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INHERITANCE OF DROUGHT TOLERANCE IN COWPEA

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ABSTRACT

This study was undertaken to elucidate the nature of inheritance of the two types of drought tolerance in cowpea {*Vigna unguiculata* (L.) Walp} so that the drought tolerant can be effectively used in breeding programme. Three cowpea lines viz TVu 11986 with 'Type 1' drought tolerance, Dan IIa with 'Type 2' drought tolerance and TVu 7778 as susceptible to drought were crossed in all possible combinations. The genetic segregation revealed that drought tolerance is a dominant trait and both 'Type 1' and 'Type 2' reactions are controlled by a single dominant gene but the genes are different in the two types. These are being designated as 'Rds 1' (resistance to drought stress) and 'Rds2'. Test of allelism indicated that 'Type 1' is dominant over 'Type 2' and the F_2 population between the two types segregated to 3 'Type 1': 1 'Type 2' plants indicating that the two genes for drought tolerance are either alleles at the same locus or tightly linked. Efforts are being made to transfer these genes into improved varieties. However, due to allelic relationship, or close linkage, both types of drought tolerance may not be bred in the same cowpea line.

Key words: Cowpea, *Vigna unguiculata*, drought tolerance, inheritance

Cowpea {*Vigna unguiculata* (L.) Walp} is one of the most important food legumes in the drier regions of the tropics and sub-tropics where drought is a major production constraint due to low and erratic rainfall [1-3]. Although cowpea is inherently more drought tolerant than other crops, it still suffers considerable damage due to severe drought in the Sahel. Early maturing varieties escape terminal drought [1], but if exposed to intermittent moisture stress during the vegetative growth stage, they perform very poorly. Therefore, a systematic breeding program has been initiated to develop improved cowpea varieties with higher levels of drought tolerance. A simple screening method using wooden-box has been developed which accurately discriminates between drought tolerant and susceptible cowpea lines and individual

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plants [4]. Using a combination of field and laboratory screening of cowpea germplasm and breeding lines several sources of drought tolerance have been identified [4, 5] Further studies have shown that the drought tolerant lines are of two types [6]. Under drought stress, 'Type 1' plants stop growth but preserve moisture and keep all the leaves and growing tips alive for long period of time whereas 'Type 2' plants mobilize moisture from the lower leaves to the growing tips resulting into the death of lower leaves but the tips remain alive for even longer time than 'Type-1' plants. Knowledge about the genetic control of these two types of drought tolerance would facilitate their use in the breeding program. Therefore, a systematic genetic study was undertaken to elucidate the inheritance of drought tolerance in cowpea. This paper summarises the nature of inheritance of the two types of drought tolerance in cowpea.

MATERIALS AND METHODS

This experiment was conducted at International Institute of Tropical Agriculture (IITA), Kano Station, Nigeria located at 12°03′ N latitude and 08°32′ E longitude. Three cowpea varieties were used. These were i) TVu 11986 with 'Type 1' drought tolerance, ii) Dan IIa with 'Type 2' drought tolerance and iii) TVu 7778 as the susceptible parent. These parental lines were crossed in all possible combinations and sufficient F_1, F_2 and backcross seeds were obtained. These populations along with the parents were evaluated for drought tolerance using the wooden-box method [4]. The boxes were lined with a polythene sheet and filled with a 12 cm layer of top soil and sand mixture (1:1) and kept on the table top in a screenhouse. Test populations were planted in the boxes about 10 cm apart between the rows with *5cm plant to plant distance within the rows. The boxes were watered daily until* the partial emergence of the first trifoliate after which the watering was stopped. Days taken to permanent wilting were recorded for each plant until all the plants of the susceptible line, TVu 7778 were completely dead. The extent of drying and senescence of the unifoliates and trifoliates on different plants were also observed at this stage to distinguish the plants with 'Type 1' from 'Type 2' drought tolerance. Based on the days taken to permanent wilting as well as general appearance of the unifoliate leaves, the plants were classified into drought tolerant and susceptible groups. In order to further confirm the results obtained from individual plant data, 144 random F_3 progenies from the cross, TVu 7778 × TVu 11986 and 80 random F_3 progenies of the cross, Dan IIa × TVu 7778 were also evaluated for drought tolerance on progeny row basis using the wooden-box method. The progenies were classified in uniformly tolerant, segregating and uniformly susceptible groups. The data in different classes were analysed using chi- square method.

