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INTRASPECIFIC VARIABILITY FOR DROUGHT RESISTANCE IN COWPEA

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ABSTRACT

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Potential drought resistances of 304 diverse cowpea (*Vigna unguiculata* (L.) Walp.) genotypes were determined using plants grown in dryland and irrigated plots near Lubbock, Texas, during a severe drought (60 mm rainfall) in 1980. Screening for drought resistance was based on total shoot dry weight 55 and 77 days after planting (DAP). Genotypes were classified as either resistant or susceptible on five criteria: (1) shoot dry weight in dryland plots, 55 and 77 DAP (SDW); (2) percentage reduction in shoot dry weight in dryland plots as compared to shoot dry weight in irrigated plots (SDW%); (3) rate of growth in dryland plots between 55 and 77 DAP (RATE); (4) percentage reduction in rate of growth between dryland and irrigated plots (RATE%); (5) mean productivity expressed as average performance in both environments (MP). Genotypes classified as resistant or susceptible by percentage reduction criteria, such as SDW% and RATE%, tended to perform well in one environment and not in the other. Therefore, identification of drought-resistant germplasm may require screening on the basis of an absolute measurement of performance, such as SDW or RATE, in combination with a percentage reduction criterion, such as SDW% or RATE%. Seven genotypes (TVu 29, TVu 2074, TVu 2157, TVu 2319, TVu 2538, TVu 5150 and TVu 5158) were classified as drought-resistant and four (TVu 1570, TVu 1630, TVu 1819 and TVu 3444) as drought-susceptible by more than three criteria. Improved drought resistance in cowpea via plant breeding appears to be feasible.

Keywords: breeding; genetic variability; germplasm; grain legume; N_2 fixation; screening; southernpea; *Vigna unguiculata*; water stress.

Abbreviations: DAP = days after planting; MP = mean productivity (average performance) in irrigated and dryland plots; RATE = rate of growth in dryland plots; RATE% = percent reduction in rate of growth; SDW = shoot dry weight in dryland plots; SDW% = percent reduction in shoot dry weight (difference method).

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INTRODUCTION

Although cowpea (*Vigna unguiculata* (L.) Walp.) is a relatively drought-resistant species as compared to other grain legumes (Wien et al., 1979), water stress reduced both yield (Hiler et al., 1972; Summerfield et al., 1976; Wien et al., 1979; Turk and Hall, 1980a,b,c; Turk et al., 1980) and N_2 fixation (Doku, 1970; Kamara, 1976; Summerfield et al., 1976; Zablotowicz, 1978; Wien et al., 1979). Attempts to identify intraspecific variability for drought resistance among otherwise adapted cultivars of cotton (*Gossypium hirsutum* L.) have not been successful (Quisenberry et al., 1981). Thus, the likelihood of identifying intraspecific variability for drought resistance in cowpea may be increased if exotic germplasm, as well as named cultivars and breeding lines, were screened. Improving drought resistance in any crop species usually involves mass-screening of many genotypes to identify uniquely drought-resistant germplasm from which specific drought-resistance traits can be selected.

According to Quisenberry et al. (1981, 1982), breeding for drought resistance should follow the same approach as has been used in breeding for disease and insect resistance. Initially, traits of germplasm which demonstrate resistance should be identified regardless of seed and yield characteristics (Quisenberry et al., 1981, 1982). Screening for drought resistance should be based on productivity in stress environments, which can be measured as either seed yield or dry matter accumulation (RATE). Screening on the basis of seed yield would be an indirect approach to evaluating productivity in a stress environment, as yield is affected by many genes not related to drought resistance. Using this approach, germplasm should be screened for dry matter accumulation (growth rate) rather than seed yield in stress environments. As Quisenberry et al. (1981, 1982) point out, growth rates and yield may be difficult to separate statistically. However, germplasm demonstrating higher RATE in stress environments can be used to identify specific traits which may be incorporated into widely adapted cultivars by plant breeding. Quisenberry et al. (1982) have successfully used this approach to identify differences in stomatal behavior and cuticular resistance among exotic lines of cotton (*Gossypium hirsutum* L.).

