Annals of the Sri Lanka Department of Agriculture 2012. 14: 55-66.

EVALUATION OF COWPEA [*Vigna unguiculata* (L). Walp] GERMPLASM FOR DROUGHT TOLERANCE

M.C. MILLAWITHANACHCHI[1], A.P. BENTOTA[1], P. WEERASINGHE[1], S.N.K. SARANASINGHE[1], N.T. PRATHAPASINGHE[1] and R.A.C. KUMARI [2]

[1]*Grain Legumes and Oil Crops Research and Development Center Angunakolapellassa, Sri Lanka*

[2]*Extension and Training Service, Uva Province, Department of Agriculture, Sri Lanka*

ABSTRACT

Cowpea [*Vigna unguiculata* (L.) Walp] cultivations have experienced yield losses due to frequent drought stress. Improvement of varieties for drought tolerance is essential for the stability of crop yields. Two experiments were conducted with the objectives of identifying donor parents for variety improvement for drought tolerance and comparison of varietal screening methods. Preliminary screening under green house conditions was carried out with minimum water supply for germination and re-watering after one month. Based on the wilting and regeneration ranks, out of 95 lines tested, 15 lines were selected for field screening in a Randomized Complete Block Design with three replicates during the dry spell of 2011, *i.e. yala* season. Significant differences ($p<0.05$) were observed among the field-tested lines for plant height, days to 50 % flowering, yield, total root length, root spread area, shoot weight to root weight ratio, shoot length to root length ratio and leaf area index. Both the average green house ranks and field ranks for wilting symptoms recorded significant negative correlations ($p<0.05$) with total root length (-0.68 and -0.62, respectively), leaf area index (-0.52 and -0.57, respectively) and significant positive correlations ($p<0.05$) with shoot weight to root weight ratio (0.58 and 0.59, respectively). A positive correlation was observed (0.46; $p<0.05$)) between the average green house ranks and field ranks. The cowpea lines CP39, CP77 and CP128 were identified as better performers with lower values for the average green house ranks and field ranks for wilting, and regeneration ranks under tested low moisture conditions. The lines CP80, CP98 and CP115 were drought susceptible, which were characterized by early flowering, superficially narrow root systems and higher average ranks at green house, field and regeneration levels. As the average green house ranks recorded significant correlations ($p<0.05$) with field-tested criteria for drought tolerance, both combinations of green house screening and field screening during dry spells could be applied for donor parent identification and later generation evaluations, while green house screening could be used for rapid screening of early segregating generations.

KEYWORDS: Cowpea, Drought tolerance, Field screening, Green house screening

INTRODUCTION

Cowpea [*Vigna unguiculata* (L). Walp] is a grain legume commonly grown in the Dry Zone of Sri Lanka. It is an important dietary component of human nutrition and also provides a considerable amount of yield and a good income. These characteristics have encouraged resources poor farmers in the Dry Zone of the country to cultivate cowpea as a major crop under rainfed conditions, which is frequently subjected to drought conditions. Yet, the national average yield of the crop remains at 1.18 t ha^{-1} (DOA, 2010). The unpredictable weather conditions, lack of good quality seeds of new varieties and occurrence of pests and diseases are the major constrains encountered by the farmers.

Cowpea is one of the few crops that suits the drought-stricken areas with barren soils. Cowpea plants can tolerate low fertility due to its high rate of nitrogen fixation (Eloward and Hall, 1987), an important characteristic in cultivation of the crop under marginal conditions. Enhancement of drought tolerance of existing varieties would further secure the income level of low input farmers in the Dry Zone. Hence, identification of donor parents for cowpea breeding programmes for drought tolerance is a crucial factor. According to Mitra *et al.* (2001), any effort for genetic improvement for drought resistance utilizing the existing genetic variability requires an efficient screening technique, which should be rapid and capable of evaluating plant performance at the critical developmental stages and screening a large population. Therefore, two experiments were carried out in order to identify a rapid screening method and identify the drought tolerant genetic resources as donor parents for developing cowpea varieties for drought tolerance.

