WFL Publisher
Science and Technology
Journal of Food, Agriculture & Environment Vol.4 (2) : 188-190. 2006
www.world-food.net

Relative drought tolerance of important herbaceous legumes and cereals in the moist and semi-arid regions of West Africa

S. U. Ewansiha* **and B. B. Singh**
International Institute of Tropical Agriculture (IITA), Kano Station, PMB 3112, Kano, Nigeria.
**e-mail:* *s.ewansiha@cgiar.org, b.b.singh@cgiar.org*

Received 5 January 2006, accepted 19 March 2006.

Abstract

Herbaceous legumes are becoming increasingly important for the crop-livestock farming systems in the moist and semi-arid regions of West Africa as these crops cover the ground quickly, check erosion, contribute to soil fertility and provide nutritious food and fodder to human beings and livestock. However, one of the major constraints in this region is the long dry season, which limits the productivity and duration of crop growth. Therefore, concerted efforts are being made to identify most suitable species and varieties with desirable agronomic traits including drought tolerance and high yield potential. This study was undertaken to screen 72 accessions/varieties of relevant herbaceous legumes along with 3 cereals-millet, sorghum and maize for their relative drought tolerance using the wooden box method. Hand selected healthy seeds of each accession were planted in single rows in wooden boxes of 130 cm long, 65 cm wide and 15 cm deep filled with soil of loamy composition. The boxes were watered daily for the first 2 weeks when the seedlings had emerged and the unifoliate leaves had fully expanded. Data were recorded for the number of days taken to first, 50% and 100% plant deaths in each row over all replications as a measure of drought tolerance for different accessions/varieties. Soybean variety TGX 1445-1D was the most susceptible as all plants were dead in 13 days while the lablab variety TLN 13 was the most drought tolerant which survived up to 46 days after water stopping. Based on the number of days taken to attain 100% plant death for each line, the most drought tolerant group comprised of lablab, horse gram, centrosema and cowpea followed by chamaecrista and pearl millet as the second group; velvet bean, joint vetch, crotolaria, stylosanthes, sorghum and groundnut formed the third group and blue pea and soybean as the most drought susceptible fourth group.

Key words: Drought tolerance, herbaceous legumes, cereals, blue pea, cowpea, horse gram, lablab, velvet bean, soybean.

Introduction

In the moist and the semi-arid regions of West Africa, drought is considered a major production constraint because of the low and erratic rainfall in the beginning and towards the end of the rainy season [1]. As a result field crops are frequently subjected to drought stress in both the seedling and terminal growth stages. This leads to low grain and fodder yields and reduced ground cover during the long dry period. Various legumes and cereals such as cowpea (*Vigna unguiculata* (L. Walp)), bambaranut (*Vigna subterranean* (L.) Verdc), lablab (*Lablab purpureus* (L.) Sweet), groundnut (*Arachis hypogea* L.), soybean (*Glycine max* (L.) Merrill), pearl millet (*Pennisetum glaucum* (L.) R. Brown), sorghum (*Sorghum bicolor* (L.) Moench) and maize (*Zea mays* L.) have dominated the cropping systems of the region. With the increase in agricultural intensification and the resultant crop-livestock integration, more herbaceous legumes and crop accessions have been introduced and screened for adoption in the recent years by International Agricultural Centers like International Institute of Tropical agriculture (IITA) and International Livestock Research Institute (ILRI) as well as many national programs. These crops include joint vetch (*Aeshcynomene histrix* Poir.), Centrosemasema (*Centrosemasema pascuorum* (Mart.) ex Benth), *C. brasilianum* (L.) Benth, *C. pubescens* Benth), chamaecrista (*Chamaecrista rotundifolia* (Pers.) Greene), blue pea (*Clitoria ternatea* L.), crotolaria (*Crotolaria ochroleuca* (G. Don)), horse gram (*Macrotyloma uniflorum* (Lam.) Verdc), velvet bean (*Mucuna pruriens* (L.) DC), stylosanthes (*Stylosanthes guianensis* (Aubl) Sweet, *S. hamata* (L.) Taubert) and their performance and various uses have been extensively documented [2-12]. These reports have highlighted the advantages of these species as sole crop legumes, legume-cereal pastures, cover crop for weed control and soil improvement strategies and improved feed-food source for livestock and people in the moist and dry savanna of West Africa. However, the ideal legumes would be the ones, which not only have fast and higher vegetative growth but also enhanced levels of drought tolerance for longer survival time during the dry period. Therefore, comparative study on the relative drought tolerance of different herbaceous legumes and cereal crops is needed to identify the most promising candidates in developing improved cropping and crop-livestock systems in the moist and semi-arid regions. However, drought tolerance is a complex trait but recently a wooden box screening method for screening and breeding for drought tolerance in cowpea and other crops was described by Singh *et al.* [13, 14] and Singh and Matsui [15]. This simple method eliminates the effect of roots and measures only the shoot dehydration tolerance indicated by the number of days it survives after watering has been stopped. This trait is highly reproducible and simply inherited in cowpea [16]. Therefore, the wooden box method was used to evaluate various herbaceous legumes and other major crops of these regions for their relative drought tolerance. This paper presents the results of screening experiments and comparative responses of different herbaceous legumes and cereals to drought stress at the seedling stage using the wooden-box screening method.