Other studies have attempted to distinguish between selecting for small differences in yield between stress and non-stress environments (difference method), and selecting for high average performance (MP) in stress and non-stress environments (Rosielle and Hamblin, 1981). On a theoretical basis, they concluded that the objective of a specific breeding program should suggest which approach is most appropriate. According to Rosielle and Hamblin (1981), if the overall objective is to improve yield in stress environments only, then breeders should select for small differences in yield between stress and non-stress environments, assuming that the genetic variance in the non-stress environment is less than the variance in the stress environment. However, if the objective is to increase average performance

in both environments, they suggest that selection for small differences will decrease both MP and performance in non-stress environments. However, if selection is based solely on MP, selected lines can be expected to have less resistance (Rosielle and Hamblin, 1981). If selection is based on accumulation of dry matter rather than on yield, as suggested by Quisenberry et al. (1981, 1982), similar outcomes might be expected.

The goal of this series of studies was to increase N_2 fixation and seed yield through enhanced drought resistance (Walker et al., 1981; Walker and Miller, 1982a,b, 1983, 1986; Walker, 1983). The objective of this experiment was to evaluate five criteria for selecting drought resistant and susceptible cowpea genotypes based on shoot biomass production under irrigated and dryland (water-stressed) conditions.

MATERIALS AND METHODS

Three hundred and four genotypes, including lines from the Cowpea Genetic Diversity Nursery, obtained from the International Institute of Tropical Agriculture, Ibadan, Nigeria, were evaluated for relative drought resistance. Plants were grown at the Texas A&M University Research and Extension Center at Lubbock, Texas, U.S.A., under irrigated and dryland (water-stressed) conditions, following a pre-plant irrigation (122 mm) of the entire field. Seeds were planted on 21 May 1980, approximately 15 cm apart in rows 4 m long and 100 cm apart, in an Amarillo sandy clay loam (Aridic Paleustalfs) and inoculated with a commercial mixed-strain *Rhizobium* inoculant. Treflan was applied pre-plant at a recommended rate of 0.45 L a.i. ha^{-1}. Adequate levels of soil P and K were verified by soil testing. The experimental design was randomized complete block with two replications.

Water was applied to irrigated plots 4 times during the growing period by furrow-type irrigation for a cumulative total of 233 mm. Total effective rainfall was only 60 mm during the growing season. A severe regional drought of a magnitude rarely experienced presented a unique opportunity to screen for drought resistance. Fifty-five and 77 DAP, two randomly selected plants from each replicated plot in irrigated and dryland treatments were severed at the soil surface, dried and weighed.

Five selection criteria were used to classify genotypes as drought-resistant or susceptible, based on shoot biomass accumulation of genotypes in irrigated and dryland plots.

(1) Shoot dry weight (SDW).

(2) Percentage reduction in shoot dry weight (difference method) (SDW%).

$$\text{SDW\%} = \frac{\text{Shoot dry weight (irrigated)} - \text{Shoot dry weight (dryland)}}{\text{Shoot dry weight (irrigated)}} \times 100$$

(3) Mean productivity (MP).

$$MP = \frac{\text{Shoot dry weight (irrigated)} + \text{Shoot dry weight (dryland)}}{2}$$

(4) Rate of growth (RATE).

$$\text{RATE (dryland)} = \frac{\text{Shoot dry weight (77 DAP)} - \text{Shoot dry weight (55 DAP)}}{\text{22 days}}$$

(5) Percentage reduction in rate of growth (RATE%).

$$\text{RATE\%} = \frac{\text{Rate of growth (irrigated)} - \text{Rate of growth (dryland)}}{\text{Rate of growth (irrigated)}} \times 100$$

Values for SDW, SDW%, MP, RATE and RATE% were determined from mean shoot dry weight of each genotype in the appropriate treatment. A rank percentile classification system was devised to identify drought-resistant or -susceptible genotypes (S.A.S., 1982). The values of each measured variable were ranked from high to low. Genotypes in the top 85 or bottom 15 percentile of ranks for SDW or MP on both 55 and 77 DAP were classified as resistant or susceptible, respectively, for each criterion. Genotypes in the bottom 15 or top 85 percentile of ranks for SDW% on both 55 and 77 DAP were classified as resistant or susceptible, respectively. Genotypes were also classified as resistant if their RATE in dryland plots fell into the top 15 percentile, and if their RATE% was in the bottom 15 percentile, of ranks. That is, for a genotype to be classified as resistant, it must have high SDW, 55 and 77 DAP, high MP, 55 and 77 DAP, or low SDW%, 55 and 77 DAP, or high RATE and low RATE%. Fifteen percent was chosen as the critical level for classification, because it classified a sufficient number of genotypes as resistant or susceptible to allow comparisons among the various selection criteria. A classification system using *t*-tests at the 5% level of significance was devised, but was found to be too restrictive, particularly for genotypes with low values for each variable.

