Indian J. Genet., 59(4): 437-444 (1999)

RELATIVE DROUGHT TOLERANCE OF MAJOR RAINFED CROPS OF THE SEMI-ARID TROPICS

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(Received: July 1, 1998; accepted: November 10, 1999)

ABSTRACT

Ten crop species were evaluated for their relative drought tolerance in seedling stage. Healthy seeds of each crop were planted in wooden boxes of 130 cm length, 65 cm width, and 15 cm depth filled with 3 soil types and watered daily. A week after germination watering was stopped and the reaction of the plants of each crop to progressive water stress was observed. Based on percent dead plants at various time intervals and days taken to 100% dead plants for the ten crops, soybean appeared to be the most drought susceptible and cowpea was the most drought tolerant. The overall ranking of the crops in the increasing order of drought tolerance was soybean < blackgram < greengram < groundnut < maize < sorghum < pearl millet < bambaranut < lablab bean < cowpea. The water stress in the wooden-box method using higher sand content was too drastic for crops other than cowpea and lablab bean. With increased clay content and gradual water stress, it may be possible to use this method to detect varietal differences in crops like maize, soybean, pearl millet, sorghum etc., which are less drought tolerant than cowpea.

Key words : Drought tolerance, field crops, water stress

Drought is a major production constraint in rainfed agriculture, particularly in the semi-arid regions of the tropics [1]. Due to erratic rainfall in the beginning and towards the end of rainy season, the crops are often subjected to drought stress in seedling as well as in terminal growth stages which cause substantial reduction in grain yield as well as biomass production. Through years of experience, farmers have selected several crop species adapted to drought-prone areas of which cowpea, millet, bambaranut, lablab bean, groundnut and sorghum are of major economic importance. In recent years, efforts have been made to introduce drought tolerant maize and soybean as well as early maturing food legumes like blackgram and green gram in low rainfall areas partly to diversify the cropping systems and partly due to preference for food crops. A large number of studies have been made on

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the intraspecific variability for drought tolerance in several crops but very few on comparative drought tolerance of different crop species [1-9]. It would be desirable, therefore, to study the relative drought tolerance of major crops and develop alternative crop production strategies to minimize losses due to drought in low-rainfall areas. A simple screening method for drought tolerance was recently developed [8, 10] to select drought tolerant cowpea varieties but it has not been tested for other crops. Since the moisture retention and extent of drought stress depends on the soil type used, it would be desirable to test different crop species in different soil types, exposing them to varying levels of drought severity. This paper presents the results of a screenhouse experiment designed to compare the relative responses of different crop species to severe drought stress at seedling stage using the wooden-box screening method with different soil types.

MATERIALS AND METHODS

This experiment was conducted at the International Institute of Tropical Agriculture (IITA), Kano Station, Nigeria, 12°3′N, 8°32′E, 476 m altitude. Ten crops were evaluated in three different soil types using the wooden-box screening method [8]. The list of varieties of the different crops used is given in Table 1. The normal

Table 1. Crop and their varieties used for drought screening

Crop	Botanical name	Variety
Bambaranut	*Vigna subteranea* (Thouvars)	Kano Local
Blackgram	*Vigna mungo* (L.) Helper	Market sample
Greengram	*Vigna radiata* (L.) Wilzek	Zankom (Kaduna)
Groundnut	*Arachis hypogea* (L.)	Kano Local
Cowpea	*Vigna unguiculata* (L.) Walp.	IT90K59-2
Cowpea	*Vigna unguiculata* (L.) Walp.	TVu 7778
Cowpea	*Vigna unguiculata* (L.) Walp.	TVu 11986
Lablab bean	*Lablab purpureus* (L.) Sweet	ILCA-7379
Maize	*Zea mays* (L.)	Market sample
Millet	*Pennisetum glaucum* (L.) R. BR	Ex-Borno
Sorghum	*Sorghum bicolor* (L.) Moench	Kaura Local
Soybean	*Glycine max* (L.) Merrill	TGx 1485-10