RESULTS AND DISCUSSION

The differences among the 3 parents as well as segregation for drought tolerance in different populations were quite clear. This permitted easy grouping of 'Type 1' and 'Type 2' drought tolerance from the susceptible plants in different segregating populations. All the plants of TVu 11986 showed 'Type 1' drought tolerance, all the plants of Da IIa showed 'Type 2' drought tolerance and all the plants of TVu 7778 were susceptible (Fig. 1 see page 316). The 'Type 1' drought tolerant plants stopped growth almost completely with the onset of drought stress. They maintained turgidity in all the plant tissues including the unifoliates (lower leaves) and the emerging tiny trifoliates for a long time and gradually the entire plant parts dried as one step phenomenon. In contrast to this, the 'Type 2' drought tolerant plants remained green for even longer time and continued slow growth of the trifoliates even after sensing the moisture stress. However, with continued moisture stress, the unifoliates of these plants started drying and they dropped keeping the trifoliates and growing tips turgid and alive suggesting that the moisture was being mobilized from the uniforliates to the growing tips. The genetic analysis in different cross combinations is described below :

TVu 7778 × TVu 11986

The segregation pattern for drought tolerance in different populations involving TVu 7778 and TVu 11986 are presented in Table 1.

Table 1. Genetic segregation for drought tolerance in different populations of the cross TVu 7778 × TVu 11986*

Population	No. of plants		X^2	Probability
	Drought Tolerant Type 1	Drought susceptible		
P_1 (TVu 11986)	59	0	-	-
P_2 (TVu 7778)	0	79	-	-
F_1 ($P_2 \times P_1$)	25	0	-	-
F_2 Self F_1	313	111	0.25 (3:1)	0.50-0.70
BC_1 ($P_1 \times F_1$)	79	0	-	
BC_2 ($P_2 \times F_1$)	47	30	3.32 (1:1)	0.050-0.10

*Planted on Oct 26, 1995; stressed from Nov 5, 1995; scored on Nov. 21, 1995

All the 59 plants of TVu 11986 showed 'Type 1' drought tolerance and all the 79 plants of TVu 7778 were drought susceptible, The 25 F_1 plants were all drought tolerant similar to TVu 11986 indicating complete dominance of 'Type 1' drought tolerance over susceptibility. In the F_2 population, there were 313 plants with 'Type 1' drought tolerance and 111 plants with susceptibility which fitted well to 3 drought tolerance: 1 drought susceptible ratio. The segregation in backcross populations further confirmed the F_2 ratio. All the 25 plants from the backcross involving TVu 11986 were drought tolerant and the 79 plants derived from the backcross from TVu 7778 segregated into 47 tolerate and 30 susceptible plants which fitted to an expected 1:1 ratio although the fit was not as good. From the 144 random F_3 progenies tested for drought tolerance on progeny row basis, 36 progenies were uniformly susceptible, 73 progenies segregated into drought tolerant and drought susceptible plants and 35 progenies uniformly showed 'Type 1' drought tolerance. This fitted very closely to an expected 1 susceptible: 2 segregating: 1 tolerant ratio ($X^2 = 0.03 = p < 0.98$). These data indicated that the inheritance of 'Type 1' drought tolerance is controlled by a single dominant gene.

Dan IIa × TVu 7778

The segregation pattern for drought tolerance in different populations of the cross Da IIa × TVu 7778 is presented in Table 2.

Table 2. Genetic segregation for drought tolerance in different populations of the cross Dan IIa × TVu 7778*

Population	No. of plants		X^2	Probability
	Drought Tolerant Type 2	Drought susceptible		
P_1 (Dan IIa)	49	0	-	-
P_2 (TVu 7778)	0	74	-	-
F_1 ($P_1 \times P_2$)	2	0	-	-
F_2 Self F_1	327	115	0.2 (3:1)	.25-.50
BC_1 ($P_1 \times F_1$)	53	0	-	-
BC_2 ($P_2 \times F_1$)	48	35	2.2 (1:1)	10-.25

*Planted on Nov. 29, 1995; stressed from Dec. 11, 1995; scored on Jan. 2, 1996.