RESULTS AND DISCUSSION

Considerable variability among genotypes was found for each drought-resistance selection criterion. SDW, 55 DAP, ranged from 3.25 to 24.75 g for genotypes classified as resistant or susceptible by SDW on both harvest dates (Table I). The range of SDW, 77 DAP, was from 4.25 to 54.75 g. Fifteen genotypes were identified as resistant and 16 as susceptible, at both 55 and 77 DAP, by the SDW criterion. For genotypes classified as resistant or susceptible by SDW% at both harvest dates, SDW% ranged from −25.32 to 91.08% and 35.06 to 94.88%, 55 and 77 DAP, respectively (Table II). Sixteen genotypes were classified as resistant by the SDW% criterion, while another 16 were classified as susceptible, 55 and 77 DAP. Mean productivity for genotypes classified as resistant or susceptible by MP

TABLE I

Shoot dry weight in dryland plots of selected drought-resistant and -susceptible genotypes, 55 and 77 DAP

Resistant[1]			Susceptible		
Genotype[2]	Shoot dry weight (g)		Genotype	Shoot dry weight (g)	
	55 DAP	77 DAP		55 DAP	77 DAP
TVu 129	20.50[3]	42.50	Purple Tip	3.50	17.00
TVu 152	14.50	45.75	TVu 1	5.25	11.00
TVu 656	14.40	39.00	TVu 281	6.25	17.50
TVu 1489	17.00	42.75	TVu 361	5.50	12.75
TVu 2074	17.75	52.50	TVu 985	5.50	17.50
TVu 215	14.50	43.75	TVu 1014	3.50	18.00
TVu 231	24.75	53.00	TVu 1258	6.25	17.00
TVu 2878	18.75	41.50	TVu 1570	6.25	4.25
TVu 2926	16.00	41.00	TVu 3165	5.75	16.25
TVu 3004	21.00	46.25	TVu 3444	5.00	17.75
TVu 3110	19.25	54.75	TVu 3766	3.25	16.75
TVu 3192	19.00	43.25	TVu 4048	5.50	14.25
TVu 5150	15.50	53.25	TVu 6441	5.50	17.50
TVu 5155	14.25	41.00	TVu 6539	5.75	18.25
TVu 5158	14.75	50.00	TVu 6565	4.75	14.25
			TVu 6639	6.25	16.25

[1]Resistant = top 85 percentile of ranks; susceptible = bottom 15 percentile for shoot dry weight in dryland plots, 55 and 77 DAP.
[2]TVu numbers as cited in Cowpea Germplasm Catalog, No. 1, 1974. International Institute of Tropical Agriculture, Ibadan, Nigeria.
[3]Means (± S.E.) for all genotypes were 10.41 ± 0.22 g and 28.11 ± 0.54 g, 55 and 77 DAP, respectively.

on both dates ranged from 11.88 to 44.38 g and from 29.50 to 123.63 g, 55 and 77 DAP, respectively (Table III). Selection by the MP criterion resulted in 19 and 14 genotypes classified as resistant and susceptible, respectively, 55 and 77 DAP. For genotypes identified as resistant or susceptible by both RATE and RATE%, values ranged from −0.19 to 2.47 g/day and from 105.30 to −46.32%, respectively (Table IV). Twenty-eight genotypes were classified as resistant by both RATE and RATE%, while 29 were classified as susceptible.

Of 304 genotypes screened for drought resistance, a minimum of 45 genotypes would be selected by each selection criterion using the rank percentile classification system at each of the two harvest dates. Tables I—III report genotypes selected by each criterion on both harvest dates. Table IV reports genotypes selected by two closely related selection criteria, RATE and RATE%. The large number of genotypes represented in Tables I—IV indicates that considerable variability for drought resistance exists in cowpea.

