhanced N_2 fixation by beans will result from selection and breeding for N yield, and perhaps from improved nodulation. Following are some strategies that aim to develop bean cultivars that incorporate one or more characteristics for improved BNF.

Bean yield. Agronomic and environmental factors may limit the yield of a legume crop and therefore the capacity to fix N. Yield will also be determined genetically. In bean, low N yield is the result of low N_2 fixation capacity rather than the cause of it (Attewell and Bliss, 1985). However, bean cultivars capable of fixing up to 70% of their N requirements have been identified (Wolyn, et al, 1991). In order to select for N_2 fixation in bean, the primary requirement is a low soil N availability. Where soil N is low, the majority of acquired N must come from fixation, and N content will relate directly to yield if the material is well adapted. A secondary requirement is the presence of sufficient numbers of rhizobia to ensure nodulation for the bean crop. Bean has been found to be an effective scavenger of soil N (George and Singleton, 1992), and resorts to production of active nodules only when growth is limited by soil N availability. If soil N is moderate, which is often the case where organic matter levels are above 2% or following a period of fallow or pasture, bean will obtain the majority of its N from the soil and rely on fixation only in the later stages of plant growth when N assimilation is low. Selection of plants for yield or N content under moderate to high soil N conditions will therefore focus on their capability to extract and utilize soil N, a characteristic which may not be desirable for on-farm production where soil N is generally limited.

In order to exploit and identify the capacity of the plant to fix N, environmental factors should be optimized as much as possible. The most readily manipulable factors for minimal stress are other (than N) soil fertility factors and disease pressure. N_2 fixing legumes are known to have a higher P requirement than mineral-N fed legumes, so P should be available in realistic amounts to ensure good crop growth. Micronutrients such as molybdenum are also specially required for nodulation and N_2 fixation, and a blanket micronutrient application may solve nutritional problems which would otherwise obscure results. Soil pH below 5.4 may also limit nodulation and therefore N_2 fixation, and liming soils below this pH is recommended. The other major limitation to identification of N_2 fixation-efficient lines is adaptation. It is important to include an optimal fertility treatment (including adequate N for optimal crop growth) in order to determine the effects of varietal adaptation, which may limit growth due to altitude or daylength

Nodulation and nodule function. There appears little value in selecting genotypes for enhanced N_2 fixation based on specific traits associated with nodules or nodulation. Nodules on bean roots indicates the presence of a viable soil population of bean rhizobia; the N fixing effectiveness of this population is unknown and not easily changed. If bean is a newly introduced crop, rhizobia may be lacking or low in numbers. Continued cultivation of bean will increase the number of bean-nodulating rhizobia, as rhizobia survive well in the soil from one crop to another and increase with each crop up to a sustainable level in the soil (usually about 3000 per g of soil). The alternative, where available, is to inoculate with rhizobia selected for efficient N_2 fixation. The Kenyan Seed Company is currently embarked on a program of rhizobia strain selection for bean, and will produce commercial inoculants.

Nitrogen fixation. Bean selection based on direct measurement of N_2 fixation will be difficult unless tools are developed to allow simple, rapid evaluation of fixation capacity. N determinations for large numbers of plant samples can be difficult under some circumstances. Considerable potential exists, however, within the CIAT-ANSES linkage due to activities at CIAT HQ in Cali. Non-nodulating bean isolines (11 lines) of varying adaptation and phenology are in the final stages of development and testing, which will enable direct measurement of N_2 fixation by the difference method. A project with the Germans and Australians will provide free natural ^{15}N abundance measurements for limited numbers of samples; growth of non-fixing crops in fields where low-N tolerance studies are conducted will allow limited analysis of lines for N_2 fixation capability. The ureide technique, if reliably calibrated, also holds promise for a nondestructive assay of N_2 fixation capacity using simple laboratory methods.

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SCREENING BEANS FOR TOLERANCE TO LOW SOIL PHOSPHORUS AVAILABILITY

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INTRODUCTION

Screening bean cultivars for tolerance to low soil P availability is part of a larger effort involving several members of the African bean research networks to screen for tolerance to edaphic stresses, including low P and N, and high Al and Mn. Bean cultivars are being screened for low P tolerance at the Regional Research Centre of Kakamega, Kenya. Kakamega RRC is located at 34° 45' E and 0° 16' N at an altitude of 1585 meters. Rainfall has a bimodal pattern with an annual mean of 2024.5mm. Monthly mean temperatures vary little from the mean annual maximum and minimum temperatures of 27.0° and 14.1°C, respectively.

This paper presents results of the evaluation of 434 accessions from the national bean germplasm collection

MATERIALS AND METHODS

During 1991 and 1992, the field site was depleted of soil P by intensive cropping with a maize/ bean intercrop, sorghum and soyabeans. During this period, crops were fertilized with N, but not P, and all above-ground crop residues were removed from the field (Wortmann, pers. comm.). Soil samples were taken for P analysis before and after planting. The 1991 soil P levels ranged from 9-13 and 11-13 ppm in surface and sub-soil, respectively. A year later, soil P ranged from 6-8 ppm in the surface soil and 4-10 ppm in the sub-soil. Four hundred thirty four germplasm lines were acquired from the National Horticultural Research Centre near Thika in 1992. Seeds of these materials were multiplied in single row plots of 3 metres each and the entries were evaluated for growth habit, seed size, reaction to common diseases, general adaptation and yield.

During the long rains of 1993, 300 of the above accessions were evaluated under low P stress for yield, general adaptation and disease reaction. Of the 300 accessions, 156 had a determinate growth habit. Most had medium seed size (59.9%), 26.2% were classed as large and 13.9% as small. The entries were reduced to 30 bush and 20 semi-climbing types and evaluated further during the short rains of 1993. The entries were further reduced to 31 and compared to five local checks during the long rains of 1994. Screening was done in two row plots of 3 m with two replications in 1993 and three replications in 1994. Data was analyzed using the Nearest Neighbor Analysis of MstatC to account for variability in stress throughout the field.

RESULTS AND DISCUSSIONS

Yield performances for the 1993 short rains season are presented in Table 1 for the most promising cultivars. Of the common released varieties, e.g. GLP 2, GLP x92, GLP 1004 and GLP 24, only GLP2 performed relatively well. The failure of these otherwise well-adapted and high yielding

Table 1. Mean yield (kg ha^{-1}) of the best 30 bush and 13 Type III accessions grown under low P stress in the 1993 short rains at Kakamega RRC.

Bush types Accession no.	Yield	Type III entries Accession no.	Yield
GLP 988	757	GLP 1150	574
GLP 29	715	GLP 66	529
GLP 10	290	GLP 329	634
GLP 135	764	GLP 14	1005
GLP 64	379	GLP 233	325
GLP 939	442	GLP 4	455
GLP 1107	666	GLP 409	795
GLP 206	942	GLP 802	630
GLP 981	575	GLP 236	629
GLP 344	612	GLP 131	789
GLP 211	585	GLP 719	561
GLP 1085	547	GLP 1155	542
GLP 282	590	GLP 433	704
GLP 271	787		
GLP 1014	1000	Overallmean	633
GLP 392	676	LSD (0.05)	358
GLP 642	727		
GLP 2[1]	399		
GLP 290	562		
GLP 634	634		
GLP 8	715		
GLP 938	768		
GLP 425	818		
GLP 240	391		
GLP 1071	439		
GLP 38	971		
GLP 295	838		
GLP 351	664		
GLP 924	675		

[1] A well adapted check variety.

varieties to perform well under low P conditions confirms the importance of screening for tolerance to this stress.

In the long rains season, 1994, the released variety GLP x92 performed very well and GLP 585 moderately well, (Table 2), but the other check varieties, including GLP 2, GLP 24 and GLP 1004 performed poorly under low P stress. GLP 585 was found to have tolerance to low soil P and moderate tolerance to low soil N in Uganda, while GLP 2 was found to be susceptible under such stress conditions (pers. comm. Wortmann).

The entries have subsequently been reduced to 10, including 2 check varieties, GLP x92 and GLP 585.

Table 2. Mean yields (kg ha^{-1}) of 36 bean varieties evaluated under low soil P stress during the long rains of 1994 at Kakamega, Kenya.

