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Recovery of Some Leave Gas-exchange Parameters in Selected Genotypes of Cowpea (*Vigna unguiculata* L. Walp) After a Period of Water Stress.

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Abstract

Cowpea, *Vigna unguiculata* [L]. Walp is generally regarded as a drought-tolerant crop. Many studies have shown that limiting soil water can have an adverse effect on crop gas exchange with a consequence of yield reduction. This study was conducted to investigate the gas exchange of different cowpea genotypes under water stress and their recovery after stress release. Leaf gas exchange was measured on a fully expanded well lit main stem leaflet using a leaf cuvette compact CO_2/H_2O porometer developed by WALZ/Germany while a second leaflet was used for measuring leaf water potential. Instantaneous water use efficiency (*IWUE*) was calculated as a ratio of *A*/*E*. The results indicated pre stress genotypic variability in leaf *A*, *E* and g_s. *IWUE* values showed little variation among the genotypes before water stress was imposed**.** Water stress reduced *A* considerably in 2 genotypes and totally inhibited it in the others. Similar trends with respect to *E* and g_s were observed. The genotypic variability in *IWUE* under water stress was high. The *IWUE* remained considerably high in 2 genotypes under stress while it was more or less strongly reduced or totally prevented in the others. Recovery with regard to *A*, *E* and g_s was almost complete in 2 genotypes and incomplete in the others. A majority of the genotypes showed almost full recovery of *IWUE*. The result suggest that genotypic differences exit in cowpea with regards to gas exchange parameters following water deficit.

Keywords: *Vigna unguiculata*; Water stress; Photosynthesis; Transpiration; Water use efficiency

Introduction

Cowpea, *Vigna unguiculata* [L]. Walp is an important nutritious food legume that plays a very significant role in the cropping systems of the moist to dry savannah zones of the tropical and subtropical regions of the world. The crop is cultivated in almost every continent of the world, however the bulk of cowpea production is in the drier zones were the rainfall plays a very significant role in crop development.

Cowpea is generally regarded as a drought-tolerant crop, but many studies have shown that water deficit can have an adverse effect on crop gas exchange with a consequence of yield reduction. Photosynthesis is closely related to dry matter production in most crops, and dry matter production determines yield (Moss and Musgrave, 1971). Therefore, measurement of photosynthesis are important when evaluating cultivars for yielding ability, agronomic fitness and their responses to specific treatments or stresses (Conocono et al., 1998)

Not very much has been done to date in evaluating differences among cowpea genotypes in gas exchange parameters under water stress. The importance of water use efficiency as a breeding value for crop improvement is well established. However determining WUE is often very tedious and therefore unattractive to breeders. Instantaneous gas exchange measurement offers a quick possibility of estimating *WUE*. It is based on the ratio of *A* to *E* and has been termed Instantaneous water use efficiency (*IWUE*) (Hall et al., 1997). *IWUE* has been found to be positively correlated with many plant parameters. Therefore genotypic differences in gas exchange can contribute a lot to the continuous search for traits related to drought resistance in cowpea.

This study was conducted to investigate the gas exchange ability of different cowpea genotypes under water stress and their recovery after stress release.

Materials and Methods

The genotypes used for this study were obtained from IITA (Ibadan, Nigeria) and Griffin, (USA) Germplasm Banks. 10 different Genotypes were selected for testing under water stress based on origin (Nigeria, India, Iran, Mali, USA, Brazil and Kenya), grain size, and growth habit such as leaf morphology, branching, days to maturity etc.
The trial was conducted in a growth chamber where the controlled growth conditions were 25/18°C day/night temperatures with 12-h photo period and a relative humidity of 70/80 (day/night). The PPFD (photosynthetic photon flux density) was approx. 500 µmol m^{-2} s^{-1} at the top of the canopy - using cool white fluorescent tubes. Tube-like pots, 50cm long by 16.6cm diameter were filled with coarse sand with a mixture of nutrient mineral. 6 seeds were sown per pot and later thinned to one seedling per pot ensuring uniformity in growth. Watering was through the use of an automatic irrigation system regulated by Tensiometers installed at a depth of 20cm. The soil moisture content was equally monitored using TDR electrodes installed at the same depth. All the pots were maintained at field capacity up to early flowering. The water stressed plants were then allowed to dry out up to -750 hPa soil water potential (about 3 vol. %). This level was maintained for 10 days before resumption of watering again to field capacity. Water content of the coarse sand decreased almost linearly from approx. 8 vol.% to approx. 3 vol.% for all genotypes after the last irrigation during the stress phase. Soil water content returned to the pre-stress levels 1 day following rewatering. The trial was a 2 factors experiment arranged in a split plot design with irrigation as main plot and genotypes as subplot.

Leaf gas exchange was measured on a fully expanded well lit main stem leaflet using a leaf cuvette compact CO_2/H_2O porometer developed by WALZ/Germany. A sampling scheme was developed which involved repeated measurements on tagged leaves at defined stress stages as follows:
a.) PS (Pre-stress) i.e. at the beginning of flowering at about 50% flowering
b.) DP (Drying phase) i.e. very mild stress at -400 hPa soil water potential after withholding irrigation
c.) SS (Start of full stress) i.e. at attainment of -750 hPa soil water potential after withholding irrigation
d.) SE (stress end) i.e. on day 10 after SS (SE)
e.) AS (After stress) i.e. on day 7 after rewatering again to field capacity.
A, *E*, and g_s, were calculated from the measured data while *IWUE* was taken as *A*/*E* ratio.