TABLE II

Percentage reduction of shoot dry weight in dryland plots of selected drought-resistant and -susceptible genotypes, 55 and 77 DAP

Resistant[1]			Susceptible		
Genotype[2]	Shoot dry weight (%)		Genotype	Shoot dry weight (%)	
	55 DAP	77 DAP		55 DAP	77 DAP
AU 70.4	27.63[3]	55.81	TVu 985	82.68	84.16
L-886	26.03	58.45	TVu 1014	91.08	85.00
SC 72-3	36.21	53.28	TVu 1243	85.23	84.37
TVu 29	20.00	49.14	TVu 1468	83.53	84.06
TVu 129	31.67	52.78	TVu 1570	85.55	94.88
TVu 1887	49.65	53.51	TVu 1630	84.76	88.40
TVu 1893	41.57	46.38	TVu 1819	89.11	93.83
TVu 2154	34.33	35.06	TVu 1840	81.44	8.13
TVu 2157	42.28	49.28	TVu 2724	81.99	86.95
TVu 2319	−25.32	56.29	TVu 3165	87.01	85.29
TVu 2538	38.16	47.27	TVu 3444	86.01	88.26
TVu 3004	52.54	56.57	TVu 3766	90.85	87.07
TVu 3279	52.31	52.13	TVu 6441	82.54	84.05
TVu 4567	50.93	49.33	TVu 6549	81.88	86.42
TVu 5158	23.38	38.65	TVu 6565	84.03	87.16
TVu 6347	52.14	55.70	TVu 6619	81.43	87.96

[1] Resistant = bottom 15 percentile of ranks; susceptible = top 85 percentile for percentage reduction of shoot dry weight in dryland plots as compared to shoot dry weight in irrigated plots, 55 and 77 DAP.
[2] TVu numbers as cited in Cowpea Germplasm Catalog, No. 1, 1974, International Institute of Tropical Agriculture, Ibadan, Nigeria.
[3] Means (± S.E.) for all genotypes were 66.69 ± 0.89% and 72.64 ± 0.71%, 55 and 77 DAP, respectively.

Several genotypes were selected as resistant or susceptible by more than one selection criterion. Genotypes classified as resistant by four criteria, SDW (55 and 77 DAP), SDW% (55 and 77 DAP), RATE and RATE%, were TVu 2157 and TVu 5158. TVu 1570 was also selected as susceptible by these four criteria. Some genotypes were classified as resistant or susceptible by three criteria, but not by four. TVu 29 and TVu 2538 were resistant by SDW% (55 and 77 DAP), RATE and RATE%, while TVu 1630 and TVu 1819 were susceptible. Genotypes classified as resistant by SDW (55 and 77 DAP), RATE and RATE% were TVu 2074 and TVu 5150. TVu 2319 was selected as resistant by SDW (55 and 77 DAP), SDW% (55 and 77 DAP) and RATE. TVu 3444 was found to be susceptible by SDW (55 and 77 DAP), SDW% (55 and 77 DAP) and RATE%. Genotypes selected by the MP criterion were the least likely to be selected by more than one criterion, since no genotype was found to be resistant by more than two selection criteria (both dates) and MP. Three genotypes, TVu 2878, TVu 2926 and

TABLE III

Mean productivity of selected drought-resistant and -susceptible genotypes, 55 and 77 DAP

Resistant[1]			Susceptible		
Genotype[2]	Mean productivity		Genotype	Mean productivity	
	55 DAP	77 DAP		55 DAP	77 DAP
TVu 290	29.38[3]	105.38	AU 70.4	16.38	38.75
TVu 1155	30.00	120.75	L-894	14.13	29.50
TVu 1243	37.88	104.50	L-886	15.88	50.25
TVu 1819	35.63	105.38	SC 72-3	11.88	47.50
TVu 2525	30.75	94.88	TVu 1	13.00	34.00
TVu 2878	31.88	95.88	TVu 36	15.50	40.50
TVu 2889	31.13	110.75	TVu 53	15.13	50.00
TVu 2905	28.63	99.13	TVu 93	15.13	51.38
TVu 2926	31.13	90.88	TVu 185	16.38	49.88
TVu 2975	34.50	90.63	TVu 2154	13.88	43.88
TVu 3099	34.00	123.63	TVu 2181	15.75	40.25
TVu 3192	27.50	112.88	TVu 3279	12.00	39.00
TVu 3388	28.13	106.00	TVu 6317	16.00	48.38
TVu 3463	28.25	87.38	TVu 6368	14.25	42.63
TVu 3535	32.50	91.75			
TVu 3537	31.75	106.50			
TVu 3751	44.38	100.63			
TVu 3898	32.00	89.00			
TVu 6621	27.50	104.33			

[1] Resistant = top 85 percentile of ranks; susceptible = bottom 15 percentile for mean productivity in irrigated and dryland plots, 55 and 77 DAP.
[2] TVu numbers as cited in Cowpea Germplasm Catalog, No. 1, 1974, International Institute of Tropical Agriculture, Ibadan, Nigeria.
[3] Means (± S.E.) for all genotypes were 21.92 ± 0.31 g and 70.00 ± 1.03 g, 55 and 77 DAP, respectively.