Entry		Yield	Entry		Yield
GLP	x92 [1]	1183	GLP	988	404
GLP	351	1079	GLP	1211	344
GLP	123	824	GLP	135	337
GLP	393	805	GLP	2 [1]	326
GLP	635	718	GLP	24 [1]	302
GLP	29	715	GLP	938	292
GLP	344	702	GLP	240	292
GLP	1014	605	GLP	981	271
GLP	924	584	GLP	14	147
GLP	21	560	GLP	271	236
GLP	206	543	GLP	802	203
GLP	295	542	GLP	772	201
GLP	425	533	GLP	131	143
GLP	585 [1]	481	GLP	433	122
GLP	642	468	GLP	409	117
GLP	38	427	GLP	1150	93
GLP	719	427	GLP	939	80
GLP	8	426	GLP	1004 [1]	72

Mean = 435, LSD (0.05) = 244.9

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[1] Well-adapted check varieties.

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SCREENING BEANS FOR TOLERANCE TO LOW SOIL POTASSIUM AVAILABILITY

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INTRODUCTION

Potassium deficiency has not been a major limitation to crop production in most of eastern and southern Africa, but it is increasing in importance due to decline in the soil's capacity to supply K and due to intensification of crop production on marginal lands. K deficiency was determined to be the cause of "Usambara Mottle" in bean in the Lushoto area of northern Tanzania (Smithson *et al.*, 1993). Anderson (1974) observed frequent responses to applied K in 91 on-farm trials conducted on the lower slopes of Mt. Kilimanjaro in Tanzania. Symptoms of K deficiency are often seen in Uganda and frequent responses to applied K occur on ferralitic soils in Uganda (Foster, 1979), especially on soils that had been continuously cropped for several years. Low K availability may reduce bean yield by more than 300 and 100-300 kg ha^{-1} on 110,000 and 1,424,000 hectares, respectively, in Africa (Wortmann and Allen, 1994). K deficiency is most likely to occur on:

soils low in organic matter after many years of continuous cropping;
sandy soils formed from parent material low in K; and
sandy soils from which K has been leached.

The functions of K in plants are well discussed by Marschner (1986). K is highly mobile in plants. It is the most abundant cation in bean plants and plays a major role in regulation of osmotic potential of cells and tissues. K is important to the regulation of pH in chloroplasts and cytoplasm through the neutralization of macromolecular anions. Besides its function in pH stabilization and osmoregulation, K is required for enzyme activation and membrane transport processes. It is probable that K is involved in the translation of genetic codes for protein production. K has a role in stomatal movement -- an increase in K concentration in the guard cells results in water uptake and increased turgor of the guard cells, followed by stomatal opening.

Potassium moves in the soil through mass flow and diffusion. Generally, the K concentration of soil water is not sufficient to nourish the crop. Diffusion of K to the roots occurs over short distances such that the concentration gradient extends to about 4 mm from the root surface (Barber *et al.*, 1985). Therefore, good root growth is needed for adequate K nutrition when soil K availability is low.

K is highly mobile in the plant and is readily transferred from old to young leaves. K deficiency is manifest in bean as marginal yellow chlorosis on older leaves with the veins remaining green. Young leaves remain green but may be smaller than normal. K deficient crops lack vigor, mature late and yield less.

K deficiency in bean appears to be associated with susceptibility to root and stem rots, and probably to other diseases (Marschner, 1985). The high susceptibility of K deficient plants to fungal diseases is related to the metabolic functions of K. In K deficient plants, synthesis of high-molecular-weight compounds is impaired resulting in higher concentrations of smaller organic compounds. The smaller compounds more easily exude from the cells to the hyphae and may be preferred food of the parasitic fungi. Wounds of K deficient plants are slow to heal giving more opportunity for infection by pathogens.

K nutrition is probably important to tolerance to insect attack. The simple organic compounds which tend to accumulate with K deficiency are preferred by some piercing/sucking insects. Healing of the wounds caused by insects is delayed in K deficient plants.

Tolerance to low K might be through: improved capacity for nutrient uptake, probably through a more extensive root system; and improved K use efficiency, both for biomass yield and for seed yield through efficient remobilization of the vegetative K.

The genetics of tolerance was studied by Shea *et al.* (1968) who found that a single recessive gene (k_e) was important to K use efficiency in beans. The frequency of this gene in common sets of bean germplasm is not known.

SCREENING BEANS FOR TOLERANCE TO LOW K DEFICIENCY

The finding of Shea *et al.* (1968) that efficiency of K use in beans is a simply inherited trait encouraged us to evaluate 140 entries for low K tolerance at Kawanda ARI. The purpose is to identify tolerant cultivars, but also to determine the mechanisms of tolerance and the frequency of occurrence of the k_e gene in this set of entries. The frequency of occurrence of the k_e gene will influence future breeding efforts. If it is rare in occurrence, it might be incorporated into superior lines. If it is commonly occurring, there may be little progress to be made in improving K use efficiency.

Thirty two lines have been identified as being relatively tolerant (Table 1). Confirmation testing is continuing. Possible mechanisms of tolerance are:

a) efficiency in uptake of scarce K;

b) K use efficiency for vegetative growth;

c) remobilization of K from the vegetative to reproductive organs; or,

d) K harvest index.

The first two mechanisms are expected to be most important and the second is the most desired. We are attempting to determine the mechanisms operating in each of the varieties. Total K uptake at the beginning of R8 is an indicator of efficiency of uptake. K use efficiency is determined at R8 as the amount of biomass produced per unit of K in the plant. Remobilization of K from the vegetative to the reproductive organs is to be determined by comparing the total K in the vegetative parts of the plant at R8 and at physiological maturity. K harvest index, the ratio of seed K to K in the whole plant, may be related to tolerance.

Table 1. Bean varieties identified as promising for tolerance to low soil potassium availability.

BAT	1220	ARA	4	CAL	96	EMP	84
RIZ	109	RWR	109	A	433	MCM	2001
RIZ	102	DOR	375	BAT	25	DOR	335
MMS	243	MUS	97	BAT	85	PorrilloSintetico	
6088		ZAN	76	DOR	351	G	4000
AFR	403	RIZ	90	RAB	482	MMS	250
RIZ	103	A	283	RAB	471	RIZ	111
Suchitan		RWR	382	RAO	52	A	439

A major problem encountered in screening for low K tolerance has been susceptibility of the test lines to root and stem rots. Poor K nutrition is expected to reduce tolerance to damage by these pathogens. Root rot resistance may be an important aspect of low K tolerance. Root rot management through crop rotation and seed dressing apparently is important to effective screening for low K tolerance.

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SCREENING FOR TOLERANCE TO ALUMINUM TOXICITY IN BEAN

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INTRODUCTION

Aluminum is the major cation associated with soil acidity. Al toxicity commonly is problematic when soil pH is less than 5.2, while exchangeable Al is low above pH 5.5 (Coleman and Thomas, 1967). Legumes, particularly beans (Rowell, 1988), are sensitive to Al toxicity. While exchangeable Al can be reduced by liming, the practice is often uneconomical and it is difficult to neutralize the Al below the plow layer. Nutrients and moisture in the sub-soil are then under-utilized because of restricted root growth. An alternative solution is to grow crop species or varieties which tolerate high Al levels.

Crop genotypes with tolerance to high Al levels have been successfully bred. Al tolerant wheat and sorghum varieties have been released (Foy, 1988), and genetic variability for Al tolerance in bean has been reported (Foy *et al.*, 1972; Salinas, 1978).

Al toxicity constrains bean yield once Al saturation exceeds 10% (Lunze, 1992), and may be problematic on 75% of the soils in the highlands of eastern Zaire, Burundi (Wouters *et al.*, 1986) and Rwanda (Rutunga and Neel, 1980).

In this paper, screening techniques are reviewed and the results of screening bean for tolerance to Al toxicity in Mulungu Research Station are reported.

SCREENING METHODS FOR ALUMINUM TOXICITY

Rapid screening

Screening techniques must efficiently detect differences in genotypes for reactions to applied stresses in the field. Plant traits measured must be those which reflect response to the applied stress. While several mechanisms of Al toxicity have been reported, most rapid screening techniques are based on root growth in medium with high Al concentration. The relative root elongation of the seedling tap root in high Al medium (soil or solution) compared to low Al medium is a commonly used measure of tolerance. This measure in the field, however, is only reliable within a few days following germination (Hill *et al.*, 1990).