Materials and Methods

The experiments were carried out from September 2005 to January 2006 in a rain protected screenhouse at IITA, Kano Station in Nigeria located at 12°3'N, 8°32'E, and 476 m above sea level. Initially, 72 different accessions of blue pea, centrosema, chamaecrista, cowpea, crotolaria, groundnut, horse gram, joint vetch, lablab, maize, pearl millet, sorghum, soybean, stylosanthes and velvet bean were screened. From these a total of 25 lines covering all the species and performance range were selected for final screening to confirm the results of the preliminary screening. The list of accessions/varieties of the different crops planted in the final screening together with their source institute is given in Table 1.

The screening for drought tolerance was done using wooden boxes measuring 130 cm long, 65 cm wide and 15 cm deep made of 2.5 cm thick planks, with sides and bottom lined with polythene sheets. The boxes were filled with soil of loamy sand composition leaving about 3 cm space on the top for watering. The boxes were kept on benches in the screenhouse, watered and test lines were planted in straight rows 12 cm apart and a within row distance of 5 cm was kept from plant to plant in a randomized complete block design. One single row was planted per accession/variety at 3 seeds per hole and later thinned to one plant per hole at the time watering was stopped. For the initial preliminary screening, planting was done in September 2005 and the boxes were watered daily up to 10 days. Observations on drought tolerance for different lines were recorded until the trial was terminated at eight weeks after planting. For the final screening, accessions/varieties were planted in November 2005 and the boxes were watered daily for 2 weeks. Watering in the final screening took more days because of some accessions/varieties that took longer days to emerge due to cooler temperatures. Data were recorded for the number of days taken to 50% emergence, number of plants at the time watering was stopped and the number of days taken to observe first plant death, 50% plant death and 100% plant death for each accession/variety. A plant was considered dead when the shoot was completely dehydrated and leaves completely dry without response to re-watering. Data obtained were statistically analyzed using GENSTAT 5 [17] following the procedure described by Little and Hills [18].

Table 1. List of crops and varieties used for drought screening.