TVu 3192, were classified as resistant by both MP (55 and 77 DAP) and SDW (55 and 77 DAP), while TVu 1 was susceptible. No other unique combinations of MP and any other selection criterion were found. Classification by MP and any other selection criterion may be nearly mutually exclusive.

Several genotypes were classified as resistant by one criterion and susceptible by another. In particular, discrepancies existed between MP and RATE or SDW%. Since MP is very dependent upon performance in irrigated plots, these discrepancies were not unexpected. Genotypes found to be resistant by SDW% and susceptible by MP were so classified because shoot dry weights in irrigated treatments were extremely low. Genotypes classified as resistant by MP and susceptible by SDW% had unusually high values for shoot dry weight in irrigated plots. Genotypes classified as resistant by MP and susceptible by RATE had high values for shoot dry weight in both

TABLE IV

Rate of growth in dryland plots expressed in g/day and as percentage reduction of selected drought-resistant and -susceptible genotypes

Resistant[1]			Susceptible		
Genotype[2]	Rate of growth		Genotype	Rate of growth	
	g/day	Reduction (%)		g/day	Reduction (%)
Miss Silver	1.33[3]	51.45	Brown Crowder	0.34	91.20
TVu 29	1.58	54.83	TVu 76	0.19	91.20
TVu 83	1.44	34.20	TVu 314	0.27	96.22
TVu 90	2.19	51.63	TVu 400	0.36	93.10
TVu 966	2.47	−10.15	TVu 521	0.24	94.39
TVu 1926	1.63	21.86	TVu 1463	0.32	90.97
TVu 2006	1.75	36.36	TVu 1570	−0.09	105.30
TVu 2074	1.58	−46.32	TVu 1630	0.42	90.39
TVu 2157	1.33	51.05	TVu 1799	0.27	90.81
TVu 2166	1.77	54.91	TVu 1819	0.24	96.09
TVu 2318	1.25	−18.28	TVu 2738	0.30	91.42
TVu 2337	1.36	47.37	TVu 2757	0.23	94.22
TVu 2394	1.74	54.60	TVu 2786	0.39	89.94
TVu 2396	1.51	47.64	TVu 2807	0.05	93.13
TVu 2408	1.20	48.04	TVu 2853	0.19	90.17
TVu 2538	1.44	50.00	TVu 2864	0.32	91.30
TVu 2891	1.23	16.92	TVu 3099	0.16	98.01
TVu 2908	1.58	35.05	TVu 3146	0.40	91.29
TVu 3007	1.35	56.57	TVu 3421	0.24	92.34
TVu 3026	2.14	36.27	TVu 3531	0.32	92.02
TVu 3121	1.34	39.18	TVu 3535	−0.19	103.46
TVu 3233	1.30	33.33	TVu 3537	0.39	93.97
TVu 5150	1.72	11.18	TVu 3716	0.36	91.44
TVu 5158	1.60	43.37	TVu 3751	0.42	91.04
TVu 6344	1.35	19.05	TVu 3767	0.31	93.25
TVu 6480	1.45	42.34	TVu 4742	0.29	90.11
TVu 6487	1.39	46.49	TVu 6317	0.31	88.36
TVu 6612	1.23	57.48	TVu 6540	0.38	90.86
			TVu 6594	0.42	89.24

[1] Resistant = top 85 percentile of ranks for g/day and bottom 15 percentile for percentage reduction. Susceptible = bottom 15 percentile of ranks for g/day and top 85 percentile for percentage reduction. Genotypes were selected as resistant or susceptible by both criteria.

[2] TVu numbers as cited in Cowpea Germplasm Catalog, No. 1, 1974, International Institute of Tropical Agriculture, Ibadan, Nigeria.

[3] Means (± S.E.) for all genotypes were 0.81 ± 0.02 g/day and 73.25 ± 1.10%.

irrigated and dryland plots at 55 DAP. However, the rate of growth was slow between 55 and 77 DAP in dryland plots. Hence, these genotypes were classified as susceptible by the RATE criterion. Maintenance of growth in the irrigated treatments resulted in a classification of resistance by the MP

criterion. These discrepancies point out that if MP is used as a selection criterion, it should be used in conjunction with another selection criterion more sensitive to drought stress.

