INHERITANCE OF TRAITS ASSOCIATED WITH DROUGHT RESISTANCE IN COWPEA

PEWARISAN KARAKTER YANG TERKAIT DENGAN KETAHANAN TERHADAP KEKERINGAN PADA KACANG TUNGGAK

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ABSTRACT

The genetic of traits related to drought-resistance in cowpea was studied using generation mean analysis. The two contrasting drought-resistance genotypes were crossed to generate F1, F2, F3, BC1, BC2, BC1S1, and BC2S1populations which were imposed to a controlled water deficit conditions from flowering to early pod formation. The analyses were performed on stem diameter, delayed leaf senescence, and leaf temperature which were identified in earlier study as good discriminators in discerning genotypes for drought-resistance. The resistant genotype was characterized by higher delayed leaf senescence, larger stem diameter, and lower leaf temperature . The means indicated that delayed leaf senescence was controlled by partial dominant gene(s) dan segregated toward resistance. Heterotic effect toward susceptibility was found on stem diameter but recombination and segregation had seemed to bring about a reversed direction. Partial dominant gene(s) also played an important role in governing leaf temperature toward susceptibility. The Hayman’s generation mean analysis suggested that additive effect was important in controlling the three traits. The dominant and epistatic (additive-additive and additive dominant) effects were significant on stem diameter, whereas additive-dominant effect was the only additional effect for leaf temperature, beside the additive effect.

Key words: cowpea, inheritance, drought-resistance

ABSTRAK

Sifat genetik dari karakter yang terkait dengan resistensi terhadap kekeringan pada kacang tunggak dipelajari dengan analisis rataan generasi. Dua genotipe yang berbeda resistensinya disilangkan untuk menghasilkan populasi F1, F2, F3, BC1, BC2, BC1S1, dan BC2S1 yang kemudian dihadapkan pada kondisi kekurangan air pada fase pembungaan hingga awal pengisian polong. Analisis dilakukan pada karakter penundaan penuaan daun, diameter batang, dan suhu daun, yang sebelum diidentifakasi sebagai karakter yang dapat digunakan untuk membedakan genotipe resisten dan genotipe peka kekeringan. Genotipe resisten dicirikan dengan skor penunadaan penuaan daun yang lebih tinggi, diameter batang lebih besar, dan suhu daun lebih rendah dibanding genotipe peka. Nilai rataan menunjukkan bahwa penundaan penuaan daun dikendalikan oleh gen dominan parsial dan bersegregasi ke arah resisten. Efek heterotik ke arah peka dijumpai pada diameter batang tetapi cenderung berbalik ke arah resisten jika mengalami rekombinasi atau segregasi. Gen dominant parsial juga mempunyai peran penting dalam mengatur suhu daun ke arah peka. Analisis rataan generasi Hayman menunjukkan bahwa efek aditif mempunyai peran penting dalam mengendalikan ke tiga karakter. Efek dominan dan epistasis (aditif-aditif dan aditif-dominan) merupakan efek tambahan yang nyata pada diameter batang, sedangkan efek aditif-dominan merupakan satu-satunya efek tambahan pada suhu daun selain efek aditif.

Kata kunci : kacang tunggak, pewarisan, resisten kekeringan

INTRODUCTION

Identification of efficient and effective selection criteria remains major challenge to cowpea breeders in developing drought-resistant cultivars. Screening for drought-resistance is more difficult compared to screening for other kinds of resistance to environmental stresses, including pest and diseases resistance. The reason is that the expressions of drought-resistance depend on action and interaction of different morphological, physiological, and biochemical characteristics (Mitra, 2001).

Many traits have been proposed as selection criteria for improving performance of drought affected cowpea, each supported by evidence of varying quality (e.g. Walker and Miller, 1986; Ludlow and Muchow, 1990; and Gwathney and Hall, 1992)

To plant breeder, drought resistance means the ability of a genotype to be more productive with a given amount of soil moisture than another genotype. Therefore, their primarily concern is simple but effective criteria for selecting the genotypes within the germplasm and the genetic mechanism that control the expression of the traits conferring resistance. In earlier study, it has been reported that stem diameter, delayed leaf senescence, and leaf temperature had showed high level of accuracy in discriminating the drought-resistance genotypes from their drought-susceptible counterparts (Chozin *et al.*, 2003). Nevertheless, the value of these traits as selection criteria should be guided by the genetic knowledge on their mode of inheritance to determine the selection strategy for drought stress improvement in cowpea. This study was aimed to observe the types of gene action controlling the expression of the three traits.