Crop	Botanical name	Accession number/variety	Source Institute
Blue pea	*Clitoria ternatea* (L.)	ILRI 7621	ILRI
Centrosema	*Centrosema brasilianum* (L.) Benth	ILRI 155	ILRI
Centrosema	*Centrosema pascuorum* (Mart.) ex Benth	ILRI 9857	ILRI
Centrosema	*Centrosema pubescens* (Benth)	ILRI 152	ILRI
Chamaecrista	*Chamaecrista rotundifolia* (Pers.) Greene	ILRI 10819	ILRI
Chamaecrista	*Chamaecrista rotundifolia* (Pers.) Greene	ILRI 15604	ILRI
Cowpea	*Vigna unguiculata* (L.) Walp.	IT99K-241-2	IITA
Cowpea	*Vigna unguiculata* (L.) Walp.	TVu 7778	IITA
Crotolaria	*Crotolaria ochroleuca* (G. Don)	Crotolaria	IITA
Groundnut	*Arachis hypogea* (L.)	UGA-2	ICRISAT
Horse gram	*Macrotyloma uniflorum* (Lam.) Verdc.	Horse gram	IITA
Joint vetch	*Aeshcynomene histrix* (Poir.)	ILRI 12463	ILRI
Lablab	*Lablab purpureus* (L.) Sweet	ILRI 7403	ILRI
Lablab	*Lablab purpureus* (L.) Sweet	PI 183451	Texas A&M Univ.
Lablab	*Lablab purpureus* (L.) Sweet	PI 388003	Texas A&M Univ.
Lablab	*Lablab purpureus* (L.) Sweet	PI 555670	Texas A&M Univ.
Lablab	*Lablab purpureus* (L.) Sweet	TLN 13	IITA
Maize	*Zea mays* (L.)	ACR 97	IITA
Pearl Millet	*Pennisetum glaucum* (L.) R. Brown	Ex-Borno	Market
Velvet bean	*Mucuna pruriens* (L.) DC	IRZ	IITA
Velvet bean	*Mucuna pruriens* (L.) DC	Utilis	IITA
Sorghum	*Sorghum bicolor* (L.) Moench	Kaura Local	Market
Soybean	*Glycine max* (L.) Merrill	TGX 1485-1D	IITA
Stylosanthes	*Stylosanrhes guianensis* (Aubl.) Sweet	ILRI 15557	ILRI
Stylosanthes	*Stylosanthes hamata* (L.) Taubert	ILRI 15876	ILRI

Abbreviations: PI = Plant introduction number; TLN = Tropical Lablab Niger; TVu, Tropical *Vigna unguiculata*; TGX = Tropical *Glycine max*, IITA = International Institute of Tropical Agriculture, Ibadan, Nigeria; ILRI = International Livestock Research Institute, Addis Ababa; ICRISAT = International Crop Research Institute for Semi-Arid Tropics, Niamey.

Results and Discussion

The results of the preliminary screening showed a wide range of variability for days taken to 100% plant death under drought stress within as well as between crop species. For example, the range for days taken to100% plant death in lablab was from 19 days to 31 days and in cowpea from 21 to 30 days. The minimum days for 100% plant death was 9 days for soybean and 10 days for groundnut indicating that these were the most drought susceptible species. Other crop species were in between these extremes.

In the final screening, major differences were observed in days to 50% emergence and seedling growth among different crop species (Table 2). Stylosanthes, joint vetch and groundnut took much longer than the other species but this was not related to their reaction to water stress. Velvet bean and lablab had much faster growth than other species but again this was not related to drought tolerant trait. In terms of drought stress at the seedling stage, there was as in the preliminary screening, a wide variation in the response among the various selected herbaceous legumes. The lablab accession TLN 13 survived for the longest period (46 days) while soybean took the minimum number of days for 100% plant death (13 days). Within each crop species there was a great deal of variation, particularly in lablab and cowpea. The most drought tolerant lablab accession, TLN 13, survived up to 46 days while the least tolerant lablab accession (ILRI 7403) succumbed in 33 days. For cowpea the number of days to 100% plant death varied between 33 (IT99K-241-2) and 29 (TVU 77778) days. Similar observations were made in centrosema accessions. Among the cereals, pearl millet showed more drought resistance (27 days) than maize (23 days) and sorghum (23 days) and the difference among these crops were not statistically significant. Based on the number of days taken for 100% plant death of each accession/variety, the most drought tolerant group comprised of lablab, horse gram, centrosema and cowpea, followed by chamaecrista and pearl millet as the second group, velvet bean, joint vetch, crotolaria, stylosanthes, sorghum and groundnut as the third group and blue pea and soybean as the most drought susceptible fourth group. These results agree with those earlier reported by Singh *et al.* [14]. However, while the report showed that cowpea was more drought tolerant than cowpea in that study, the present study revealed that lablab could be more drought tolerant and this is likely due to the different accessions/varieties used in the two studies and underscores the need to exploit to maximum existing and available variation in crop species in evaluation studies.