To understand what kind of plant response is described by each selection criterion, shoot dry weight in dryland plots was plotted against shoot dry weight in irrigated plots for genotypes classified as resistant or susceptible by each selection criterion at each harvest date. A reference line for mean shoot dry weight for all genotypes in each treatment at each date was plotted. Genotypic means greater than the mean value in both environments of all genotypes screened are found in the upper, right-hand quadrant. These genotypes performed well in both environments. Genotypes falling into the upper, left-hand quadrant did well in the dryland treatments, but not in the irrigated treatments. Those with values in the lower, right-hand quadrant grew well in the irrigated treatments, but not in dryland treatments. Finally, the lower, left-hand quadrant is the location of genotypes which did not perform well in either treatment environment.

For instance, the SDW criterion selects genotypes with high biomass production in dryland plots without regard to performance in the irrigated treatment (Fig. 1). Therefore, a diverse set of traits can be expected in

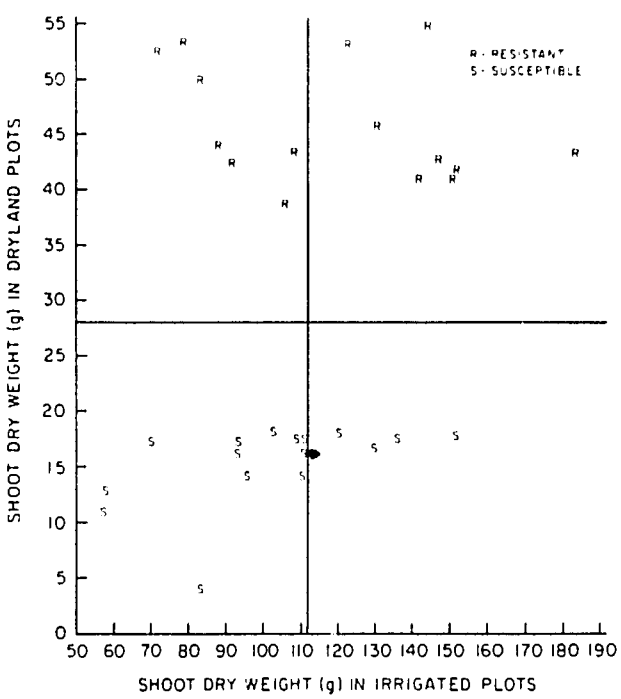

Fig. 1. Shoot dry weight of selected genotypes grown in irrigated and dryland plots, 77 DAP. Genotypes were classified as resistant or susceptible by shoot dry weight in dryland plots, 55 and 77 DAP. The vertical and horizontal reference lines represent the mean value of all genotypes screened.

genotypes identified as drought-resistant or -susceptible by this criterion, ranging from drought resistance traits unique to a few genotypes to traits which impart high baseline biomass production in both environments.

SDW% tends to classify genotypes as resistant because they do not perform well in the irrigated environment. Figure 2 shows a large number of selected resistant genotypes falling into the upper, left-hand quadrant, and susceptible genotypes falling into the lower, right-hand quadrant. Thus, SDW% appears to select genotypes which perform well in one environment but not the other. In fact, genotypes selected by SDW% are identified as resistant or susceptible because they do not perform well in one environment. Therefore, selecting genotypes solely on the basis of SDW% may ultimately reduce performance-potential in non-stress environments, as suggested by Rosielle and Hamblin (1981).

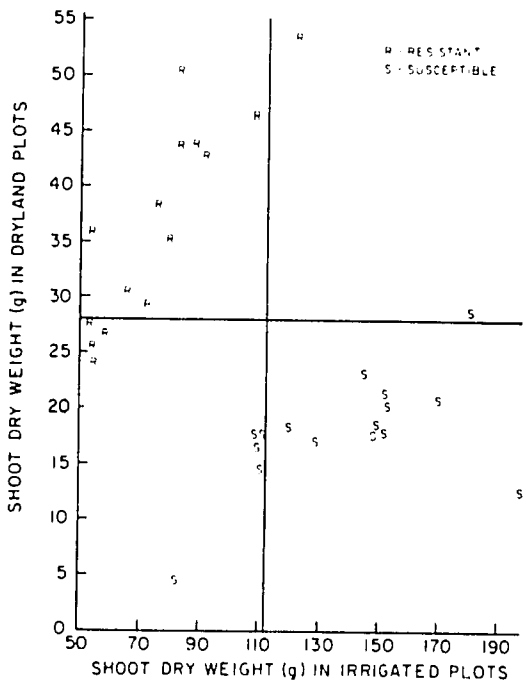

Fig. 2. Shoot dry weight of selected genotypes grown in irrigated and dryland plots, 77 DAP. Genotypes were classified as resistant or susceptible by percentage reduction in shoot dry weight in dryland plots, 55 and 77 DAP. The vertical and horizontal reference lines represent the mean value of all genotypes screened.