METHODOLOGY

The study was conducted at greenhouse of the Mississippi Agricultural and Forestry Experiment Station (MAFES) Plant Science Research Center, Mississippi State, MS during summer 2001. Seven generations of cowpea genotypes derived from two genotypes, Tvu 11986 and Tvu 7778, which have previously been identified as drought-resistant and drought-susceptible genotypes, respectively (Singh, 1999, personal communication). They were the parental, F1, F2, F3, BC1, BC2, BC1S1, and BC2S1. The cross of the parental was made during summer 1999, and the F1 seeds were planted and self-pollinated in the following season to produce F2 seeds. The F3 seeds were obtained from F2 plants, whereas BC1 and BC2 were obtained by crossing F1 plants to Tvu 11986 and Tvu 7778, respectively, during summer 2000. Both BC1 and BC2 seeds were planted and self-pollinated the following season to produce BC1S1 and BC2S1 seeds, respectively.

Plastic pots (25-cm diameter) filled with a mixture of spaghum peat moss and sand (1:1 v/v) were used as the planting media. Basal fertilizers (equivalent to 40 kg N, 80 kg P_2O_5, 80 kg K_2O hectare^{-1}) and 2.2 kg m^{-3} dolomitic limestone and micro-nutrients (0.6 kg m^{-3} of Micromax®) were added to each pot. The pots were randomly arranged on benches with 50-cm spacing between adjacent pots. Two seeds were sown in each pot but thinned to one plant pot^{-1} after emergence. Water was supplied on alternate days until they reached late vegetative stage. The plants were subjected to water-deficit from flowering to early pod formation stages (15 d). The moisture level was monitored daily using tensiometers and maintained by replenishing water at 3% of media weight.

The following traits were measured on all individual plants at the end of the water deficit period: a) Delayed leaf senescence, scored 1 to 5 (1=plant dead; 2= plant still alive, but most leaves abscised; 3= leave yellow and/or wilting; 4=leaves partially yellowed; and 5=leaves green); b) Stem diameter (mm), measured using a digital caliper at 1.5 cm above soil surface; and c) Leaf temperature (°C), measured on the youngest, fully expanded middle trifoliate leaf using a Li-1600 steady-state porometer (Li-cor, Inc.)].

Hayman's (1960) generation means analysis with notation as described by Gamble (1962) was performed to estimate the type of gene action confering the expression of these traits. There was inequality of population size among generations and heterogeneity of error variances. Weighted least squares, therefore, were used to estimate the genetic parameters with the model suggested by (Rowe and Alexander, 1980). Then analysis was performed using REG procedure in SAS statistical software (SAS Institute, Inc., 1988). The variance estimates were obtained as suggested by Gamble (1962). The degree of dominance that determine the importance of dominance effects relative to the additive effects was estimated following Kearsey and Pooni (1996).

RESULTS AND DISCUSSION

Population means and variances

Means and variances of the populations derived from the cross Tvu 11986 x Tvu 7778 are presented in Table 1. The means of the F1 and F2 populations for delayed leaf senescence were intermediate between the parental means. Similarly, the backcross means were intermediate between the F1 and the recurrent parent. Positive and negative deviations of the F1 generation for delayed leaf senescence from the mid-parent and the resistant parent, respectively, suggested that the gene(s) governing the expression of this trait were partially dominant toward resistance.

For stem diameter, the mean of the F1 population was lower than both parental means. This suggested a heterotic effect toward susceptibility. The means of the F2 and F3 generations were considerably higher than the resistant parent (P1), suggesting recombination and segregation for stem diameter with increased resistance. Furthermore, the difference between the F1 and BC1 was greater than between the F1 and BC2. This also supported the idea that there was considerable recombination for resistance.

The means of the parental populations indicated that drought resistance is characterized by lower leaf temperature. The F1 for leaf temperature was intermediate between the parental means. The resistant parent was characterized by lower leaf temperature. Therefore, positive deviation of the F1 from both the mid-parent and the resistant parent values for leaf temperature implied that the gene(s) controlling the expression of the leaf temperature was partially dominant toward susceptibility. Both selfing and backcrossing of the F1 did not result in a lowered leaf temperature.