Prolonged exposure to Al toxicity affects shoot growth. Salinas (1978) observed less growth at higher Al levels in nutrient solution. Leaf area of four bean varieties decreased as Al concentration was increased from 25 to 300 umoles (Lunze, 1991). Al toxicity induces P deficiency (Lee and Foy, 1986; Rowell, 1988) which is expressed in bean as fewer and smaller leaves, i.e. less leaf area (Lynch *et al.*, 1990). Therefore, shoot growth and leaf area index are plant parameters which might indicate tolerance to Al toxicity. By growing plants in high Al solution, Ramalho *et al.* (1982) found dry plant weight at flowering to be a good indicator of tolerance in the field. Recovery of plants, which were stressed with high Al at early stages, when restored to non-stress conditions is apparently an important mechanism of high Al tolerance in barley (Buchholtz and Schuster, 1987).

Two rapid screening techniques were evaluated for bean. With the first, at three days after germination, seedlings were rolled in paper soaked with nutrient solution, either with or without Al (Konzak *et al.*, 1976). With the second method, root elongation in acid soil was compared to elongation in soil of moderate pH when the plants were grown in conical plastic test tubes of 20 cm length. Root length was measured after 3 or 4 days of growth. The second method was most efficient for screening bean varieties for tolerance to Al toxicity (Lunze, 1991). The results of the second technique explained much variation in the field (Spearman's rank correlation coefficient of 0.49), and the technique adequately differentiates between susceptible and tolerant genotypes to confidently eliminate the most susceptible.

Field screening

Screening of bean genotypes has been conducted for three seasons at Kidumbi site of Mulungu Research Station. Entries were evaluated under stress (37% Al saturation and 4.7 pH) and limed, non-stress (7% Al saturation and 5.5 pH) conditions. The stress level was intended to be sufficient to reduce yields to 50% of non-stress conditions. Fertilizer was applied to supply deficient nutrients. The ratio of stress : non-stress yield was the main selection criterion, but plant vigor and the expression of toxicity symptoms were considered. Varieties with a stress : non-stress yield ratio of greater than 0.85 were considered tolerant, provided they performed well under non-stress conditions.

Varying levels of Al throughout the screening site has been a problem. Much of the variation is accounted for by placing a sensitive check variety after every five test genotypes.

The ANSES evaluations

A set of 280 bean genotypes of the first cycle of the Africa Network for Screening for Edaphic Stresses (ANSES) was evaluated under stress conditions only during the first season of evaluation. The soil pH was 4.4, but it was subsequently amended by applying one ton of lime to 4.7. After one season of testing, 50% of the entries were selected for further evaluation under both stress and non-stress conditions. Testing during the first two seasons was done with two replications. After the second season of testing, 50 entries were selected and tested in multi-location trials for two cropping seasons. The soil characteristics of the sites are given in Table 1. The yield of the best varieties is presented in Table 2. The performance at Nyamunyunye was very poor and the results are not presented.

Table 1. Soil properties for four high Al test sites in Zaire.

Properties	Sites			
	Kavumu	Burhale	Mubumbano	Nyamunyunye
pH water	4.6	4.6	5.1	4.7
KCl	4.1	4.0	4.3	4.0
Organic C (%)	3.3	1.2	2.2	2.3
P Bray I (ppm)	7.2	3.8	0.1	0.5
Ca exch. (meq/100g)	2.1	1.2	2.3	2.6
Mg exch. (meq/100g)	0.8	0.6	0.3	1.1
K exch. (meq/100g)	0.11	0.09	0.07	0.07
Al exch. (meq/100g)	6.26	4.00	3.52	2.67
Al saturation (%)	67.6	67.9	56.4	41.8

Table 2. Yield (kg ha^{-1}) under high Al stress of the best 21 of 50 bean varieties in multi-location trials.

	1993a season		1993b season		
Varieties	Kavumu	Burhale	Kavumu	Burhale[1]	Mubumbano[1]
7/4 ACC	751.3	250.0	170.0	130.8	431.7
MUYINGA	394.6	175.0	225.0	179.0	595.8
NTEKERABASILIMU	570.9	29.2	150.0	62.5	79.2
EM 24/6	178.3	91.7	166.0	91.7	300.0
IZO 0201461	144.2	83.3	208.3	95.8	241.7
RWR 28B	241.7	0.0	145.8	41.7	241.7
UBUSOSERA	272.1	41.7	316.7	12.5	16.7
ACV 22	375.5	33.3	62.5	112.5	87.5
KIRUNDO	164.6	41.7	166.7	137.5	120.8
PAD 124	172.9	70.7	195.8	91.5	95.8
AFR 476	186.7	112.5	16.7	58.3	229.2
NANGURUBWA	205.4	93.8	166.7	94.2	25.0
AFR 300	85.4	16.7	150.0	93.3	169.2
RAB 415	164.6	45.8	225.0	104.2	38.3
RWR 612	233.6	29.2	166.7	50.8	100.0
EM 6	209.6	16.7	208.3	95.8	37.5
AFR 344	270.0	41.7	33.3	83.3	79.2
EM 73	117.1	133.3	41.7	20.8	154.2
URUGEZI	147.9	29.2	125.0	93.3	70.0
CAL 32	128.9	45.8	166.7	41.7	75.0
RWR 603	234.6	29.2	83.3	52.5	35.8
Mean	296.4	49.5	180.2	27.9	55.8
LSD 0.05	192.9	105.6	189.1	42.0	114.4

[1] Several varieties gave no yield at the Burhale and Mubumbano sites.

Promising varieties have been distributed to other national bean research programs to confirm their tolerance.

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SCREENING BEAN GENOTYPES FOR TOLERANCE TO MANGANESE TOXICITY

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ABSTRACT

Manganese toxicity is often a major constraint to bean production on low pH soils. In Uganda, it has been associated with crush breccia ridges in Buganda and Andosols in the southwestern highlands. Two hundred and eighty varieties were evaluated for tolerance to Mn toxicity over three seasons. Varieties with small seed tended to be more tolerant than those with large seed. Black seed types were generally more tolerant than types with other seed colours. However, several medium to large seeded Calima types showed good tolerance. MCM 5001, with a small tan seed type, performed best under the high Mn conditions. Several Rwandan varieties, including RWR 382, RWR 982 and RWR 980, were relatively tolerant. XAN 76, which has proven to be tolerant to scarcities for several nutrients, was relatively tolerant to Mn toxicity.

INTRODUCTION

Mn toxicity is commonly associated with low pH soils (Foy, 1984) which account for 70% of the soils of humid tropical regions (Sanchez, 1976). Soils with a high sesquioxide content often are high in Mn (Kamprath, 1984). Conditions favouring Mn toxicity include: parent materials high in Mn such as crush breccias, laterite rocks and volcanic rocks (Le Mare, 1977); low soil pH; low Ca : Mn ratio; poor drainage; and soil compaction (Foy, 1973; 1980). Mn toxicity generally occurs in soils with a pH of 5.5 or less, but can occur at higher pH and in the absence of Al toxicity if poor aeration enhances reduction of Mn^{+4} to Mn^{+2} (Foy, 1973, Le Mare, 1977).

In Uganda, Mn toxicity has been associated with patchy, unproductive soils called "lunyu" in Buganda. On such soils, toxicity problems occur on well-drained soils of moderate soil pH and moderate soil organic matter levels. Such soils are often found near crush breccia (brecciated quartzose rocks) ridges with high Mn and Fe contents in the breccia (Chenery, 1960; Wayland, 1921). Thus soils derived from alluvium washed from these ridges are likely to be high in total Mn. An observation is that "lunyu" soils are commonest near swamps.

Species vary in their tolerance to excess Mn, but legumes generally are more susceptible than non-legumes (Foy, 1976). In Uganda, beans, banana, cotton, simsim and groundnuts have been observed to be relatively susceptible while tea, sweet potatoes, finger millet and soybeans are relatively tolerant (Chenery, 1954; Jones, 1976; Le Mare, 1977).

Symptoms of Mn toxicity vary with species and genotypes. Crinkled leaves are a common symptom. Brown spots surrounded by chlorotic zones due to concretions of precipitated Mn are symptomatic in some legume species (Foy, 1983). Symptoms of deficiencies of Fe, Mg or Ca induced by high Mn may prevail in some cases (Foy *et al.*, 1981). In bean, symptoms begin as chlorosis of the margins of younger leaves with the yellowing progressing to the interveinal areas. The margins curl down and develop a crinkled, puckered appearance, with the eventual appearance of brown specks. The leaf and petiole blacken and fall from the plant.