wooden-box method for screening cowpea varieties involves a 1:1 mixture of top soil : river sand, giving a loamy sand composition. Since 10 crops were being evaluated in this experiment, it was thought desirable to evaluate them in different soil types providing various levels of drought stresses to ensure better separation among crops. Therefore, in addition to the usual 1:1 mixture of top soil and river sand, two other soil types were included. These were 1) sandy soil from the Chalawa river bed, and 2) sandy loam from Kadawa irrigation area, both in the Kano State of Nigeria. The three soil samples were analysed at the Institute of Agricultural Research, Ahmadu Bello University, Zaria (IAR/ABU) and their characteristics are presented in Table 2. Wooden boxes of 130 cm length, 65 width and 15 cm depth made of 2.5 cm thick plants were kept on benches in a rain-protected screenhouse lined with polythene sheets and filled with the three soil types up to 12 cm depth leaving about 3 cm space on the top for watering. The polythene sheets were lined along the sides and bottom of the boxes to ensure even distribution of water in the boxes. A spirit level was used to ensure flat soil surface on the boxes after are watered. By using a ruler, equidistant holes were made in straight rows 12 cm apart with a hill-to-hill distance of 5 cm within the row. The trial was planted on June 14, 1995. Each variety/crop was represented by 1 row with replications in each soil type. From planting to the onset of drought stress, each box received three liters of water daily. Watering was withheld at the emergence and full expansion of the unifoliate leaves in the cowpea lines (drought onset June 22, 1995). Soil samples were taken by pushing a metallic tube in the boxes. Soil moisture was determined after drying the samples for 48 h in an oven at 105°C as percentage of fresh weight. Data on daily cumulative wilting and death percentage were recorded and statistically analysed. However, the relative differences among the crops were ascertained both on the basis of the visual observations of physical appearance (qualitative assessment) as well as quantitative data.

RESULTS AND DISCUSSION

Effect of Soil Type on The Severity of Drought Stress

The three soil types had different composition with respect to clay, silt and sand contents, and probably this affected their relative moisture holding capacity after termination of watering. The river sand with 90% sand, 6% clay and 4% silt dried much faster than the sandy loam with 61.5% sand, 15.5% clay and 23% silt (Tables 2, 3). The differences between river sand and loamy sand were not so pronounced because of minor differences in their composition.

The drought stress in different soil types at different time intervals after termination of watering as measured by the mean percent dead plants in different

Table 2. Characteristic of the soils used for drought screening

Soil type	Percent composition			Organic matter %	pH
	clay	silt	sand		
River sand	6.0	4.0	90.0	0.5	5.9
Loamy sand	7.5	8.5	84.0	0.8	5.9
Sandy loam	15.5	23.0	61.5	1.8	5.6

Table 3. Soil moisture content in different soil types at various intervals after termination of watering

Soil type	Soil moisture on different days (%)		
	1	9	15
River sand	4.4	1.5	0.7
Loamy sand	6.0	1.5	0.8
Sandy loam	8.4	3.8	1.7
LSD 5%	NS	1.4	NS

crops was relatively less in sandy loam and more in river sand. The differences between river sand and loamy sand were not significant. This affected the relative separation of crops for their ability to stand drought stress in different soil types. The mean percentage of dead plants over all the crops was higher on any given day in sandy soil and loamy sand compared to the sandy loam which had more gradual increase in drought stress (Fig. 1). Also, the differences among different crops were more discernible on sandy loam compared to the other soil types (Table 4). For example, combining the results of 19 and 23 days after termination of watering, the 10 crops can be divided into six groups on sandy loam soil, whereas only 3 groups were apparent on the other two soil types. With further modification in clay and silt content it may be possible to discern even minor differences among crops and/or varieties within each crop.