For stem diameter, the F1 and parent populations had higher variances than the F2 population. This was not expected as the F1 and the parents are non-segregating populations. Similarly, the F1 and F2 populations had comparable variance for leaf temperature.

Gene effects

Generation means analysis indicated that additive gene effects were of primary importance for each three drought resistance traits, although the role of non-additive gene effects were not negligible (Table 2). The absolute magnitudes of non-additive gene effects are varied depending on the trait. For delayed leaf senescence, the dominance effect was as large as the additive gene effect. There was also a large dominance x dominance gene effect, indicating possible epistasis for delayed leaf senescence; however, none of the non-additive gene effects were significant for this trait. The method used to estimate standard errors of effect tended to overestimate variances of effects.

For stem diameter, the contributions of non-additive gene effects to the phenotypic expression were as important as the additive gene effect. This can be seen from the absolute values of the dominance and epistatic effects which were comparable in magnitude to the additive effect. Moreover, with the exception of dominance x dominance gene effect, the non-additive gene effect showed significance as well as the additive gene effect. For leaf temperature, the absolute magnitudes of additive x dominance and dominance x dominance gene effects were larger than the additive gene effect; however, significance tests indicated that the additive x dominance gene effect was more important than the additive gene effect.

These results suggested that the heterotic effect played an important role in the expression of the three drought resistance traits. In addition, the degree of dominance for these trait were much larger than 1.0, indicating high levels of heterosis. The presence of heterosis in cowpea is not an uncommon phenomenon.

Many plant characteristic including yield and most yield component exhibit considerable heterosis (Kheradnam et al., 1975; Adu-Dapaah *et al.,* 1988).

This study indicated that incorporation of the genes controlling the three traits into improved cowpea varieties to enhance their drought-resistance is possible and backcross method would be good choice to meet this purpose, although the heterosis phenomena for these traits might not be easily fixed.

Table 1. Means and variances of populations derived from the cross Tvu 11986 x Tvu 7778

Population	Delayed leaf senescence		Stem diameter		Leaf temperature	
	Mean (mm)	Variance	Mean(mm)	Variance	Mean (^oC)	Variance
P1 (Tvu 11986)	3.87	0.40	9.02	4.42	33.55	0.68
P2 (Tvu 7778)	2.50	0.17	8.66	3.55	34.05	1.48
F1	3.25	0.75	8.12	5.49	33.83	1.73
F2	3.40	1.04	9.16	3.25	34.11	1.67
F3	3.05	0.41	9.81	2.94	33.98	2.21
BC1	3.35	0.28	9.31	3.56	33.79	1.80
BC1S	3.50	0.89	9.71	1.98	34.18	2.18
BC2	2.80	0.68	7.20	1.48	34.20	1.02
BC2S	2.70	0.46	7.97	1.77	34.05	1.82
F1-MP	0.07		-0.72		0.03	
F1-RP	-0.62		-0.90		0.28	

MP = mid parent, RP = resistant parent

Table 2. Estimates of gene effects for drought resistance traits

Parameter[†]	Delayed leaf senescence		Stem diameter		Leaftemperature	
	Effect	Variance	Effect	Variance	Effect	Variance
M	3.05 **	1.04	8.80 **	3.25	34.08 **	1.67
A	0.60 *	0.10	2.36 **	0.50	0.43 *	0.28
D	0.59	2.28	-2.52 *	9.09	-0.20	4.37
Aa	0.28	2.05	-2.06 *	7.22	-0.20	3.81
Ad	-0.10	0.13	2.07 *	1.00	0.68 *	0.42
Dd	-1.88	4.10	2.80	20.76	-0.65	80.99
Degree of dominance		6.75		6.02		5.99

[*] m = mean effect; a = additive effect; d = dominant effect; aa = additive x additive interaction effect; ad = additive x dominant interaction effect; dd = dominant x dominant interaction effect; *,** significant at the 0.10 and 0.05 levels of probability, respectively

In conclusion, additive gene effect played the most important role in controlling the three characters which were formerly identified as good criteria for drought resistance in cowpea. Similarly, the presence of heterotic effects offered good progress during selection supposed that the hybrid vigor can be fixed throught appropriate breeding procedure

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