Mechanisms of tolerance to Mn toxicity are located in the shoots (Heenan *et al.*, 1976). Tolerance to Mn toxicity may be due to restricted translocation or confinement of the excess Mn, or due to ability of the plant tissue to tolerate the excess Mn. Critical Mn toxicity levels of leaf tissues differ between and within plant species (Horst, 1983). Mn is uniformly distributed in mature leaves of tolerant genotypes, but concentrated in concretions in susceptible genotypes. Restricted translocation of Mn to young leaves may be involved in tolerance (Blatt and Diest, 1981), possibly through the formation of stable Mn-oxalate complexes (Menon and Yatagawa, 1984). Tolerance to excess Mn may be related to tolerance to Al toxicity (Foy *et al.*, 1973; Nelson, 1983).

Rapid screening techniques for tolerance to excess Mn have not been effective for bean. Tolerance under field conditions may differ from that in the lab, and tolerance during the vegetative stage may differ from tolerance during the reproductive stage (Kang and Fox, 1980). A possible rapid screening technique, which involves application of Mn to the petioles of leaves, has been tried on bean, soybean, cotton and cowpea (Horst, 1982). As destruction of indole - 3 - acetic acid (IAA) by indole - acetic acid oxidase (IAAO) is an effect of Mn toxicity in cotton, IAAO assays might be used to screen for tolerance to Mn toxicity (Kennedy and Jones, 1991).

Mn^{+2} availability is largely dependent on reducing conditions which are largely dependent on soil pH and soil aeration. Mn also interacts with other nutrients including Fe, P, Ca and Mg resulting in abnormal rates of uptake. Some P fertilizers can increase Mn uptake (Page, 1962; Larsen, 1967), possibly due to the acid solution that diffuses through the soil from a bank of mono-calcium phosphate which carries a high concentration of Mn (Lindsay *et al.*, 1959). Rhizospheres of some crops are more reducing than of other crops (Bromfield, 1958) and the reducing nature of the banana rhizosphere may have been the cause of higher Mn levels in leaves of bean grown under bananas relative to sole crop levels (Wortmann *et al.*, 1992).

Mn^{+2} levels, or their toxic effects on crops, might be managed through raising soil pH, improving aeration, application of organic manures, and ensuring a proper Ca : P ratio (Jones, 1976; Le Mare, 1977; and Zake, 1986).

Genetic variation within species for tolerance to low soil pH complexes has been observed for several crops (Neenan, 1960; Foy *et al.*, 1967), with varying sensitivities to Al toxicity, Mn toxicity, and low soil P availability (Foy *et al.*, 1973). This genetic variability provides the opportunity to better adapt crop species to low pH soils (Brown and Jones, 1977).

This paper presents results from the field screening of 280 bean varieties for tolerance to Mn toxicity.

MATERIALS AND METHODS

The first cycle of the ANSES (African Network for Screening for Edaphic Stresses) consisted of 280 entries collected from national bean research programmes in Africa. These materials were evaluated for tolerance to Mn toxicity under field conditions at Buikwe, and later Sempa, in Uganda. Details of trial designs are presented in Table 1. All trials were conducted under high Mn stress. Climbing and non-climbing types were tested separately. Check varieties were G2333 for the climbers, and Carioca and K20 for the non-climbers. Susceptible varieties were rejected after the first and second season of testing. Observations were made on emergence, vegetative vigour, symptoms of high Mn during the late vegetative stage, amount of brown specks during pod elongation, and yield. Seed yield

Table 1. Details of trial designs.

Season	Number of entries	Number of reps	Plot size	Trial design
1991B	280	2	2.4 m^2	RCBD
1992A	124	4	3.9	RCBD
1992B	36	4	5.4	6 x 6 lattice
1993A	36	4	6.9	6 x 6 lattice

Table 2. Yields of 34 varieties selected from a set of 280 for tolerance to Mn toxicity.

Variety	Yield (kg ha^{-1})		
	1992 b	1993 a	1993 b
MCM 5001	1268	1133	1256
ZPV 292	761	513	
NEPA 29	726	583	
BLACK DESSIE	1004	500	
OBA 1	746	413	
DOR 404	606	257	
PVA 774	646	387	
PAD 126	813	737	
A 197	907	597	
XAN 76	1394	707	1290
AFR 378	856	607	
CAL 96	683	623	
RUBONA 5	765	787	
SUG 69	757	710	
AFR 531	811	753	
AND 871	1003	680	
LRK 29	626	427	
RWR 982	846	770	
IZ 021240	926	557	
URUGEZI	1094	727	1000
AND 829	572	353	
SUA 90	518	230	
AFR 476	715	483	
RWR 960	826	1093	1046
A 120	1217	453	
AFR 544	567	287	
AFR 13	481	517	
RWR 221	1248	650	
URUBONOBONO	759	350	
LYAMUNGU 85	772	440	
MCM 2001	706	67	1000
NEPA 38	507	437	
RWR 382	1241	590	
KID 54	939	897	
K20 (check)	467	410	793
CARIOCA (check)	617	190	
LSD 0.05	378	--	--

was the primary selection criterion, but the other observations were considered. To account for variation in the stress across the field, plot values were adjusted by the mean yield of the two or four adjacent plots.

RESULTS AND DISCUSSION

Yield results are presented (Table 2) for the 34 entries selected from a set of 280 after two seasons of evaluation. The level of the stress is indicated by the poor performance of the well-adapted check varieties. MCM 5001, a recently released variety in Uganda, has given the best performance under high Mn conditions. CAL 96 and OBA 1, two other recently released Ugandan varieties of Calima seed type, have also performed well under the high Mn conditions. MCM 2001, a fourth Ugandan release, gave a fair performance largely because of consistently poor emergence under high Mn conditions. The good performance of XAN 76 is of interest as it has been found by other ANSES collaborators to be tolerant to low availabilities of several nutrients and to be moderately tolerant of Al toxicity. Several Rwandan varieties of the RWR series have done well under high Mn conditions.

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RESULTS OF TESTING FOR TOLERANCE TO A LOW pH COMPLEX IN MALAWI

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INTRODUCTION

Bean (*Phaseolus vulgaris* L.) is important in the diet of Malawian people. It is widely grown in sole crop and in intercrop, usually with maize, at mid (1100 m) to high altitudes (1500 m and above), but with increasing population pressures and intensive land cultivation, soil fertlity is becoming increasingly important. Low soil fertility constrains production of major crops and most farmers can not afford chemical fertilizers to restore acceptable fertility levels in their fields.

Usually low P and N and Al toxicity associated with low soil pH are the main soil fertility related constraints to bean yields in Malawi (Mughogho, 1975). Similar problems exist in other parts of Africa (Rachier, 1994; Wortmann, 1994). Centro Internacional de Agricultura Tropical (CIAT), in close association with the national bean program in Malawi, has started a bean improvement program to develop varieties that can tolerate poor soil fertility conditions. The work is carried out at the Ministry of Agriculture research sub-station at Bembeke (1650 m, 14° 19'S and 34° 15'E). The average annual rainfall is approximately 900 mm falling in a single growing season (November to April), and the mean temperature is around 19°C.

The work was started in the crop season of 1992-93. The site selected has low pH, low P and high exchangeable Al. It is also low in available N, and probably some micro-nutrients. Screening of beans has been done using different of levels of lime to neutralise exchangeable Al, different levels of P and N, and addition of zinc and boron. Three experiments were conducted, one in the 1992-93 and two in the 1993-94 crop seasons.

GERMPLASM EVALUATION

A set of 350 entries of the ANSES II (Bush) were tested in the 1993-94 crop season in a RCBD design with two replications. The plot size was a single row, 3 m long. The soil analysis, before planting of the trial, showed a pH of 4.8 in water and P (Bray) levels of 2.45 to 2.70 ppm. In one replication, 30 kg N, 30 kg P, 0.5 kg B and 5 kg zinc oxide were applied per hectare. No fertilizer was applied in the second replication. In both replications, however, neither P and lime were applied in order to select for tolerance to low P and Al toxicity. Therefore, varieties were compared under high fertility stress (no fertilizer) versus some application of N and other nutrients, but without any P and lime.