The results of this experiment showed that the wooden-box screening method is very effective in determining drought tolerance in accessions/varieties in seedling stage of plant growth and provides an estimate of the true potential of a crop species to survive under drought stress. However,

Table 2. Relative drought tolerance of different herbaceous legumes and cereals.

Crop	Accession/ Variety	SEM	NP	Days to plant death after water stopping		
				First PD	50% PD	100% PD
Lablab (early maturing)	TLN 13	5	8	31	38	46
Lablab (grain)	PI 388003	5	8	27	32	39
Lablab (dual-purpose)	PI 183451	5	8	29	32	34
Lablab (vegetable)	PI 555670	5	7	26	29	34
Lablab (late maturing)	ILRI 7403	6	8	28	31	33
Horse gram	Horse gram	5	8	30	34	43
Centrosema	ILRI 155	7	7	23	30	37
Centrosema	ILRI 9857	5	8	20	25	32
Centrosema	ILRI 152	6	8	22	26	28
Cowpea	IT99K-241-2	5	8	27	30	33
Cowpea	Tvu 7778	5	8	23	27	29
Chamaecrista	ILRI 15604	7	4	22	26	27
Chamaecrista	ILRI 10918	5	7	23	22	27
Pearl millet	Ex-Borno	4	8	21	25	27
Mucuna	IRZ	8	8	23	26	27
Mucuna	Utilis	8	8	20	21	23
Jointvetch	ILRI 12463	16	5	21	24	25
Crotolaria	Crotolaria	5	8	18	22	24
Stylo	ILRI 15557	16	7	20	22	24
Stylo	ILRI 15876	10	8	14	16	22
Maize	ACR 97	5	7	19	21	23
Sorghum	Kaura Local	5	7	21	21	23
Groundnut	UGA-2	10	8	19	21	22
Bluepea	ILRI 7621	7	7	12	14	16
Soybean	TGX 1445-1D	7	8	9	10	13
Mean		7	7	23	25	28
LSD		1.0	1.7	4.0	3.1	4.5

SEM = days to 50% seedling emergence; NP = number of plants/row; PD = plant death

the species can survive even longer if it also has deep and dense root system to draw moisture from deeper soil strata. Many years of work by IITA scientists at Zaria, Nigeria (11°11'N, 07°38'E; alt. 686 m) with various herbaceous legumes including those tested in this trial showed that the established blue pea is remarkably drought tolerant in the field during dry season even though it was highly susceptible in the present study. Also, Ewansiha [19] has shown that within lablab, accessions Grif 1246, ILRI 730, NAPRI 2, PI 195851, PI 388013 and PI 532170 appear to be the most drought tolerant lablab under field conditions during dry season but this was not so in the present study. Again, while the well-established stylosanthes in the field is known to be extremely drought tolerant, it showed very low drought tolerance in the present study. All this may be probably due to the deeper and dense root systems of these crops under field conditions [20]. Therefore, in breeding program for drought tolerance efforts should be made to combine shoot dehydration tolerance with deep and dense root system.

Conclusions

The results of this experiment have shown that significant differences exist among and within herbaceous legumes and cereals for drought tolerance at the seedling stage. The results further suggest that the wooden-box method can be used for screening different crop species for drought tolerance. However, the final field performance of the crop species will depend upon the root system also and therefore, legume species combining shoot drought tolerance and deep roots would be most desirable.

References

[1]Ashley, J. 1993. Drought and crop adaptation. In Rowland, J. R. J. (ed.). Dryland Farming in Africa 1993. Macmillan Press Ltd., London, pp. 46-67.

[2]Tarawali, G. 1991. The residual effect of *Stylosanthes* fodder banks on maize yield at several locations in Nigeria. Tropical Grasslands **25**:26-31.

[3]Tarawali, S.A. 1994. Evaluating selected forage legumes for livestock and crop production in the subhumid zone of Nigeria. Journal of Agricultural Science **123**:55-60.

[4]Tarawali, S.A. 1995a. Evaluation of *Stylosanthes hamata* (L.) Taub. accessions for livestock and crop enterprises in subhumid Nigeria. Australian Journal of Experimental Agriculture **35**:375-379.

