Tropentag 2013, Stuttgart, Germany
September 17-19, 2013

Conference on International Research on Food Security, Natural Resource Management and Rural Development
organised by the University of Hohenheim

Genetic Analysis of Vegetative-Stage Drought Tolerance in Cowpea

Sanatu Alidu Mustapha[1], Ibrahim Dodzie Kwesi Atokple[2], Richard Akromah[3]

[1]University for Development Studies, Dept. of Agronomy, Ghana
[2]Savanna Agricutural Research Institute, Ghana
[3]Kwame Nkrumah University of Science and Technology, Dept. of Crops and Soil Sciences, Ghana.

Introduction

Cowpea (*Vigna unguiculata*) [L.] Walp) is a source of livelihood to millions of relatively poor people in less developed countries of the tropics. It is one of the ancient grain legume crops cultivated in semi-arid West Africa where rainfall is characteristically low (mean annual range of 300-600 mm), variable in time and space and undependable (Fussell et al., 1991). The grain is valued for its high protein content of about 23-25% and 50-67% starch. The fresh young leaves, immature pods and peas are used as vegetables, whilst several snacks and main dishes are prepared from the grain. The haulms are used as fodder for livestock particularly during the dry season (Blade et al., 1997). Although cowpea contributes significantly to the income of farmers in the northern savannah zones of West Africa where varieties with grain yield potentials in excess of 3.0 t/ha have been developed for cultivation, farm level yields of cowpea are within the range of 0.3 to 0.65 t/ha (SARI, 1996 and 1997). Besides the problem of insect pests (Singh and Jackai, 1985), sensitivity to soil moisture stress during the various growth stages of the crop significantly reduces grain yield. The timing and intensity of drought in relation to the crop phenology, sensitivity of flower, pod and seed development to high night temperatures are important constraints to sustainable cowpea production. The Northern sector of Ghana produces the bulk of cowpea for Ghana. After the cowpea is planted, drought incidence of between 20 and 30 days are not uncommon. Under this production system however, the variety of cowpea that is planted need to be particularly tolerant to drought during the vegetative phase. Identification and separation of varieties that tolerate unfavourable conditions such as drought would be of great value to farmers in the semi-arid zones including Northern Ghana.

Material and Methods

Nine genotypes of cowpea were used for the study. Four of these genotypes, Omondaw, Apagbaala, Milo and Padi Tuya were obtained from CSIR - Savannah Agricultural Institute (CSIR-SARI) and used as female lines. These lines have been developed by SARI for general cultivation to increase productivity in the three Northern Regions of Ghana. The other five genotypes which were among the best drought-tolerant cowpea lines came from the International Institute of Tropical Agriculture (IITA) Kano, Nigeria. These lines included IT 93K-503-1, IT 89KD-374-57, IT 97K-499-35, IT 99K-241-2 and IT 97K-568-19. Seeds of the parental lines were planted in 32cm-diameter plastic pots filled with black, loamy top soil in the screen house at

CSIR-SARI. At flowering, the female parents were each crossed with the same male parents to generate F1 populations.

Table 1: Crossing scheme to generate F_1 seeds

	Male Parents				
Female Parents	**IT 93K-503-1**	**IT89KD-374-57**	**IT97K-499-35**	**IT 99K-241-2**	**IT 97K-568-19**
APAGBAALA	APA X 503	APA X 374	APA X 499	APA X 241	APA X 568
PADITUAYA	PADI X 503	PADI X 374	PADI X 499	PADI X 241	PADI X 568
OMUNDAW	OMUN X 503	OMUN X 374	OMUN X 499	OMUN X 241	OMUN X 568
MILO	MILO X 503	MILO X 374	MILO X 499	MILO X 241	MILO X 568

Soil physical and chemical analyses

Soil samples were taken from the two main plots (i.e stressed and non-stressed plots) and the physical and chemical analyses was carried in the laboratory for each of the block.

After the characterization of the two plots, both the non stress and water stress experiments were irrigated to its water holding capacity and planted on the same day. For the water-stress experiment no further irrigation was done until after 30 days after planting. The non-stress experiment however received water based on the crop water demand established by daily field observations. After the 30 days had elapsed, both fields received water till pod maturity.

The experimental design was split-plot with watering regimes as main plots and test genotypes as sub-plots in three replications and completely randomized. The data collected were analyzed using the GenStat Statistical Program (Discovery Edition 3.0). First, the data on each trait was separated into moisture stress or non-stress set and analysed, followed by analysis of variance using the North Carolina II Design. The ANOVA of this cross-classified experiment, involving n_1 males crossed to n_2 females and genotypes replicated r times.

Results and Discussion

The ANOVA following the North Carolina II design provided estimates of the general combining ability (GCA) for the five advanced breeding lines used as males and for the four cultivars used as females, and the specific combining ability (SCA) for their crosses. In general, the GCA estimates for males were not significant ($P > 0.05$) for the majority of traits studied. Only for biomass and days to flowering under non-stress condition (Table 2) and hundred seed weight (Table 2) were the GCA estimates for males significant. On the other hand, female GCA estimates were significant for all six traits studied under both stress and non-stress conditions. For grain yield, Apagbaala and Padi Tuya contributed positively but their GCA estimates were significant only under adequate soil moisture conditions. The Milo cultivar was the best female under moisture stress conditions, contributing to increasing grain yield. Omondaw was the worst female as its GCA indicated that it reduced grain yield under both moisture regimes.