Highly significant differences for grain yield were observed among varieties, indicating the presence of genetic variability for tolerance to low soil fertility. The mean grain yield was higher in the replication where fertilizer was added (549 kg/ha) as compared to the one where no fertilizer was added (328kg/ha). Grain yield ranged from 67 to 1491 kg/ha in the replications with, and 1 to 1236 kg/ha without, fertilizer. The performance of varieties without fertilizer is of interest as varieties which tolerated this complex of stresses, and produced reasonable grain yield of more than 750 kg/ha, represented both the Andean and the Mesoamerican gene pools.

Among the top 40 varieties (Table 1), some were good only under better fertility, others at low fertility, and some at both fertilty levels. A relatively high proportion of these varieties were also selected for tolerance previously in Zaire and Uganda, suggesting some consistency in selection of germplasm. Many UBR lines contributed by CIAT, Uganda performed well under stress and originated from a few closely related crosses. Their parentage requires further evaluation. Overall the results obtained in this study clearly indicated that it is possible to select bean germplasm adapted to low soil fertility.

Table 1. Best performing lines from the ANSES II planted at Bembeke, Malawi, 1993-94.

Line	Seed yield (kg/ha)		Line	Seed yield (kg/ha)	
	Basal fertilizer	No fertilizer		Basal fertilizer	No fertilizer
433	958	837	RAO 55	1111	840
A 321	1294	1094	RWR 5	1047	586
A 585	1491	657	RWR 109	953	949
AFR 609	457	1222	RWR 382	712	605
AFR 637	1072	510	SUG 74	531	811
AND 1011	1188	876	SUG 83	1271	475
AND 925	795	728	UBR (92)02	614	674
AND 983	1204	414	UBR (92)11	1283	707
ARA 4	1761	813	UBR (92)13	1057	605
BAT 85	730	763	UBR (92)18	760	651
CNF 5506	737	769	UBR (92)25	738	621
F$_8$ DC 86-244	661	833	UBR (92)29	399	886
A 286	703	1236	UBR (92)30	697	1011
G 5059	513	810	ZAN 97	683	643
G 5706	823	517	ZPV 292	789	643
KID 31	753	727			
AFR 499	728	581	**Controls:**		
IKINIMBA	1045	637	CAL 143	596	392
IZ 0201240	631	689	PHALOMBE	709	260
MCM 2203	1109	643	.CARIOCA	471	115
MCM 5001	808	866			
OBA-1	398	737	Trial Mean	549	328
PAI 149	1039	433	S.E.	132.6	

RESPONSE OF BEAN VARIETIES TO LIME AND PHOSPHOROUS

Crop response to applied P and lime was evaluated in the 1992-93 crop season using 15 varieties and in the 1993-94 crop season using 8 varieties.

In the 1992-93 crop season trial, the main factor was calcitic lime, with levels sufficient to neutralise 0, 25, 50, 75 and 100% of the exchangeable Al. 100%+P was included considering levels of P were 1.4 ppm in the top 0-15 cm soil. The experiment was replicated thrice. Data were recorded on nodule number, nodule weight, shoot weight, root weight and grain yield. Although performance of varieties was poor due to low fertility, liming caused a linear increase in nodule number, nodule weight, and grain weight upto 75% levels of aluminium neutralization (Table 2), but declined at higher levels except for root and shoot weight. The decline at higher levels may be due to nutrient imbalances induced by lime application. Shoot and root weight were inconsistently affected by liming.

Table 2. Mean values of five characters in a soil fertility trial at Bembeke, 1992-93.

Lime level to neutralize (%) exch. Al	Seed yield (kg/ha)	Nodules/plant	Nodule weight (mg/plant)	Root weight (g/plant)	Shoot weight (g/plant)
0	147	0.85	7.59	0.41	1.59
25	161	1.52	13.98	0.42	1.63
50	153	2.43	19.11	0.40	1.41
75	266	5.01	37.29	0.43	1.78
100	235	3.95	32.46	0.43	1.64
100+P	253	4.84	44.93	0.44	1.71
SE	194.2	0.920	6.883	0.039	0.159

Three varieties, Sankana, Ngwangwa and Masai Red, from Zambia, and G 16140 from CIAT, Colombia, appeared to be the most promising (Table 3). Low fertility areas of northern Zambia were the source of the three varieties suggesting that more tolerant varieties might be found there.

The 1993-94 season trial had a split-split plot design, where the main plots were P treatments (0 and 20 kg P/ha), the sub-plots were lime applications to neutralize 0, 50, 75 and 100% exchangeable Al, and the sub-sub-plots were eight bean varieties. The whole experimental site received a basal dose of borate at 0.5 kg B, zinc oxide at 5.0 kg Zn, muriate of potash at 30 kg K and urea at 30 kg N per hectare. The experiment had three replications.

Data were recorded on nodule number, shoot weight, root weight and grain yield. Application of P produced significant differences in grain yields and other characters, but the local variety, Phalombe, was most responsive to P with a yield increase from 444 kg/ha at 0P/0Lime to 910 kg/ha at 20P/0Lime. The most tolerant variety appeared to be CAL 143, which produced the highest mean grain yields at different fertilty levels (Table 4).

Table 3. Mean performance of 15 varieties for yield and other characters in the low fertility trial at Bembeke, Malawi, 1992/93.

Varieties	Nodules/plant (mg/plant)	Nodule weight (g/plant)	Root weight (g/plant)	Shoot weight (kg/ha)	Seed yield
Calima	2.99	20.13	0.48	1.57	212
Pintado	1.81	17.26	0.36	1.78	180
G 5059	2.38	12.88	0.43	1.56	86
BAT 477	1.54	14.74	0.37	1.29	215
Carioca	2.17	20.07	0.33	1.42	243
A 283	2.07	10.70	0.35	1.08	97
G 16140	7.64	69.80	0.59	1.85	215
Kabulangeti	4.26	47.45	0.40	2.03	146
Sankana	4.88	44.69	0.45	1.99	336
Ngwangwa	4.58	30.56	0.49	1.95	307
Masai Red	2.49	28.21	0.44	1.67	299
C. Mukulu	3.74	29.27	0.44	1.82	236
G 19428	3.69	17.57	0.45	1.36	162
2-10	1.54	19.22	0.40	1.79	178
Rio Tibagi	0.72	5.87	0.32	1.27	127
SE	0.871	6.361	0.031	0.136	99.1

Table 4. Variety means of four characters studied in the soil fertility trial at Bembeke, Malawi, 1993/94.

Variety	Seed yield (kg/ha)			Nodules perplant			Shoot wt (g/plant)			Root wt (g/plant)		
	0P	20P	Mean	0P	20P	Mean	0P	20P	Mean	0P	20P	Mean
RWR 221	852	927	890	0.70	0.35	0.52	8.74	9.22	8.98	0.80	0.77	0.78
AND 873	905	1196	1050	0.28	0.12	0.20	5.63	7.34	6.48	0.62	0.92	0.77
MLB-40-89A	703	760	732	0.42	0.30	0.36	8.53	7.62	8.07	0.85	0.98	0.91
CAL 143	1054	1208	1131	0.93	2.03	1.48	8.63	12.51	10.57	0.81	0.92	0.87
Rio Tibagi	887	1137	1012	1.55	2.95	2.25	8.06	12.69	10.38	0.99	1.23	1.11
A 74	885	967	926	1.07	1.28	1.17	6.17	9.21	7.69	0.70	0.91	0.81
H2 Mulathino	885	1085	985	0.67	0.92	0.79	6.31	8.07	7.19	0.65	0.80	0.72
Phalombe	784	847	816	0.20	0.37	0.28	6.66	7.27	6.97	0.55	0.50	0.53
SE (P)		21.7			0.108			0.528			0.028	
SE (V)		80.4			0.233			0.797			0.057	
SE (P x V)		67.5			0.411			1.252			0.085	

Liming effects were not significant. Nevertheless, seed yield, nodule number, shoot weight and root weight increased with limimg up to the 25% Al neutralization level at zero P. At other P and lime levels no specific trend was observed. The results were somewhat similar to the previous experiment, where a linear response was also observed, but up to 75% Al neutralization. This difference could be attributed to various soil nutrients (N, K, B, Zn) applied as a basal dose in this experiment, whereas no such nutrients were applied in the previous experiment.