RELATIVE DROUGHT TOLERANCE OF DIFFERENT CROP SPECIES

The reaction of various crops to water stress at seedling stage was quite different and the differences became more pronounced with increasing drought stress (Fig. 1, Table 4). Considering the relative drought tolerance over all the soil types, soybean

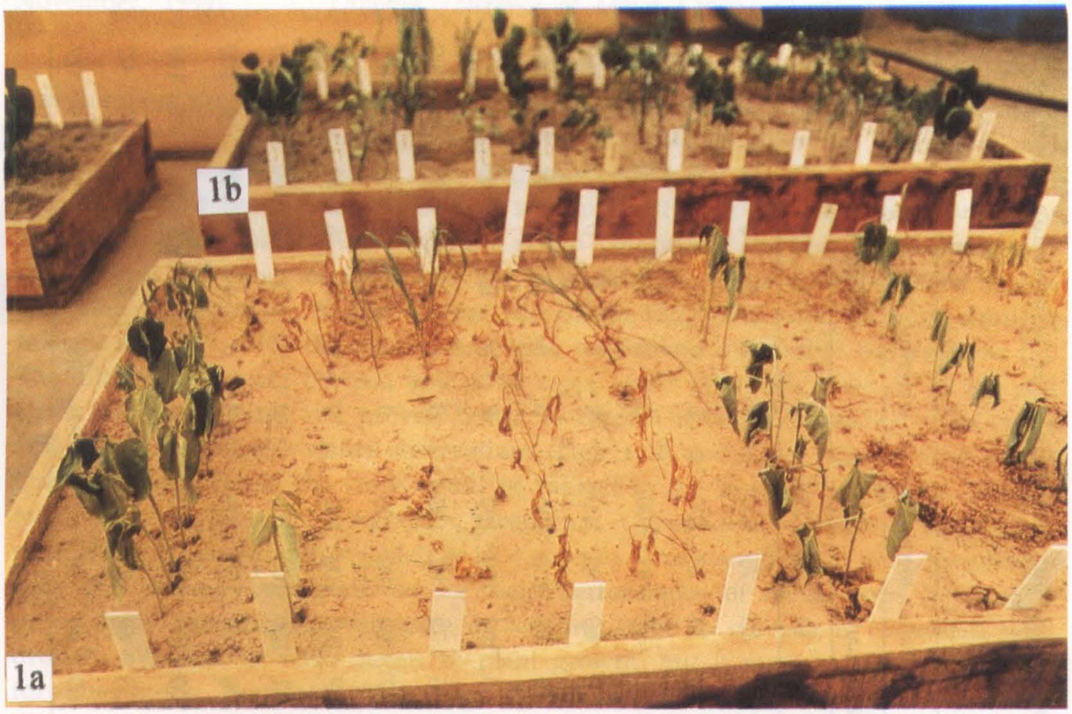

Fig. 1. Relative drought tolerance of different crops and effect of sandy soil (1a) and sandy loam soil (1b) on the degree of drought stress