In contrast, MP performed as the literature suggested it would, with some of the resistant genotypes performing relatively well in both environments, while most of the susceptible genotypes performed poorly in both environments (Rosielle and Hamblin, 1981) (Fig. 3). It does not seem likely that traits which specifically impart drought resistance can be easily identified by the MP criterion, since selection by MP was more strongly influenced by performance in irrigated plots than by performance in dryland plots.

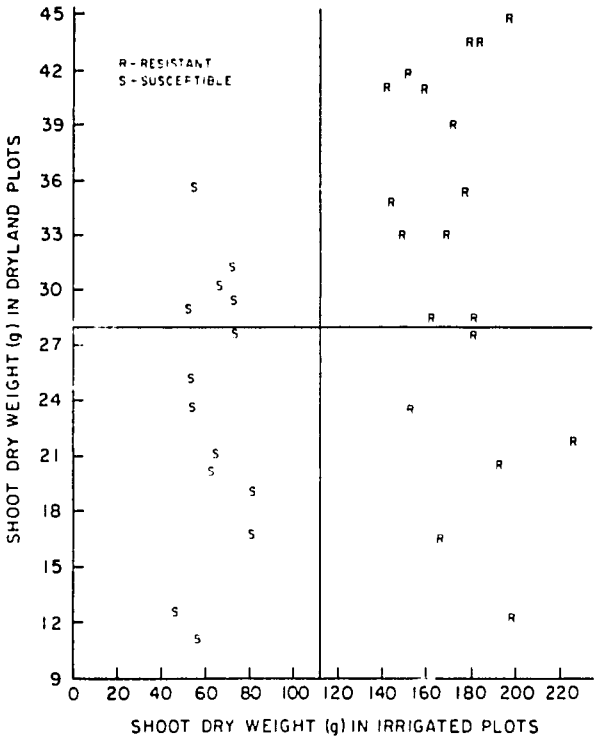

Fig. 3. Shoot dry weight of selected genotypes grown in irrigated and dryland plots, 77 DAP. Genotypes were classified as resistant or susceptible by mean productivity, 55 and 77 DAP. The vertical and horizontal reference lines represent the mean value of all genotypes screened.

At 77 DAP, the plot for RATE% resembles the plot for SDW% (Fig. 4). This indicated that RATE% tends to identify genotypes which perform well in one environment and not the other. In fact, both percentage reduction methods are probably identifying genotypes as resistant or susceptible because they do not perform well in one of the environments.

RATE, as a selection criterion, identifies genotypes without regard to their performance in irrigated plots, in much the same manner as the SDW criterion (Fig. 5). Both RATE and RATE% select genotypes based solely on performance at the second harvest date, without regard to shoot dry weight at the first harvest date, suggesting that these criteria tend to select indeterminate or non-flowering genotypes unless daylength-sensitive (non-flowering) genotypes are exclusively used to identify specific drought-adaptation traits.

These results suggest that identification of drought-resistant germplasm requires screening on the basis of an absolute measurement of performance, such as SDW or RATE, in combination with a percentage reduction criterion, such as SDW% or RATE%. Actually, using all four approaches,