MATERIALS AND METHODS

Preliminary evaluation of cowpea germplasm for moisture stress

Ninety five germplasm lines of cowpea [*Vigna unguiculata* (L). Walp] collected from the Plant Genetic Resources Center (PGRC) at Peradeniya and from farmer fields were evaluated under moisture stress conditions in a green house during the late *maha* season 2010/2011 at Grain Legumes and Oil Crops Research and Development Center (GLORDC), Angunakolapellassa, Sri Lanka. Eight plants per each line were maintained as a single row in a 10 cm thick sand:soil (2:1 v/v) mixture on a concrete bench. The soil mixture was allowed to dry evenly and sieved to remove large stones and soil debris. The prepared soil mixture was used to fill a 10 cm layer of the seeding bed on the concrete bench, where an even height was maintained by using bricks for open sides. Seeds were placed at 10 cm spacing and an even planting depth of seeds was maintained by using a wooden plank with nails at the size of 2 cm long spaced at 10 cm. All the accessions were watered equally at a rate of 5 L m^{-2}. After the first watering the accessions were allowed to undergo moisture stress without any watering. Accessions were ranked from 1 to 4, *i.e.* green, no wilted appearance = 1, lower leaves showing slight wilted appearance = 2, yellowing of lower leaves and wilted = 3, yellowing of whole plant and wilted = 4, in three-day intervals until most of the plants showing wilting symptoms and dying.

After one month, when most of the plants were wilted, collapsed and dead, re-watering was done at the rate of 5 L m^{-2}. After three days from watering, the recovery of the lines was ranked again as 1 to 4, *i.e.* 100 - 75 % of the plants recovered = 1, 50 – 75 % the plants recovered = 2,.50 – 25 % plants recovered = 3, less than 25 % plants recovered = 4.

Field screening of selected cowpea germplasm for moisture stress

Fifteen lines (12 tolerant 3 susceptible) were selected based on the lower average green -house wilting ranks and regeneration ranks from preliminary evaluations for field screening at GLORDC. The experiment was carried out in a Randomized Complete Block Design (RCBD) with three replicates under existing drought conditions to further confirm the results of the preliminary study. The late planting was carried out (2nd of June 2011) to overlap the drought period of the *yala* season with the vegetative and reproductive stages of cowpea lines. Seeds were established in single 5 m rows at spacing of 45 cm between rows and 30 cm within rows. Seeds of the cowpea variety MI 35 were planted as boarder rows. Two irrigations were practiced within three days to ensure seed germination, and gaps were filled immediately. No irrigation was practiced until the end of the experiment. The soil moisture content was measured by using three soil samples obtained at weekly intervals from each replicate at depths of 10, 20, 30 cm using the dry oven method. The plant height was measured at weekly intervals. At the pod maturing stage, the leaf area, root length at different depths and root spread area were measured for three random plants per each line, using the grid method (Breada, 2003). The root and shoot dry weights were also obtained from the same plants using the dry oven method. Plants were ranked for wilting symptoms according to the ranks used for preliminary screening, starting from the 4th week to the end of the experiment, in three-day intervals. Days to 50 % flowering and yield were also recorded.

Data analysis

Analysis of Variance was performed for the quantitative characters using the SAS computer software package and the mean comparison was done using DMRT (p=0.05). The average green house rank was obtained by averaging the final three consecutive ranks (Singh and Matsui, 2003a). The field ranks were analyzed with Friedman test and the average field ranks were estimated based on the final ranks of three replicates (Conover, 1999). The correlation coefficients between the average green house rank, regeneration rank (green house), average field rank, total yield kg ha^{-1}, days to 50 % flowering, total root length, total root spread area, ratio of shoot weight:root weight, ratio of shoot length:root length, and leaf area index were obtained with Pierson correlation analysis using the SPSS computer software package (DeCoster, 2004).

RESULTS AND DISCUSSION

According to the field and screen house ranks for drought symptoms, and regeneration ranks after watering, the cowpea lines CP39, CP77, CP128 and CP122 have recorded lower values for both field, and screen house ranks and exhibited better recovery after watering by scoring lower values for regeneration (Table 1). The cowpea lines CP80, CP98 and CP115 recorded higher ranks under both field and green house conditions, and for plant recovery and expressing less adaptability towards drought. The results of the field experiment were in concurrence with the average green house ranking, which was a rapid early screening method. It is evident that the early stage screening under green house conditions would result in better selection for drought tolerance. Singh and Matsui (2003a) described the close correspondence of results of seedling screening, field screening and pot screening indicating that the phenomenon responsible for drought tolerance in the seedling stage is also manifested at the reproductive stage of cowpea.