In conclusion, the experiments have shown major varietal differences in overall performance under different levels of fertility stress, confirming the potential of selecting bean cultivars tolerant to low soil fertility, either for release as varieties or for use as breeding parents.

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SCREENING BEAN GENOTYPES FOR SALT TOLERANCE

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INTRODUCTION

Dry beans are very sensitive to soil salinity and alkalinity. Soil salinity is a major constraint to bean production in Northern Sudan, and the salinity problem is aggravated under hot, arid conditions. The objective of this study was to evaluate different dry bean genotypes for tolerance to soil salinity.

METHODOLOGY

Thirty eight dry bean genotypes, including local material plus introductions, were evaluated for salt tolerance by growing them on two soil types:

a) a non-saline 'Karu' soil and

b) a high terrace saline soil

Properties of these soils were: 0.7 and 3.8 mmohs cm^{-1} EC; 12.2 and 19.0 meq l^{-1} Na; 3.7 and 2.7 meq l^{-1} Ca + Mg; and 8.0 and 8.5 pH for the 'Karu' and saline soils, respectively.

On both soil, seeds were sown on both sides of ridges 60 cm apart at a seed rate of 20 cm between holes and two seeds per hole. Trials were sown during the second week of November 1993 in a randomized complete block with three replications. Plot size consisted of 3 ridges (1.8 x 4 m). For the non-stress trials on 'Karu' soil yield component analysis was done on 5 randomly selected plants and 3 m of the three ridges were harvested for final yield. For the high terrace saline soil, plant counts at 35 (C1) and 90 (C2) days after sowing were recorded and considered important indicators of tolerance. Seed yield of surviving plants was also recorded.

RESULTS AND DISCUSSION

Varieties differed for yield on the non-saline 'Karu' soil. The differences were associated with highly significant differences in number of pods per plant, number of seeds per pod and seed size (Table 1). The best yields were obtained with genotypes HRS 614 and HRS 534. These were followed by Beladi (local check), HRS 341 and R/0/21/(released variety). The poorest yields were obtained with genotypes AFR 478, RAO 55 and AND 667.

Emergence was not affected on the saline soil, but emerging seedlings were generally stunted and yellowish in color compared to those of the non-saline 'Karu' soil. Two weeks after sowing, salt injury symptoms (stunted growth, marginal leaf burn followed by the complete death of the seedling) were very clear. Highly significant differences in the number of surviving plants were observed (Table 2). Accordingly genotype PEF 9 was rated as most tolerant. This was followed by genotypes PEF 14 and G2816. CIAT 23 was rated as the most susceptible. Seed yield was very low under the saline soil conditions and differences were non-significant (Table 2). It is very likely that genotypic differences for yield potential were masked by the high level of salinity stress.

The lack of relationship between yield under non-saline conditions (Table 1) and stand counts under stress (Table 2) is of interest. The introductions performed poorly compared to the local varieties under non-saline conditions suggesting poor adaptation of the introductions to high temperature and/or arid conditions. However, several of these introductions had relatively good plant survival under saline conditions indicating tolerance to salinity, while being apparently susceptible to high temperatures and arid conditions. HRS 614 and HRS 534 gave the highest yield under non-saline conditions, but had poor plant survival under saline conditions. The results suggest that tolerance to heat and arid conditions is not closely related to salinity tolerance. The results demonstrate potential for obtaining salinity tolerance in introduced materials.

Table 1. Yield and yield components of dry bean genotypes grown on non-saline 'Karu' soil.

Genotype	Yield kg/ha		No.pods/ plant	No.seeds/ pod	TSW (g)
HR 614	968	A	9.7	2.6	212
HRS 534	961	A	7.3	3.2	245
Beladi	898	AB	6.7	4.2	162
HRS 341	896	AB	7.7	3.7	214
R/O/21	875	AB	8.0	3.8	227
RedMexican	851	ABC	7.3	3.2	241
Giza	818	ABC	7.0	3.8	214
HRS 545	770	ABCD	5.3	3.5	243
HRS 537	770	ABCD	9.7	2.7	232
8R	732	BCD	7.3	3.6	197
Berber Large	719	BCD	5.3	3.5	262
HRS 514	708	BCD	6.3	3.3	240
Salwabrown	799	BCDE	7.3	3.9	160
PEF 9	682	BCDEF	8.0	4.0	172
CIAT 69	638	CDEFG	7.3	2.8	212
CIAT 85	636	CDEFG	6.7	5.5	172
P1	624	CDEFG	8.3	3.2	172
Basabeir	622	CDEFG	5.7	4.3	172
G 2816	583	DEFGH	7.3	3.0	137
PEF 14	575	DEFGH	6.7	2.8	264
SUG 50	478	EFGHI	3.7	2.6	229
PEF 7	460	FGHIJ	4.7	3.6	209
CIAT 37	460	FGHIJ	7.0	3.0	218
GLP 92	458	FGHIJ	5.3	2.9	236
CIAT 23	440	GHIJ	6.0	3.1	306
GLP 2	420	GHIJ	4.7	2.2	245
PEF 2	302	HIJ K	5.0	3.1	185
K20	324	IJ KL	3.3	3.4	207
AND 661	264	IJ KLM	6.7	2.7	169
AND 618	253	IJ KLM N	4.7	2.9	196
IRZ 111	249	J KLM N	5.3	3.4	105
PAN MEKO	183	KLM NO	6.0	2.0	200
RWK 3	124	LM NO	6.0	2.8	184
MARENGUE	117	LM NO	7.7	3.4	137
NIC 145	106	LM NO	4.7	2.2	115
AFR 478	65	M NO	2.0	2.7	136
RAO 55	39	NO	3.7	4.3	87
AND 667	24	O	2.0	1.7	151
S.E.	68	-	0.9	0.4	13.2
Sig. Level	***	-	***	***	***

Figures followed by the same letter are not significantly different (P=0.05). ***: significant at (P = 0.001).

Table 2. Number of plants and seed yield on a high terrace saline soil.

Genotype	Plant C1	Count C2	Seed yield (g 4.8 m^{-2})
PEF 9	230 A	177	21.7
PEF 14	219 AB	142	11.8
G 2816	217 AB	170	5.9
Berber large	206 ABC	150	15.0
HRS 537	204 ABC	144	14.8
R/0/21	200 ABC	167	40.2
PEF 7	200 ABC	153	8.1
AND 661	194 ABC	114	1.9
AND 618	192 ABC	110	6.5
Salwa brown	191 ABC	104	3.5
CIAT 85	189 ABC	119	15.7
HRS 514	188 ABC	143	42.3
Giza 3	186 ABC	123	23.7
PEF 2	182 ABCD	129	0.2
Red Mexican	181 ABCD	103	9.9
GLP 92	181 ABCD	109	9.9
HRS 545	179 ABCD	116	28.8
NIC 145	179 ABCD	104	2.0
Basabeir	179 ABCD	122	18.4
HRS 341	175 ABCD	127	25.3
Beladi	173 ABCDE	130	18.9
IRZ 111	173 ABCDEF	91	0.8
CIAT 69	168 ABCDEF	87	3.8
SUG 50	165 ABCDEF	99	12.7
HRS 614	162 BCDEFG	43	0.7
MARENGUE	161 BCDEFG	121	14.6
AND 667	161 BCDEFG	95	0.1
K20	159 BCDEFG	47	0.6
GLP 2	159 BCDEFG	80	0.4
8 R	159 BCDEFG	110	6.8
P1	158 BCDEFY	108	46.2
RWK 3	149 CDEFG	96	1.0
PAN MEKO	147 CDEFG	88	3.1
HRS 534	146 CDEFG	76	21.4
CIAT 37	122 DEFG	75	2.6
RAO 55	144 EFG	49	0.03
AFR 478	112 FG	77	1.7
CIAT 23	104 G	88	4.8
S.E.	18 -	26	10.2
Sig. level	*** -	*	ns

ns, * and *** indicate not significant, and significant at P = 0.05 and 0.001, respectively.

ISSUES OF SITE MANAGEMENT AND SCREENING METHODS -- DISCUSSION AND RECOMMENDATIONS

The name

It was agreed that the Africa Network for Screening for Edaphic Stresses (ANSES) as a name for this research effort has some inadequacies. ANSES does not include mention of beans. The word "network" is commonly used with another meaning by the same audience. The work excludes screening for many other edaphic stresses. The working group agreed the ANSES should henceforth be called Bean Improvement for Low Fertility in Africa (BILFA).