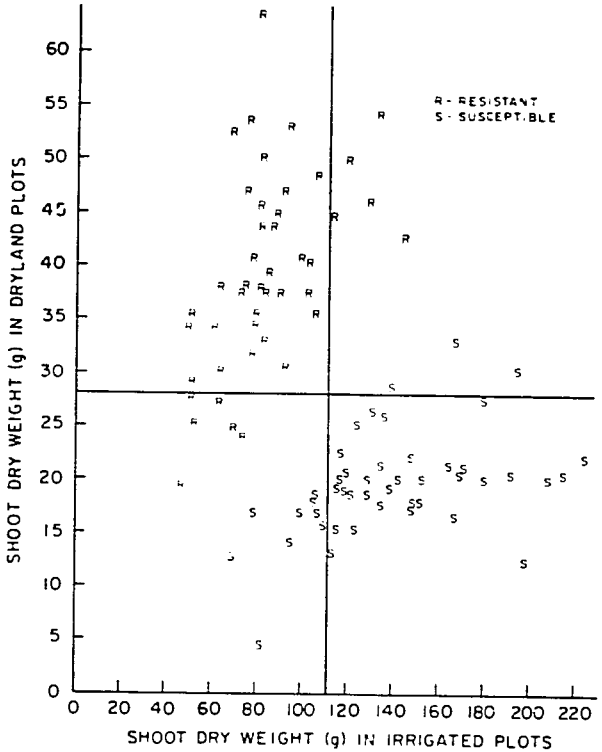

Fig. 4. Shoot dry weight of selected genotypes grown in irrigated and dryland plots, 77 DAP. Genotypes were classified as resistant or susceptible by percentage reduction in rate of growth. The vertical and horizontal reference lines represent the mean value of all genotypes screened.

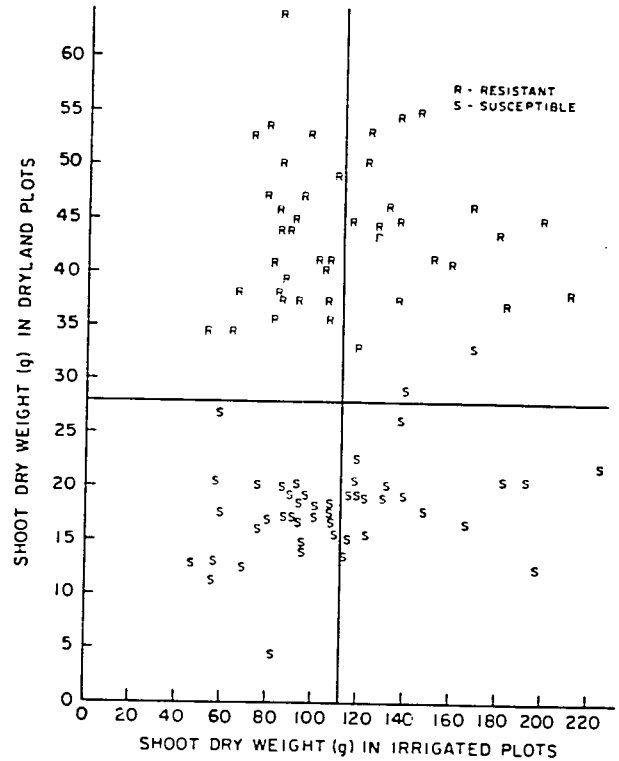

Fig. 5. Shoot dry weight of selected genotypes grown in irrigated and dryland plots, 77 DAP. Genotypes were classified as resistant or susceptible by rate of growth in dryland plots. The vertical and horizontal reference lines represent the mean value of all genotypes screened.

when screening on the basis of biomass production, is relatively simple if two environments can be created. Mean productivity does not appear to be a useful criterion for determining relative drought resistance.

Since the criteria used seem to select for different plant responses, it would appear that the greatest likelihood of successfully identifying superior germplasm would be to intensively study genotypes selected by several diverse selection criteria. Genotypes such as TVu 29, TVu 2074, TVu 2157, TVu 2319, TVu 2538, TVu 5150 and TVu 5158, identified as resistant by several selection criteria, should be compared to genotypes such as TVu 1570, TVu 1630, TVu 1819 and TVu 3444, classified as susceptible by several criteria, for the purpose of identifying specific drought-resistance traits to be used in a breeding program. The nitrogen-fixation potential of these genotypes was determined in a separate experiment (Walker, 1983).

It should be emphasized that a drought of the magnitude (60 mm rainfall) experienced in 1980 has not occurred again in this region since this initial study was completed, nor can a severe drought be predicted in future years; hence, only data from 1980 was presented. Furthermore, variation was quite large, as expected, and statistical tests, although significant for the effect of genotype on SDW, were impossible to interpret meaningfully for the 304 genotypes sampled on two dates in two treatments. However, numerous genotypes were classified as resistant or susceptible by more than one criterion using the rank percentile system. Intraspecific variability for a drought-resistance trait, namely reduced loss of water from leaves, has been identified among genotypes classified as drought-resistant or -susceptible by the SDW criterion (Walker, 1983; Walker and Miller, 1986). It is expected that other specific traits can now be identified using the genotypes described here. In conclusion, the identification of drought-resistant germplasm by four drought-screeening criteria, SDW, SDW%, RATE and RATE%, based on biomass production, strongly suggests that the development or selection of drought-resistant cowpea genotypes appears to be feasible.

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