Table 1. Ranking of selected cowpea lines for wilting symptoms under green house and field conditions

Cowpea Line	*Average Green house rank for wilting*	*Regeneration rank*	*Average field rank for wilting*
CP 115*	2.2	4	3.3
CP 77	1.5	1	2
CP 39	2	1	2
CP 67	2.3	2	2
CP 122	2.7	1	2
CP 36	2.1	1	2.5
CP 128	1.3	1	2
CP 80*	2.5	4	3
CP 88	2	2	2
CP 90	1.7	2	3
CP 53	2.5	2	3
CP 71	2.8	1	2.5
CP 98 *	2.5	4	3.5
CP 45	2.1	3	2.5
CP 35	2.4	1	3

*Poor performer

There were no significant differences ($p>0.05$) among the cowpea lines for plant height at initial growth stage (second week) under field conditions (Table 2). However, significant differences ($p<0.05$) were observed in plant height at 4 and 6 weeks after seed establishment. Of the lines tested, CP115 gave the tallest plants at the 4th week, suggesting that it is a line susceptible to moisture stress towards the end of the season. The cowpea line CP39 was the shortest line at the 4th week and CP88 was the shortest line when the crop was 6 weeks old. These two lines recorded lower values for field ranking and green house ranking, ratio of shoot weight to root weight and the ratio of shoot length to root length, which were drought tolerant characteristics.

Days to flowering ranged from 35 to 54 days among the tested lines. There was a significant difference ($p<0.05$) for days to 50 % flowering and yield among the tested lines. Negative correlations ($p<0.01$) were observed for 50 % flowering with both the average green house ranks and average field ranks. Moisture stress conditions normally induce early flowering and early maturity in drought escaping varieties. The cowpea line CP 80, recoded a higher yield and early flowering under drought which are characteristics related to drought escape. Fatokun *et al.* (2009) reported that the early flowering cowpea lines flowered 12 days earlier under moisture stress conditions than none stressed.

Table 2. The mean plant height at two weeks intervals, mean days to 50 % flowering and mean yield of evaluated cowpea lines under field conditions

Cowpea lines	*Height at 2 weeks (cm)*	*Height at 4 weeks (cm)*	*Height at 6 weeks (cm)*	*Days to flowering*	*Yield (kg ha^{-1})*
CP 115	10.9 a	5.0 a	6.2 ab	4.3 abcd	6.1 abc
CP 77	9.3 a	14.5 ab	32.6 a	47.3 abcd	29.6 c
CP 39	8.5 a	10.1 e	19.1 b	49.3 ab	48.4 bc
CP 67	9.7 a	12.2 cde	22.8 ab	35.0 d	75.2 abc
CP 122	10.7 a	14.9 a	22.8 ab	41.0 bcd	93.9 abc
CP 36	8.7 a	11.6 de	19.8 b	41.7 bcd	111.1 ab
CP 128	10.7 a	11.9 de	25.3 ab	48.7 abc	78.0 abc
CP 80	10.7 a	14.3 abc	27.9 ab	38.3 cd	137.1 a
CP 88	9.0 a	10.3 e	17.1 b	54.7 a	27.5 c
CP 90	10.5 a	11.5 de	20.4 b	48.0 abc	20.7 c
CP 53	9.3 a	12.0 de	21.9 ab	43.7 bcd	87.3 abc
CP 71	9.5 a	11.3 de	26.0 ab	37.0 d	88.9 abc
CP 98	10.9 a	12.6 bdc	20.4 b	41.3 bcd	80.6 abc
CP 45	10.5 a	11.5 de	19.2 b	44.7 abcd	109.7 ab
CP 35	10.7 a	12.1 cde	25.8 ab	42.0 bcd	107.1 ab
CV	15.19	10.41	30.82	12.28	45.6