All the 49 plants of Dan II a showed 'Type 2' drought tolerance and all the 74 plants of TVu 7778 were susceptible. The 2 F_1 plants showed 'Type 2' drought tolerance indicating that drought tolerance is a dominant trait. The F_2 population segregated into 327 'Type 2' drought tolerant plants and 115 susceptible plants closely fitting to a 3 tolerant: 1 susceptible ratio. All the 53 backcross F_1 plants involving Dan IIa showed 'Type 2' drought tolerance whereas the backcross population involving TVu 7778 segregated into 48 drought tolerant : 35 susceptible plants with close fit to a tolerant : 1 susceptible ratio. The random progeny test involving 80 F_3 lines showed 18 progenies with uniform 'Type 2' drought tolerance, 44 progenies with segregation for drought tolerance and 18 progenies with uniform susceptibility which fitted close to the expected 1 tolerant : 2 segregating: 1 susceptible ratio. These data indicated that the inheritance of 'Type 2' drought tolerance is also controlled by one dominant gene.

TVu 11986 × Dan IIa

This cross was studied in order to ascertain whether the two types of drought tolerance are controlled by the same or different genes. The segregation pattern in different populations of this cross is presented in Table 3.

Table 3. Genetic segregation for drought tolerance in different populations of the cross TVu 11986 × Dan IIa*

Population	No of plants		X^2	Probability
	Drought Tolerant Type 1	Drought tolerant Type 2		
P_1 (TVu 11986)	39	0	-	-
P_2 (Dan IIa)	0	38	-	-
F_1 ($P_1 \times P_2$)	6	0	-	-
F_2 Self F_1	68	23	00 (3:1)	99

*Planted on Jan 14, 1996; stressed from Jan. 24, 1996; scored on Feb. 27, 1996

As excepted, all the 39 plants of TVu 11986 showed 'Type 1', drought tolerance and all the 38 plants of Dan IIa showed 'Type 2' drought tolerance. The 6 F_1 plants were all drought tolerant like TVu 11986 indicating the dominance of 'Type 1' over 'Type 2' drought tolerance (Fig. 1 see page 316). The F_2 population segregated into 68 'Type 1' drought tolerant : 23 'Type 2' drought tolerant plants showing a near perfect fit to 3:1 ratio. These data suggested that the two types of drought tolerance are either very closely linked or controlled by two alleles at the same locus.

The results of the present study have shown that shoot drought tolerance in cowpea is simply inherited for both 'Type 1' and 'Type 2' mechanisms with drought tolerance as a dominant trait. The gene symbols 'Rds1' (resistance to drought stress) and 'Rds2' are being assigned to the genes conferring drought tolerance in TVu 11986 and Dan IIa respectively. The allelic test further indicated that the genes, 'Rds 1'.and 'Rds 2' are either closely linked or they are allelic at the same locus making it difficult or impossible to combine both of these in the same variety. However, 'Type-2' tolerance seems to be better than 'Type-1' and both are simply inherited and therefore, incorporation of these genes into improved cowpea varieties to ensure higher level of drought tolerance is possible. This study further indicated that wooden-box method can be used to screen segregating populations for drought tolerance and the derived plants can be transplanted after ascertaining the differences. This method is, therefore, simple and non destructive for drought tolerant plants.

The simplicity of the wooden-box method and the simple inheritance of drought tolerance in this study may be due to its focus on only the shoot drought tolerance without involving the contribution of roots and other factors. There are several mechanisms of drought tolerance which operate at different stages of the plant growth [7-11]. Most of the earlier studies on drought tolerance have been conducted in the field where different mechanisms contribute to the overall drought tolerance of the [12-14] and make it appear to be a complex trait. Screening for dehydration tolerance of the shoots only in the seedling stage using the wooden-box method involves primarily the stomatal behaviour and/or osmotic adjustments as other mechanisms are not operative. Once the plants sense water stress, the genes controlling stomatal behaviour and/or osmotic adjustments would be activated. The opening and closing of stomata and permitting solutes to accumulate in the cells may be simple phenomena, and therefore, they may be under major gene control as evident from the results of this study. However, this needs to be further studied using different crop species.

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