[5]Tarawali, S.A.1995b. Evaluation of *Chamaecrista rotundifolia* accessions as a fodder resource in subhumid Nigeria. Tropical Grasslands **29**:129-133.

[6]Tian, G., Kang, B.T., Akobundu, I.O. and Manyong, M. 1995. Food production in the moist savanna of West Africa. In Kang B.T., Akobundu, I.O., Manyong, V.M., Carsky, R.J., Sanginga, N. and Kueneman E.A. (eds). Moist Savannas of Africa: Potentials and Constraints for Crop Production. Proceedings of an International Workshop, International Institute of Tropical Agriculture (IITA), pp. 87-104.

[7]Thomas, D. and Sumberg, J.E. 1995. A review of the evaluation and use of tropical forage legumes in sub-Saharan Africa. Agriculture, Ecosystems and Environment **54**:151-163.

[8]Tarawali, S.A. and Peters, M. 1996. The potential contribution of selected forage legume pastures to cereal production in crop-livestock farming systems. Journal of Agricultural Science **127**:175-182.

[9]Peters, M., Kramer, H., Tarawali, S.A. and Schitze-Kraft, R. 1998. Characterization of a germplasm collection of the tropical pasture legume *Centrosema brasilianum* in subhumid West Africa. Journal of Agricultural Science **130**:139-147.

[10]Tarawali, S.A., Peters, M. and Schultze-Kraft, R. 1999. Forage legumes for sustainable agriculture and livestock production in subhumid West Africa. ILRI Project Report. ILRI (International Livestock Research Institute), Nairobi, Kenya, 132 p.

[11]Peters, M., Horne, P., Schmidt, A., Holman, F., Kerridge, P.C., Tarawali, S.A., Schultze-Kraft, R., Lascano, C.E, Argel, P., Stur, W., Fujisaka, S., Muller-Samann, K. and Wortmann, C. 2001. The role of forages in reducing poverty and degradation of natural resources in tropical production systems. Agricultural Research and Extension Network, Network Paper No. 117, 12 p.

[12]Schulz, S., Carsky, R.J. and Tarawali, S.A. 2001. Herbaceous legumes: the panacea for West African soil fertility problems? Sustaining Soil Fertility in West Africa. Soil Science Society of America and American Society of Agronomy, USA. SSSA Special publication no.58, pp. 179-195.

[13]Singh, B.B., Mai-Kodomi, Y. and Terao, T. 1999a. A simple screening method for drought tolerance in cowpea. Indian Journal Genetics **59**:211-220.

[14]Singh B.B., Mai-Kodomi, Y. and Terao, T. 1999b. Relative drought tolerance of major rainfed crops of the semi-arid tropics. Indian Journal of Genetics **59**(4):437-444.

[15]Singh, B.B. and Matsui, T. 2002. Breeding cowpea varieties for drought tolerance. In Fatokun, C.A., Tarawali, S.A., Singh, B.B., Kormawa, P.M. and Tamo, M. (eds). Challenges and Opportunities for Enhancing Sustainable Cowpea Production. IITA, Ibadan, Nigeria, pp. 287-300.

[16]Mai-Kodomi,Y., Singh, B.B, Terao, T., Myers, Jr. O., Yopp, J.H. and Gibson, P.J. 1999. Inheritance of drought tolerance in cowpea. Indian Journal Genetics **59**:317-232.

[17]Lawes Agricultural Trust 1995. Genstat 5, Release 3.2 (PC/Window NT). Rothamsted Experimental Station, London, UK.

[18]Little, T.M. and Hills, F.J.1978. Agricultural Experimentation. John Wiley and Sons, Inc., USA, 350 p.

[19]Ewansiha, S.U. 2002. Evaluation of *Lablab purpureus* (L.) Sweet for Crop and Forage Production Potential at Samaru in the Northern Guinea Savanna of Nigeria. MSc. Thesis, Ahmadu Bello University, Zaria, Nigeria.

[20]NAS 1979. Lablab bean. Tropical Legumes: Resources for the Future. National Academy of Sciences, Washington DC, pp. 59-67.