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Drought effect on yield, leaf parameters and evapotranspiration efficiency of cowpeas

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Abstract

Two experiments with nine cowpea [*Vigna unguiculata* (L.) Walpers] genotypes were carried out in the greenhouse to study the response of yield and related parameters including total leaf area (LA), specific leaf area (SLA), intrinsic transpiration efficiency (TE_i), evapotranspiration efficiency (ETE) and stem mass density (SMD) under drought at the generative phase. In experiment 1 pod weight $plant^{-1}$ ranged from 51 to 62g under well-watered (ww) conditions with similar pod weight under water deficit (wd) conditions, except ExUkwala which produced very few small pods. The seed yield $plant^{-1}$ ranged from 38 to 49g for ww plants and 32 to 36g under wd, except ExUkwala. Single grain weight (SGW) of ww treatments ranged from 101 to 230mg, but it ranged from 48mg, 109 to 146 and 190mg under drought. ETE of ww plants varied between genotypes and was positively correlated to three yield parameters. Under wd rank order of ETE was altered and ETE displayed no significant relationship to yield components. SMD was positively correlated with pod weight. SMD had a stronger correlation to seed weight and SGW under drought. Under ww conditions LA had no significant correlation to yield, but SLA was negatively correlated to yield components. LA and SLA showed negative correlations to pod weight, seed weight and SGW under wd.

In experiment 2, ExUkwala and Vita7 did not flower. There were similar ww and wd effects. However, sizes of yield components were several magnitudes lower than in experiment 1. In both treatments relationships of parameters to yield components were similar to those in experiment 1. The data presented here seem to point to a possibility to select cowpea genotypes under drought during the generative phase for their yield performance using parameters like TE_i, SLA, but especially SMD.

1. Introduction

Cowpea, an important, versatile crop and the most important food legume in Sub-Saharan Africa, is widely grown under rainfed conditions in semi-arid regions. In Sub-Saharan Africa, where about two thirds of the world's cowpeas are produced (Ehlers and Hall, 1997), drought remains one of the major production limitations. Yields of cowpeas in Africa are reported to be around 500kg/ha, well below the 2 t/ha reported in the United States of America (Ortiz, 1998) and experiment stations. A better understanding of the physiology of cowpeas under drought could lead to the improvement of its drought tolerance and water use, in order to improve yield.

The main objectives were to determine cowpea yield and yield stability, intrinsic transpiration efficiency (TE_i) and evapotranspiration efficiency (ETE) under water deficit (wd) and find out possible associations among these characteristics and various leaf parameters with the aim of establishing surrogate characteristics in breeding for improved performance under wd stress.

2. MATERIALS AND METHODS

Two greenhouse experiments were conducted at Humboldt University of Berlin (Dahlem) in winter 2003/2004 (experiment 1) and winter 2004/2005 (experiment 2) with nine upright, non-trailing cowpea genotypes from Africa, Asia and America.

Pregerminated seeds of the different genotypes were sown in grey PVC pots (0,16m diameter and 0,5m long) filled with 14kg sand mixed with some organic substance and nutrients. Staggered sowing was done so as to have all genotypes at a similar physiological stage at the induction of wd stress. Plants were exposed to a light regime of 12 hours (day), 12 hours (darkness), temperature of 28°C±4 (day) and 16°C (night) and relative humidity ranging from 30 (day) to 80 % (night). A tensiometer-controlled automatic irrigation system was used. Gas exchange was determined using a steady state porometer (CQP 130i, Walz Mess- und Regeltechnik, Effeltrich/ Germany). At about 3 weeks before beginning of flowering water deficit (wd) stress was imposed to 50% of the pots and the other half continued as the well-watered treatment. Six cowpea genotypes were used in experiment 1 and nine in experiment 2. Whereas in experiment 1 wd stress was imposed for 19 days (d) (5 d of drying down and 14 d at constant level), in experiment 2 the duration of wd stress was 22d (7d drying down and 15d at constant stress). For both experiments stress was maintained at -350 hPa±-50 (c. 4 – 5 vol. % substrate water content). Measurements of the various parameters was done at the end of the stress period. Analysis of variance and other statistical analyses were performed using SPSS 10.0 (Duncan's Multiple Range Test, $\alpha = 0,05$).