Within each column, the means followed by the same letter are not significantly different at $p=0.05$

Early flowering lines (CP 67, CP 80 and CP 71) tend to have shorter lateral roots, when compared with medium duration lines (CP 88, CP 128, CP 39 and CP 77) expressing drought escaping characteristics. Dense and well spreading lateral root systems with increased root lengths can be used efficiently to absorb water under moisture stressed conditions. Thus, the plants would be less affected and would not express drought escaping characters such as early flowering and early maturity. Assimilates generated through photosynthesis of these plants would be partitioned for root maintenance rather than producing yield. According to Ludlow and Muchow (1988), diversions of assimilates for root growth and maintenance and for shoot growth may decrease the yield potential. In this study a negative correlation was observed between total root length and yield. The cowpea lines CP 80, CP 36 and CP 45 were the top yield recorders although the yield levels were generally low. According to Hall (1993), adaptations to water limited environments can induce both drought resistance defined as where a cultivar has higher average grain yields than another cultivar when grown in the same water limited environment and drought escape. In this context, the cowpea lines with a short life cycle and higher yielding ability are mostly suitable for late planting and as catch crop in between two seasons. However, this characteristic is less important in a full season crop, especially for the *maha* season, which sometimes undergo intermittent drought conditions or unpredictable long raining periods which reduce the yield of short duration varieties. Yet, according to Hall (1992), the sensitivity of early flowering drought escaping varieties to drought stress during pod development can be solved by combining early flowering with delayed leaf senescence in varieties, which are possessing genes to delay leaf senescence when subjected to drought.

The total root length, root spread, root width and root spread area were significantly different ($p<0.05$) among the tested lines (Table 3 and 4). The cowpea lines CP 39, CP 77 and CP 128 possessed the drought tolerant characteristic of a well-spread root system at different soil depths, while in CP 71, CP 98, CP 36, CP 53 and CP 115 roots were only concentrated in shallow depths with less lateral roots, which is a susceptible characteristic.

The cowpea lines CP 128, CP 88 and CP 39 recorded a higher root spread areas and lower field ranks for drought symptoms. Recorded values for root depths and root widths were also comparatively higher in the former lines showing better drought tolerance characteristics. The cowpea line CP 115 recorded lower values for root depth, width, spread and susceptibility to low moisture stress (Table 3). Ludlow and Muchow (1988) described that the differences in rooting pattern change the amount and timely water availability to the crop. Singh and Matsui (2003b) using the root box and pin board screening method, observed that some cowpea varieties have well spreading deep root systems while the others have roots concentrated only in the upper soil strata. These differences affect plants ability to absorb water from the receding water after the rains cease.

Table 3. Mean values of root characteristics of cowpea lines under field conditions

Cowpea line	*Tap root length (cm)*	*Root depth (cm)*	*Root width (cm)*	*Root spread area (cm^2)*
CP 115	9.4 abc	10.8 abc	5.0 bc	12.2 cd
CP 77	10.9 ab	12.0 abc	7.6 abc	19.1 bc
CP 39	10.0 abc	11.3 abc	7.5 abc	20.5 abc
CP 67	9.0 abc	10.3 abc	6.3 abc	13.7 cd
CP 122	9.8 abc	10.4 abc	7.4 abc	16.7 bcd
CP 36	8.4 bc	8.8 c	4.2 c	13.1 cd
CP 128	10.2 abc	12.3 ab	9.7 a	28.4 a
CP 80	11.3 a	12.7 a	6.0 abc	19.2 bc
CP 88	9.1 abc	11.8 abc	9.8 a	25.6 ab
CP 90	7.7 c	9.1 bc	4.8 bc	9.7 d
CP 53	8.0 c	10.3 abc	5.0 bc	16.0 cd
CP 71	8.0 c	8.7 c	4.1 c	13.2 cd
CP 98	8.7 abc	9.7 abc	4.0 c	12.3 cd
CP 45	7.7 c	10.1 abc	8.3 ab	19.8 abc
CP 35	9.4 abc	11.1 abc	6.0 abc	19.2 bc
CV %	17.82	18.83	37.43	31.07

Within each column, the means followed by the same letter are not significantly different at p=0.05