Table 2: General combining abilities for grain yield, biomass and days to flowering of nine cowpea lines evaluated under contrasting moisture regimes during the vegetative phase

		Grain yield		Biomass		Days to flower	
		No stress	***Stress***	***No stress***	***Stress***	***No Stress***	***Stress***
Females	Apagbaala	0.26	0.16	0.24	-0.57	-1.72	-2.03
	Milo	-0.22	0.311	0.17	-0.02	1.48	-0.17
	Omondaw	-0.49	-0.46	-0.99	-0.22	2.08	2.50
	Padi Tuya	0.46	0.02	0.58	0.81	-1.85	-0.30
	Standard error	*0.126*	*0.120*	*0.492*	*0.324*	*0.641*	*0.706*
Males	IT89KD-374-57	0.10	-0.11	-1.34	-0.45	-0.58	-0.47
	IT93K-503-1	-0.01	0.12	-0.37	0.00	0.25	0.20
	IT97K- 499-35	0.22	0.03	-0.34	0.72	-0.67	-1.38
	IT97K-568-19	-0.15	-0.15	1.03	-0.35	1.75	0.95
	IT99K-241-2	-0.16	0.07	1.03	0.10	-0.75	0.70
	Standard error	*Ns*	*ns*	*0.550*	*ns*	*0.717*	*Ns*

Specific Combining Ability Estimates

For grain yields, few SCA estimates were significantly different from zero ($P < 0.05$) under either moisture regimes. Under moisture stress, only Apagbaala × IT 97K- 499-35 and Padi Tuya × IT89KD-374-57 produced significant positive estimates (Table 3). Omondaw × IT 89KD-374-57 produced a significant negative SCA estimate for grain yield under moisture stress.

Table 3: Specific combining ability estimates for grain yield in a diallel mating of nine cowpea genotypes under moisture stress during the vegetative phase

	Males				
Females	IT89KD-374-57	IT93K-503-1	IT97K- 499-35	IT97K-568-19	IT99K-241-2
Apagbaala	0.19	-0.11	0.60	-0.46	-0.22
Milo	0.05	0.09	-0.48	0.42	-0.07
Omondaw	-0.81	0.45	0.18	-0.01	0.20
Padi Tuya	0.58	-0.42	-0.29	0.05	0.09

Standard error: 0.269.

The additive and dominance variance components were estimated for each trait under stress or adequate soil moisture conditions. Days to flowering, weight of hundred seeds and number of seeds per pod were conditioned mainly by additive genes. For biomass production, number of pods per plant and grain yield, dominance variance was higher than the additive variance component.

Pearson's correlation coefficient was determined between the six traits recorded in the experiment. Late flowering genotypes were associated with high biomass yields with $r = 0.547$. Under adequate soil moisture conditions, genotypes that were late to flower produced lower grain yields. In the present study, Padi Tuya combined well for yield under adequate soil moisture conditions, but not for stress conditions. On the other hand, Milo combined well for yield under stress conditions. A recurrent selection program that makes use of favourable alleles from different genetic backgrounds might help develop cultivars with increased yield under both adequate and moisture stress conditions.

Conclusions and Outlook

This study demonstrated that the development of high yielding hybrids, which equal or exceed the performance of elite commercial cultivars, is possible by crossing between high-yielding cowpea germplasms. The contributions of both GCA and SCA were important in explaining variation in grain yield among these hybrids. These results clearly indicate that yield can be improved by exploiting additive gene effects through such selection schemes as recurrent selection using genotypes that possess different responses to drought, and with high GCA effects to capitalize on favourable additive .With the relatively small effects of additive variance obtained for yield, recombinant inbred lines should be developed from crosses of lines that showed favorable GCA for yield

References

Blade, S. F., Shetty, S. V. R., Terao, T., and Singh, B. B., (1997). Recent development in cowpea cropping systems research. Pages 114-128. In: B. B. Singh, D. R. Mohan Raj, K. E. Dashiell, L. E. N. Jackai (eds). *Advances in cowpea research*. Co-publication of International Institute of Tropical Agriculture (IITA) and Japan International Research Centre for Agricultural Science (JIRCAS). IITA, Ibadan, Nigeria

Fussell L K, Bidinger F. R. Bieler P (1991) Crop physiology and breeding for drought tolerance: research and development. *Field crops Res* 27:183-199.

SARI (1996), Legumes improvements Programme. Pages 46-60. Savannah Agricultural Research Institute, Tamale – Ghana.

Singh, S. R., and Jackai, L. E. N., (1985). Insects pests of cowpea in West Africa: their life cycle, economic importance and potentials for control. Pages 217-231 In: B. B. Singh, D. R., Mohan Raj, K. E. Dashiell, L. E. N. Jackai (eds) *Advances in cowpea research.* Co-publication of International Institute of Tropical Agriculture (IITA) and Japan International Research Centre for Agricultural Science (JIRCARS). IITA, Ibadan, Nigeria

SARI (1997), Legumes improvements Programme. Pages 111-118. Savannah Agricultural Research Institute, Tamale – Ghana.