3. RESULTS

In the well-watered (ww) treatment of experiment 1, TE_i ranged between 2,2 and 4,6µmol CO_2 $mmol^{-1}$ H_2O, with ExUkwala having the lowest and UCR 386 having the highest. UCR328 had the highest ETE (7,9g L^{-1}), while ExUkwala had the lowest (4,7). Contrary to IT18, which produced a seed yield of 48,6g $plant^{-1}$, ExUkwala yielded lowest (3,8g $plant^{-1}$) and there were significant yield differences among the six genotypes. However, under wd stress the seed yield was significantly reduced, so that the highest yield was 6,3g (UCR328) and the lowest 2,1g (UCR1340). The pod weight $plant^{-1}$ ranged from 51,1 to 62,0g, with similar pod weight under wd. Significant differences among the genotypes also existed for total leaf area (LA), specific leaf area (SLA), total water use (WU) and single grain weight (SGW). In the same experiment under water deficit (wd) significant differences existed among the genotypes for all parameters measured. Water deficit reduced significantly the total leaf area and the total dry matter (data not shown) of all genotypes during the generative phase. Wd stress affected the ranking of the genotypes for TE_i, ETE, SLA and seed yield.

For the ww plants significant positive correlations existed between TE_i and SLA, ETE and pod weight, seed weight and SGW, stem mass density (SMD) and pod weight. Significant negative correlations were found between TE_i and SLA, ETE and SLA, SLA and SMD, pod weight, seed weight and SGW. Stress caused variations in the associations among parameters. TE_i was no longer correlated with the above characteristics. ETE was negatively correlated with SMD. LA and SLA were both negatively correlated with pod weight, seed weight and SGW. SMD showed significant positive relationship with pod weight, seed weight and SGW. Using seed weight data stress susceptibility index (SSI) was calculated according to Fischer and Maurer (1978). UCR328 had the lowest SSI (0,4899) followed by UCR1340 (0,5889), then Lagreen (0,8270), UCR386 (0,8299). IT18 had a SSI above 1 (1,7268) and ExUkwala displayed the highest susceptibility (4,8946). The drought stress intensity (DSI) in experiment 1 was 0,1812.

In experiment 2 under water-replete conditions TE_i and ETE ranged from 1,7 to 3,1µmol $mmol^{-1}$ and 0,9 to 1,6g L^{-1} respectively. Seed yield ranged from 3,7 to 11,2g $plant^{-1}$. Ample water led to significant differences among genotypes for all characteristics analysed. The same applies for wd stress. Wd stress affected most of the traits which where studied. TE_i was generally enhanced, whereas ETE remained stagnant. LA, SLA as well as SMD and yield were reduced. Seed yield ranged from 2,1 to 6,3g $plant^{-1}$. SGW was reduced in some genotypes (UCR386 and TVu12348) but not in others (UCR1340, IT18, UCR328 and IFH27-8).

Correlations existed for both treatments in experiment 2. In the ww treatment TE_i was positively associated with SMD, ETE with LA, SLA and SMD. LA was negatively correlated with pod weight and seed weight. SLA was negatively associated with SMD, pod and seed weight. SMD exhibited a positive relationship with pod and seed weight. Under wd stress TE_i was related to LA and SGW, whereas ETE was related to LA and SMD. SMD was associated with all the three yield parameters measured. DSI in experiment 2 was found to be 0,5183. Under these conditions TVu12348 showed the greatest drought tolerance with a SSI of 0,2972. The next was IFH27-8 (0,3398), then UCR328 (0,8408) and UCR386, IT18 and UCR1340 had SSI values above 1.

4. Discussion

Levels of wd stress imposed were strong enough to affect the measured plant parameters. Due to the longer stress period in experiment 2, most of the characteristics were affected more negatively in experiment 2. As indicated by the higher DSI in experiment 2 the stress was stronger in the second experiment.

Direct selection and breeding for yield under stress is more labour intensive and time consuming. Therefore it is important to identify traits which can be used as substitute characteristics in breeding such that the length of time can be reduced since breeders do not have to wait until yield formation. As mentioned in literature (for example Nageswara Rao and Wright, 1994; Brown and Byrd, 1997) SLA is usually negatively correlated to biomass and yield. Similar results were found in this study.

We also found that SMD was consistently positively correlated to ETE and three yield components under drought stress. This seems to point to the possibility of using SLA but especially SMD just before flowering as a surrogate trait for yield when screening for drought tolerance. The method of Fischer and Maurer (1978) to determine the drought stress susceptibility of genotypes appears to be a good method for determining the drought intensity and the genotypic ranking for drought tolerance, particularly when the wd stress is moderate to severe. Sio-Se Mardeh et al. (2006) came to the same conclusion. Accordingly, TVu12348, IFH27-8 and UCR328 were found to be the most drought tolerant genotypes. However, it is desirable to conduct more studies, also in the field, to ascertain these findings.

5. References

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