Table 4. The mean values of cumulative lateral root length at different root depths

Cowpea line	*Depth in soil*			
	4 cm	*8 cm*	*12 cm*	*16 cm*
CP 115	18.9 c	34.5 bc	37.2 bcde	37.2 bcde
CP 77	36.0 ab	58.7 ab	69.5 a	69.9 a
CP 39	41.2 a	55.4 ab	60.4 ab	61.8 ab
CP 67	23.6 bc	43.0 abc	43.0 abcde	43.0 abcde
CP 122	26.4 abc	43.4 abc	50.7 abcd	50.7 abcd
CP 36	11.1 c	22.8 c	28.7 cde	28.7 cde
CP 128	36.6 ab	63.6 a	67.2 a	67.2 a
CP 80	15.7 c	25.5 c	28.8 cde	30.3 cde
CP 88	26.6 abc	42.7 abc	52.2 abcd	52.2 abcd
CP 90	22.8 bc	40.7 abc	41.5 abcde	41.5 abcde
CP 53	15.3 c	29.8 c	33.8 bcde	33.8 bcde
CP 71	13.1 c	19.0 c	21.0 e	21.1 e
CP 98	11.1 c	19.6 c	25.5 de	25.5 de
CP 45	25.4 abc	37.7 bc	42.4 abcde	42.4 abcde
CP 35	26.3 abc	42.6 abc	55.8 abc	55.8 abc
CV	42.3	39.5	39.0	39.3

Within each column, the means followed by the same letter are not significantly different at p=0.05

The shoot weight to root weight ratio, shoot length to root length ratio and leaf area index were significantly different ($p<0.05$) among the cowpea lines tested (Table 5). Lower shoot weight to root weight ratios were recorded in lines CP39, CP77, CP128, and CP88 in addition to lower values for both average green house and field ranks. The cowpea lines CP128, CP36 and CP77 recorded lower shoot length:root length ratio and lower field ranks, while lines CP115 and CP67 recorded higher values for shoot length to root length ratios (Table 5). Strong root systems with comparatively lower biomass of shoots are preferred for drought tolerance which results in lower shoot weight:root weight ratios. Therefore, the lines with lower shoot weight:root weight ratios having a well spreading root systems with low average green house and field rankings could be considered as better performers for drought tolerance. Lines CP 39, CP 128 and CP 77 perceived many characteristic related to drought tolerance such as higher root lengths, lower shoot weight to root weight ratios and lower average green house and field rankings. These lines could be effectively used for breeding programs in drought tolerance specially to make crosses with drought escaping high yielding lines and medium duration high yielding lines to incorporate tolerance to subsequent generations.

Table 5. Shoot weight to root weight ratio, shoot length to root length ratio and leaf area index of evaluated cowpea lines

Cowpea line	*Ratio of shoot weight to root weight*	*Ratio of shoot length to root length*	*Leaf area index*
CP 115	9.47 bcd	0.92 abc	0.17 b
CP 77	7.15 d	0.75 abc	0.35 a
CP 39	5.93 d	0.37 c	0.32 ab
CP 67	9.62 bcd	1.31 ab	0.28 ab
CP 122	8.80 cd	0.60 bc	0.25 ab
CP 36	10.30 abc	1.08 abc	0.21 ab
CP 128	7.64 d	0.44 bc	0.20 ab
CP 80	9.13 cd	1.33 ab	0.19 ab
CP 88	7.85 d	0.37 c	0.28 ab
CP 90	9.23 cd	1.03 abc	0.32 ab
CP 53	9.27 cd	1.25 abc	0.17 b
CP 71	11.67 ab	1.61 a	0.26 ab
CP 98	12.30 ab	1.27 abc	0.17 b
CP 45	7.55 d	0.58 bc	0.23 b
CP 35	8.36 d	0.68 abc	0.26 ab
CV %	28.75	40	33

Within each column, the means followed by the same letter are not significantly different at p=0.05

There was a significant difference among the tested lines for leaf area index. Low values were recorded by all the tested lines due to moisture stress conditions. The cowpea lines CP 77, CP 39 and CP 90 recorded higher values of 0.35, 0.32 and 0.32, respectively.