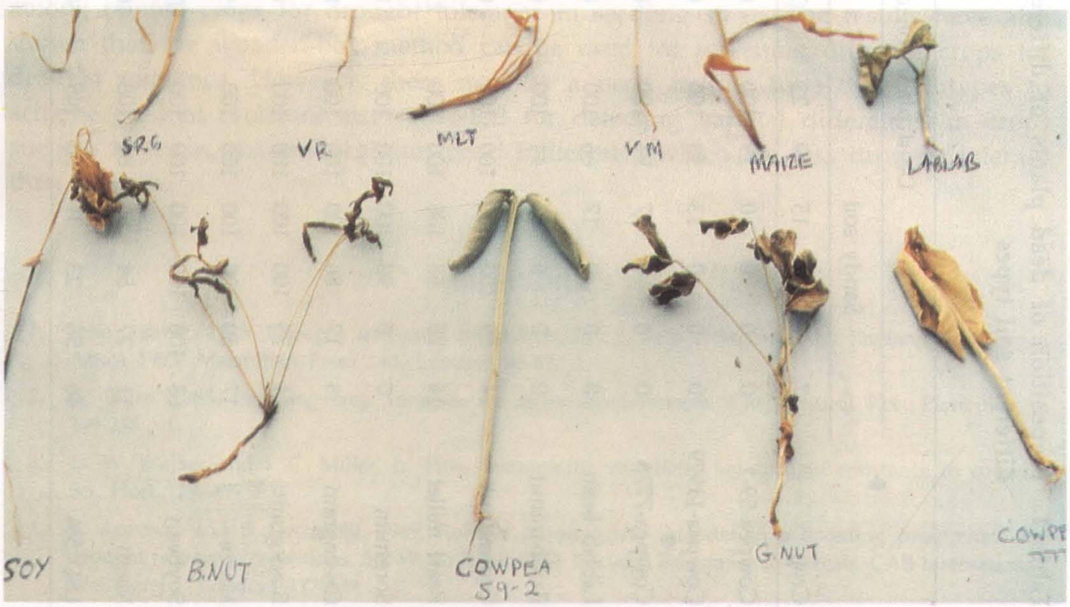

Fig. 2. Relative drought tolerance of different crops after 3 weeks of drought stress on sandy soil (during the period 14 June - 14 July, 1995)

Table 4. Proposition of dead plants of different crops at various intervals after termination watering in different soil types

	Dead plants on different days after termination of watering, %																		
	Sandy soil						loamy sand						sandy loam						
Crop	7	9	11	15	19	23	7	9	11	15	19	23	7	9	11	15	19	23	26
Cowpea-59-2	0	0	0	0	29	100	0	0	0	13	75	100	0	0	0	0	0	6	71
Cowpea-11979	0	0	0	13	53	100	0	0	0	13	23	100	0	0	0	0	0	13	100
Cowpea-7778	0	0	0	27	94	100	0	0	0	17	81	100	0	0	0	0	0	35	88
Lablab bean	0	0	0	17	66	100	0	0	0	60	90	100	0	0	0	0	7	57	100
Bambaranut	0	0	6	33	44	100	0	0	10	55	100	100	0	0	0	0	15	100	100
Groundnut	14	59	100	100	100	100	0	0	0	100	100	100	0	0	0	13	63	100	100
Pearl millet	14	28	68	100	100	100	21	42	56	75	81	100	0	0	0	6	27	88	100
Sorghum	0	0	93	100	100	100	8	50	67	100	100	100	0	0	0	0	24	100	100
Greengram	8	17	86	100	100	100	0	13	57	100	100	100	0	0	0	6	81	100	100
Blackgram	14	75	100	100	100	100	0	49	81	100	100	100	0	0	0	7	100	100	100
Maize	17	50	100	100	100	100	19	50	100	100	100	100	0	0	0	0	31	100	100
Soybean	63	100	100	100	100	100	67	83	100	100	100	100	0	7	29	69	100	100	100
Mean	11	27	54	66	82	100	10	24	35	69	83	100	0	1	2	8	37	75	97
LSD 5%	46	56	23	31	50	NS	38	70	60	48	35	NS	NS	NS	26	48	35	19	27

was the most susceptible to seedling drought and it was first to show sign of wilting after termination of watering. Blackgram was the next, followed by greengram and groundnut. Maize, pearl millet and sorghum constituted the next group in which millet appeared better than maize and sorghum although the differences were not significant. The most drought tolerant group comprised cowpea, bambaranut and lablab bean. Of these, cowpea was the most drought tolerant, followed by lablab bean and bambaranut. Within cowpea, the strain IT90K59-2 was the most drought tolerant and TVu 7778 the most susceptible, confirming our earlier observations [8]. The differences among cowpea and other crops could be clearly seen on all the soil types but sandy loam soil proved better to discern differences among other crops (Table 4). Based on the visual observations (Figs. 1, 2) and mean percent dead plants due to drought stress, the crops could be ranked in the increasing order of drought tolerance as soybean < blackgram < greengram < groundnut < maize < sorghum < pearl millet < bambaranut < lablab bean < cowpea. This classification is in consonance with the general observation on the field performance of these crops in drought prone areas. The drought tolerance at seedling stage in cowpea is correlated with drought tolerance at other stages of plant growth, but it may or may not be true for other crops. Therefore, these crops should be screened for drought tolerance at different stages using a combination of wooden-box and pot-screening method [8].

The results of this experiment have clearly demonstrated major differences among rainfed crops for drought tolerance in seedling stage. The results have also shown that the wooden-box method can be used for screening different crops for drought tolerance. However, there may be a need to fine tune the soil types to achieve gradual moisture stress needed for detecting varietal differences in crops such as soybean, maize, sorghum, pearl millet etc., which are less drought tolerant than cowpea.

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