The stresses

Previously, screening was done for single stresses. While soil fertility problems commonly are complexes of two or more stresses, complexes are highly variable. Screening for tolerance to complexes may have a direct application if the primary objective is to identify adapted genotypes that can be used by farmers who produce beans under such a complex. Alternatively, if the objective is to identify genotypes which have tolerance genes to specific stresses, then emphasis should be on screening under single stresses. Such genotypes can be utilized as parental lines in a breeding programme to generate nurseries for specific stresses and may also have moderate tolerance to a number of other stresses. As complexes are highly variable, it is difficult to screen for tolerance to a complex of stresses on a pan-African basis.

The two major complexes of soil related stresses of concern are:

low N and P at moderate pH; and,

low P, low Ca, high Al and Mn at low soil pH.

The advantages of screening for tolerance to complexes of stresses are: cultivars adapted to such production conditions are easily identified; and fewer screening nurseries are needed and less resources are required. Disadvantages include: the representativeness of the complex is questionable; and individual genotypes with specific tolerance are overlooked.

The working group has set its priorities to focus on:

1) low P at moderate soil pH (>5.0);

2) low N at moderate soil pH (>5.0); and

3) a low soil pH complex which is likely to include low Ca, high Al, low K and high Mn.

The first two are single stresses under moderate pH while the last is a complex of stresses under low pH.

The sites

Some changes were recommended in the sites for both primary and secondary screening for the various stresses. The following was recommended.

Screening will be done at two altitudes;

a) medium altitude (1200 to 1600 m asl)

b) high altitude (1700 to 2200 m asl).

Researchers at the primary sites will take the leading role in coordinating with collaborating scientists in various countries to put together germplasm and form nurseries for specific stresses. These nurseries will be evaluated at primary sites first and at secondary sites latter. The primary and secondary sites for all three stresses are presented below.

Table 1. Recommended sites for BILFA activities.

NUTRIENT STRESS	PRIMARY SITE	SECONDARY SITE
Low Nitrogen	Malawi (MA)	N. Tanzania
	Uganda (MA)	Ethiopia
	S. Tanzania (HA)	Rwanda
Low Phosphorous	Uganda (MA)	N. Tanzania
	Kenya (MA)	Malawi
	Rwanda (HA)	Ethiopia
	S. Tanzania (HA)	
Low pH complex	Malawi (MA)	Zambia
		Madagascar
	Zaire (HA)	Rwanda

MA = Medium altitude; HA = High altitude

Secondary sites will not be limited to ones listed above, but the promising entries will be available to others who wish to do the evaluations.

Site management and screening procedures

Levels of stress

For both single stresses or complexes, germplasm will be screened at two levels. All entries should first be well evaluated at moderate stress levels, i.e. when a well-adapted control variety under stress performs at 40 to 50% of its normal unstressed performance (Table 2). Promising materials should also be screened at high stress, i.e. when the control variety gives no yield under stress, in order to identify potential parents with high levels of tolerance.

Selection criteria

Germplasm should be evaluated primarily for yield under stress, as well as expression of deficiency symptoms and plant vigor. At advanced stages of testing, biomass production, nutrient uptake or exclusion, and root development should be considered. Yield under non-stress conditions should be considered where feasible, especially for the advanced materials.

Table 2. Recommended procedure for screening bean germplasm for tolerance to soil fertility related stresses.

Season	Details	Plot size/number	Stress level
		Stage I	
A	360 entries, Primary sites only, Criteria: yield under stress, Select best 50%	Single rows 2 replications	Moderate stress
B	180 entries, Primary sites, Criteria: yield under stress, Select 40-50 lines	2 row plots 2 replications	Moderate stress
C	50 lines, Primary and secondary sites, Criteria: yield	2-4 row plots 3 replications	Moderate stress and no stress
D	20-35 lines Primary and secondary sites Criteria: yield, root/shoot ratio, total nutrient uptake	4 row plots 3 replications	Moderate stress and no stress
		Stage II	
C2	50 lines, Primary and secondary sites, Criteria: yield, biomass, root/ shoot ratio	2-4 row plots 3 replications	High stress

Managing variations in stress

The level of stress throughout the experimental material at a site may be variable. Often, effective blocking for homogeneity can be achieved. Intensive cropping with an extractive crop may improve homogeneity. A field might be mapped according to degree of stress enabling estimation of covariate values against which to adjust plot-level measurements. Inclusion of a check variety every 5-7 entries will enable some adjustment for variations in stress and in other factors affecting yield. Similarly, using the mean of the two or four nearest neighbors can be effective in accounting for variations in stress level.

Germplasm screening procedures

The group recommended that the screening flow as shown in Table 2. During the first stage, varieties of good agronomic type will be identified which might be suitable as cultivars or as breeding parents. In the second stage, promising materials are evaluated at higher stress levels to identify superior breeding parents. The first stage requires four seasons, while the second stage requires only one additional season, but can be done concurrently with the third or fourth season of stage 1.

Sources of entries for the BILFA

For the first two cycles of the BILFA, entries have been collected from CIAT and regional and national breeding programmes in Africa. These entries were generally promising lines of good agronomic type, but which had not been previously evaluated for reaction to soil fertility problems.

The working group recommended:

1. national programs should contribute a greater share of the entries in the future;
2. the entries for the third cycle should be submitted (200 seeds of each entry) to Malawi by April, 1996 (a request will be made before then);
3. entries should not have the "I" gene, but should include all promising materials;
4. Andean types are preferred;
5. the steering committees should provide funds to the BILFA coordinator to reimburse national programs for the cost of providing seed.

Distribution of tolerant varieties

It was recommended that varieties be made available in two forms:

1. nurseries of proven varieties, for each of the major stresses/complexes, be available by June, 1995;
2. information and seed on varieties which have been tested should be made available in order that seed of particular varieties can be requested.

Further research needs

The group recommended:

1. mechanisms of tolerance be identified for the most promising varieties; and
2. the genetics of these mechanisms be determined to facilitate the incorporation of these traits into cultivars or varieties of interest.

GENERAL ISSUES OF THE BILFA -- DISCUSSION AND RECOMMENDATIONS

Collaboration within BILFA

The members of the working group recommended:

1. working group meetings every three years, with the next in either Bujumbura or Kigali in May of 1997;
2. a monitoring tour of BILFA activities in Zambia and Malawi in early 1996, and possibly another in eastern Africa to correspond with the EA Regional Workshop in 1996;
3. leaders of screening for specific stresses should strive to achieve recognition for expertise in this area in order to serve as resource persons for the bean research networks;
4. funding for screening be provided on a regional sub-project basis by the steering committees;
5. BILFA collaborators report on their activities at the end of each season, with reports circulated to other collaborators;
6. the coordinator of the BILFA

a. prepare and distribute sets of entries for new cycles of the BILFA;

b. channel communications; and

c. organize monitoring tours, meetings and visits.

Dr. Wortmann agreed to coordinate the BILFA until the end of 1995 when the responsibility will shift to Malawi.

Collaboration with specialized institutions

Opportunities for further collaboration with specialized institutions were discussed. Possibilities discussed included:

CIAT for mechanism and genetics studies and for supervision of post-graduate studies;

a network for salinity and drought for the Mediterranean Region (INR in France);

ICRAF for systems management studies;

Penn State University for mechanism studies, esp. root studies;

local universities who have specialized in relevant areas, e.g. the University of Zimbabwe for N fixation and the University of Nairobi for bean breeding.

Training needs and opportunities

The group recommended:

1. a short course on management of BILFA sites to be held in southern Africa in 1996 (at time of monitoring tour?);

1. a short course on management of BILFA sites to be held in southern Africa in 1996 (at time of monitoring tour?);
2. funding be sought for two MSc and one PhD training opportunities in the physiology or breeding of tolerance to low soil fertility stressed;
3. three BILFA collaborators to go to CIAT as visiting scientists to further study aspects of tolerance to nutritional disorders.

Special funding for the BILFA

It was agreed that special funding, to be administered by the Networks, be sought to support BILFA activities:

1. basic BILFA activities
2. higher degree training, short courses, and visits to CIAT;
3. publications and information;
4. improvement of facilities.