The average green house ranks recorded significant negative correlations ($p<0.05$) with days to flowering, total root length and total root spread area, and significant positive correlations ($p<0.05$) with the yield, ratio of shoot weight:root weight, and ratio of shoot length:root length obtained from field evaluation (Table 6). As the lower values for the average green house rankings and field rankings are associated with better drought tolerance, a negative correlation with total root length indicates that the increased root lengths are associated with better drought tolerance. Simultaneously, higher values for root spread area are also associated with drought tolerance. Further, the positive correlations show that lower values for the ratio between shoot weight to root weight and shoot length to root length are also associated with drought tolerance.

There was a significant negative correlation ($p<0.05$) between days to 50 % flowering and yield (Table 6). A significant positive correlation ($p<0.05$) between the total root length and days to flowering also provides evidence that well spread root systems are less affected by drought and shallow, less spreading root systems are more prone to drought stress. A positive correlation between yield and average green house ($p<0.01$) and field ranks revealed that yield levels declined with increased drought tolerance (Table 6).

Table 6. Corelation between estimated characters under low moisture sress conditions

	AGR	REGR	AFR	YLD	DF	TRLEN	TRA	SWWR	SLLR	LAI
AGR	1.00	0.24	0.46	0.56*	-0.68**	-0.68**	-0.44	0.58*	0.55*	-0.35
REGR		1.00	0.64**	0.25	-0.17	-0.5	-0.26	0.34	0.32	-0.56*
AFR			1.00	0.35	-0.31	-0.62*	-0.58*	0.59*	0.47	-0.59*
YLD				1.00	-0.67**	-0.47	-0.05	0.31	0.34	-0.64*
DF					1.00	0.59*	0.54*	-0.63*	-0.76**	0.28
TRLEN						1.00	0.67**	-0.85**	-0.81**	0.55*
TRA							1.00	-0.68**	-0.70**	0.08
SWWR								1.00	0.82**	-0.475
SLLR									1.00	-0.305
LAI										1.00

**Correlation is significant at the p=0.01, * Correlation is significant at p=0.05. AGR = average green house rank, REGR = regeneration rank (green house) AFR = average field rank YLD = total yield ha^{-1} DF = days to 50 % flowering, TRLEN = Total root length, TRA = total root spread area, SWWR = shoot weight:root weight, SLLR = shoot length:root length, LAI = leaf area index

In this study, there was a negative correlation of leaf area index with yield and average field rank (Table 6). Under moisture stress conditions plants tend to produce yield quickly and reduce the leaves by senescence to reduce transpiration. CP 53, CP 98 and CP 115 recorded lower leaf area indices. According to Ludlow and Muchow (1988), reduced leaf growth and accelerated leaf senescence are common responses to water deficits. While these responses tend to enhance the survival by conserving water, they can be detrimental to productivity upon the relief of water deficits. In terms of yield stability, leaf area maintenance would improve yield stability in intermittent stress situations due to better radiation interception when water is available, whereas the opposite would be the case in terminal stress situations because leaf area maintenance would increase the rate of water use and increase the probability of the crop running out water before maturity.

During the field testing period moisture content of the top 10 cm layer of soil was between 6-7 % and 8–9 % at the 10-20 cm level. As field conditions are less controllable for moisture contents, both field screening along with screen-house screening is much preferred for confirmation of results. In the present study, the correlation coefficient between the average field rank and average screen house rank was 0.47 (Table 6). According to Watanabe *et al.* (1987), a strong relationship exists between pot evaluation under greenhouse conditions and ranking under field drought conditions. Singh and Matsui (2003a) also described the close correspondence of results of seedling screening, field screening and pot screening. Therefore, combination of the two methods would increase the reliability of identification better donor parents for drought tolerance. Seedling stage screening under greenhouse conditions would be practiced for early generation selection and combined method of both field and green house screening would be applicable to screen the selected lines at the latter generations such as F6.

Under drought-stressed conditions, the growth of crops varies according to the adaptation ability of a variety to the specific condition. Genotypes more adapted to tolerate drought stress would express the tolerance ability at the early growth stages. According to Ludlow *et al.* (1988), genotypes with early vigor and good seedling establishment under normal conditions would tend to enhance transpiration at the expense of direct soil evaporation. If the crop is not subjected to drought stress, early vigor would have positive influence on yield potential. However, in some situations early vigor may result in rapid and early water use followed by a severe water deficit at critical growth stage.