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APPENDIX

REACTIONS OF ENTRIES FROM THE FIRST CYCLE OF THE BILFA (ANSES) TO SOIL FERTILITY RELATED DISORDRS

Entries of the BILFA I were characterized for their reactions to various soil fertility related constraints using information available as of Jan., 1994 (Table 1 & 2). Confirmation testing of the promising varieties has been done in two to four environments, but further verification is desired.

Table 1. Reactions of selected varieties to various soil fertility related constraints.

Variety	Low N	Low P	Low K	High Al	High Mn
433 ACC	T	MT	T	S	S
54/4	S	S	S	MT	S
6088	T	S	T	S	S
7/4 ACC	S	S	S	VT	S
A 120	S	S	S	S	T
A 197	S	S	S	S	T
A 283	S	S	T	S	S
A 321	S	T	S	S	S
A 439	S	S	T	S	S
ACV 22	S	S	S	T	S
AFR 13	S	S	S	S	T
AFR 298	S	S	S	S	T
AFR 300	S	MT	S	T	S
AFR 344	S	S	S	MT	S
AFR 378	S	S	S	S	T
AFR 403	T	S	MT	S	S
AFR 476	S	S	S	T	T
AFR 531	S	S	S	S	T
AFR 544	MT	T	S	S	T
AFR 88	S	T	S	S	S
AND 61	S	MT	S	S	S
AND 740	S	S	S	MT	S
AND 773	S	S	S	MT	S
AND 829	S	S	S	S	T
AND 871	S	S	S	S	T
ARA 4	S	S	T	S	S
BAT 1220	S	S	T	S	S
BAT 25	S	VT	T	S	S
BAT 85	T	T	MT	S	S
BLACK DESSIE	S	MT	S	S	T
BRU 22	T	S	S	S	S
CAL 32	S	MT	S	T	S
CAL 96	S	S	MT	S	T
CAL 98	S	S	S	MT	S
CALIMA	MT	S	S	S	S
CARIOCA	T	T	S	S	T
CLH 13	T	S	S	S	S

cont.

Table 1. continued. Reactions of selected varieties to various soil fertility related constraints.

Variety	Low N	Low P	Low K	High Al	High Mn
DOR 335	S	S	T	MT	S
DOR 375	S	T	T	S	S
DOR 404	S	S	S	S	T
DPR 351	S	S	T	S	S
EM 24/18/1	S	S	S	MT	S
EM 24/6	S	S	S	T	S
EM 40	S	T	S	S	S
EM 6	S	S	S	T	S
EM 73	S	S	S	T	S
EMP 84	S	S	T	S	S
G 05053	S	T	S	S	S
G 4000	S	S	T	S	S
GLP 582	S	S	S	S	S
GLP 585	MT	T	S	S	S
IKINIMBA	T	MT	S	S	S
IZ 0201240	S	S	S	S	T
IZ 0201461	S	S	S	T	S
KIBUGA	S	S	S	MT	S
KID 34	S	S	S	S	T
KIRUNDO	S	S	S	T	S
KYABAIKILA	S	S	S	MT	
LRK 29	S	S	S	S	T
LUSHARO	S	S	S	MT	S
LYAMUNGU 85	S	S	S	S	T
MCM 2001	S	S	T	S	S
MCM 5001	MT	S	S	MT	VT
MMS 224	T	T	S	S	S
MMS 232	T	S	S	S	S
MMS 243	S	T	S	S	S
MMS 250	T	S	MT	S	S
MMS 253	T	S	S	S	S
MUHINGA	S	T	S	VT	S
MUS 18	S	S	S	MT	S
MUS 97	VT	S	T	S	S
NAKAJA	S	S	S	MT	S
NANGURUBWA	S	S	S	T	S
NEPA 29	S	S	S	S	T
NEPA 38	S	S	S	S	T
NIC 116	MT	S	S	S	S
NTEKERABSILIMU	S	S	S	VT	S
OBA 1	T	T	S	S	T
PAD 114	S	T	S	MT	S
PAD 126	S	S	S	S	T
PAI 112	T	T	S	S	S
PEF 14	MT	MT	S	S	S
PEF 2	T	S	S	S	S
PINTADO	T	S	S	S	S
PORRILLO SIN.	T	S	T	S	S
PVA 774	S	S	S	S	T
RAB 445	S	T	S	S	S
RAB 471	S	S	T	S	S

cont.

Table 1. continued. Reactions of selected varieties to various soil fertility related constraints.

Variety	Low N	Low P	Low K	High Al	High Mn
RAB 476	T	S	S	S	S
RAB 482	S	S	MT	S	S
RAO 52	MT	T	T	S	S
RAO 55	VT	T	S	MT	S
RIZ 102	S	S	T	S	S
RIZ 103	S	S	T	S	S
RIZ 111	S	S	T	S	S
RIZ 129	S	S	T	S	S
RIZ 90	S	S	T	S	S
RUBONA	S	S	S	S	T
RWK 5	T	T	S	S	S
RWK 8	T	S	S	T	S
RWR 109	S	S	T	S	S
RWR 221	S	MT	S	S	T
RWR 229	S	S	S	MT	S
RWR 288	S	S	S	MT	S
RWR 382	T	T	T	S	T
RWR 603	S	S	S	T	S
RWR 612	S	S	S	T	S
RWR 980	S	S	S	S	T
RWR 982	S	S	S	S	T
RWR 994	S	S	S	MT	S
SUA 90	S	MT	S	MT	S
SUCHITAN	S	S	VT	S	S
SUG 69	S	S	S	S	T
UBUSOSERA	S	S	S	T	S
URUBONOBONO	S	S	S	S	T
URUGEZI	S	S	S	T	T
XAN 76	VT	VT	T	S	VT

VT, T, MT and S indicate very tolerant, tolerant, moderately tolerant and susceptible, respectively.

Table 2. Entriesof the first cycle of the BILFA (ANSES) found to be susceptible to all soil fertility related constraints.

1149 RR
213/1
4445
53/4
A 439
AFR 260
AFR 340
AFR 406
AFR 478
AFR 493
AFR 516
AFR 540
AFR 542
AND 10
AND 192
AND 659
AND 664
AND 748
AND 863
AND 875
BAT 271
BAT 41
BAT 474
BAT 67
C 10
CAL 9
CHINONI
COMP- HONDUREO
DOR 351
DOR 394
DOR 401
DOR 410
DOR 420
DOR 432
DRK 43
DRK 7
Em 1/22
Em 1/23
Em 13/3
Em 13/8
Em 15
Em 18/11
Em 18/2
Em 18/27
Em 2/14
Em 2/7
Em 24/10
Em 24/5
Em 24/8
Em 24/9
Em 32
Em 51
Em 58
Em 60
Em 64
Em 65
Em 8
Em 41
G 04397
G 5059
G 685
G 858
HOND 210
IBIRAMBIRA
IZ 0201236
IZ 0201238
IZ 0201239
IZ 0201242
IZ 0201243
IZ 0201247
IZ 0201444
IZ 0201447
IZ 0201449
IZ 0201451
IZ 0201453
IZ 0201456
IZ 0201457
IZ 0201459
IZ 0201465
IZ 0201467
IZ 0201471
IZ 0201473
IZ 0201475
IZ 0201477
K20
KAIBA
KAIRAGUJU
KAKARA
KID 37
KYABABIKILA
LYAMUNGU 90
MBAGARIRUMBISE
MMS 221
MMS 225
MMS 227
MMS 234
MUS 94
MUYIGA
MUYONJA
NAIN DE KYONDO
NEPA 51
NIC 103
NIC 113
NIC 115
NIC 119
NIC 128
NIC 141
NIC 152
NIC 156
NSHORO
NSIZEBAISHONJE
PEF 7
PVAD 782
RAB 475
RAB 477
RAB 479
RAB 480
RAB 518
RAD 14
RAO 53
RIO-TIBAJI
RIZ 112
RWK 3
RWR 359
RWR 1008
RWR 136
RWR 140
RWR 148
RWR 150
RWR 222H
RWR 602
RWR 945
RWR 968
RWR 971
RWR 990
RWV 167
Red haricot
SUG 41
SUG 50
SUG 71
TIKYAKUPONZA
V-ZAN-83063
VIDAC ROJO 384
WHITE HARICOT
ZAV 83052
ZPV 292