In this study seedlings were subjected to early water stress conditions at the preliminary screening, and therefore, the lines selected with lower green house ranks were better performers under water deficit conditions. The field experiment revealed that these lines were able to cope up with moisture stress under the field grown conditions, too. There was no significant difference ($p>0.05$) between the field ranks, yet there was a correlation ($r=0.458$) between the average green house ranks and the average field ranks for wilting.

CONCLUSIONS

The cowpea lines CP 128, CP 39 and CP 77 performed better than the rest under the experimented moisture stress conditions, having well-spread root systems at different root depths and lower ratio of shoot weight to root weight while recording lower values for the average ranks for green house, field and regeneration. The lines CP 80, CP 98 and CP 115 were drought susceptible characterized by early flowering, superficial narrow root systems with higher average greenhouse, field and regeneration ranks. A close correspondence was observed between the average field ranks and average green house ranks. Since average green house ranks showed significant correlations with field-tested criteria for drought tolerance, both combinations of green house screening and field screening during dry spells could apply for the donor parent identification and later generation evaluations while green house screening can be used for rapid screening for early segregating generations.

ACKNOWLEDGEMETS

The authors wish to acknowledge the Sri Lanka Council for Agriculture Research and Policy for financial assistance granted (vote 285-2-5-2502 ii) for this study.

REFERENCES

Breada, N.J.J. 2003. Ground-based measurements of leaf area index: a review of methods, instruments and current controversies. Journal of Experimental Botany, 54(392): 2403-2417

Conover, W.J. 1999. Practical nonparametric statistics, 3rd edition. New York: John Wiley & Sons.

DeCoster, J. 2004. Data Analysis in SPSS. http://www.stat-help.com/notes.html (accessed on 20th March, 2012)

DOA. 2010. Pocket book of agricultural statistics Socio Economic and Planning Center, Department of Agriculture, Perdeniya. 15-17.

Eloward, H.O.A. and A.E. Hall. (1987). Influence of early and late nitrogen fertilization on yield and nitrogen fixation of cowpeas under well watered and dry field conditions. Field Crops Res 15: 229-244.

Fatokun, C.O., S. Boukar, S. Muranaka and D. Chikoye. 2009. Enhancement of drought tolerance in cowpea. African Crop Science Conference Proceedings 9: 531-536.

Hall, A.E. 1993. Physiology and breeding for heat tolerance in cowpea, and comparison with other crops, Eds. C.G. Kuo. pp 271-284. Proceedings of the International Symposium on adaptation of food crops to temperature and water stress, 13-18 August, Asian Vegetable Research Development Center, Shanhua, Thaiwan.

Hall, A.E. 1992. Breeding for heat tolerance. Plant Breed 10:129-168.

Ludlow, M.M. and R.C. Muchow. 1988. Critical evaluation of the possibilities modifying crops for high production per unit of precipitation, Eds. F.R. Bidinger and C. Johansen. pp 179-211. Drought Research Priorities for the Dry Land Tropics. ICRISAT, Patancheru, Indhra Pradesh, India.

Mitra, J. 2001. Genetics and genetic improvement of drought resistance in crop plants. Current Science. 80: 758-763.

Singh, B.B. and T. Matsui. 2003a. Cowpea varieties for drought tolerance, Eds. C.A. Tarawali, S.A. Singh, B.B. Kormawa, P.M. Thamo and M. Fatodun. pp 287-300. Challenges and opportunities for enhancing sustainable cowpea production, world cowpea conference in proceedings, 4-8 September. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Singh, B.B. and T. Matsui. 2003b. Root characteristics in cowpea related to drought tolerance at the seedling stage. Experimental Agriculture 39: 29-38.

Watanabe, I., S. Hakoyama, T. Terao, and B.B. Singh. 1997. Evaluation methods for drought tolerance of cowpea, Eds. B.B. Singh pp 87–97. Advances in Cowpea Research. IITA, Ibadan, Nigeria.