Results and Discussion

Selected results of the SE and AS stages are presented in this Paper. However references are made to other stages where necessary. Pre-stress leaf water potential (LWP) was high in all the genotypes with an average of -0.5 MPa (figure 1a). Following withholding of irrigation, leaf water potential decreased slightly to average –1.30 MPa by DP and a further decrease to an average –2.34 MPa was observed by SS. This decreasing trend was seen up to the end of the 10 days sustained water stress (though the soil water potential remained relatively stable during these 10 days) reaching low mean value of –3.20 MPa. After rewatering, the *LWP* was partially restored in all the genotypes. However, the *LWP* remained low 7 days after rewatering in Lobia, suggesting an irreversible damage (figure1b). Pre-stress *A* varied significantly among the genotypes. As the soil drying out progressed, a drastic decline in *A* was evident reaching negative values in some genotypes by SB. The *A* values remained generally low on day 10 of maintained stress (figure 2a). 7 days after rewatering, *A* recovery was almost complete in 4 genotypes while the pre-stress levels were not attained in the others (figure 2b). Two genotypes (UCR 386 and Ex Sangha) did not follow the general trend, while almost a 100% decrease was observed in the other genotypes, these 2 decreased only 70 and 50% respectively. Ex Sangha which maintained a moderately reasonable *A* during the water stress could not recover after stress release. Lobia on the other hand, maintained very low levels of *A* throughout the 10 days period of sustained stress and did not recover 7 days after rewatering. Genotype “RCXAC” which had very high pre-stress *A* and was strongly affected or totally inhibited by water stress recovered better than the others.

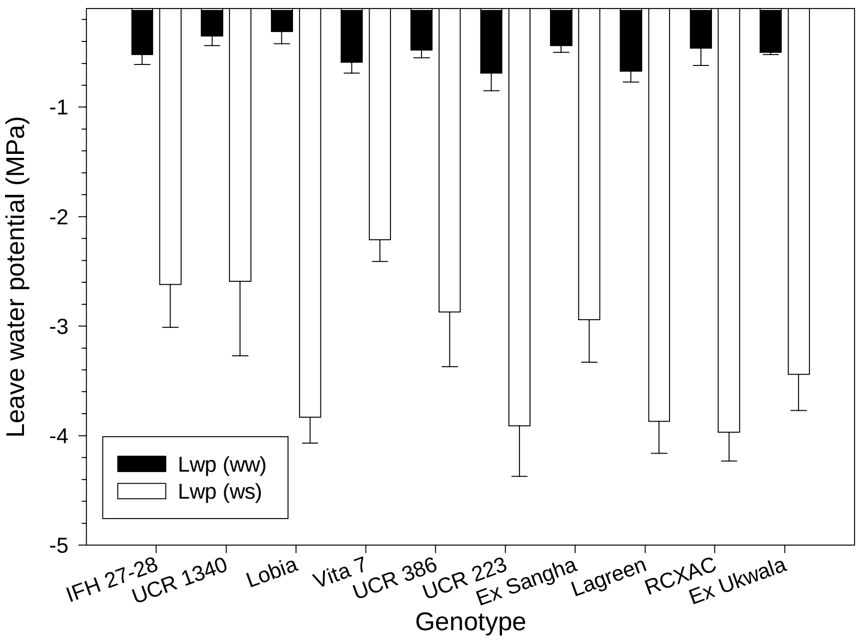

Figure 1a. The effects of water stress on leaf water potential of different cowpea genotypes. Data were collected on day 10 of maintained low soil water potential at -0.075 MPa. S.E is shown by vertical bars

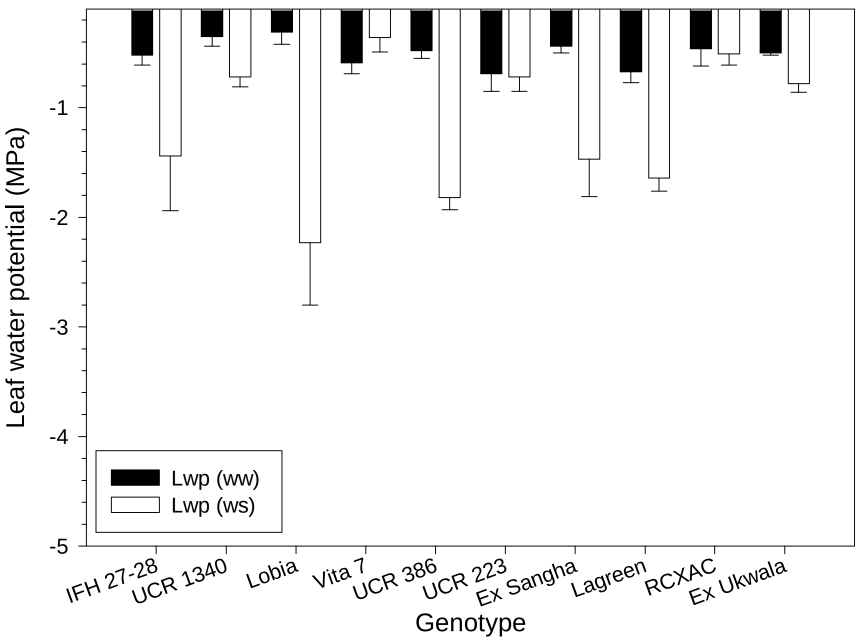

Figure 1b. The effects of water stress on recovery of assimilation rate of different cowpea genotypes. Data were collected on day 7 after stress release. S.E is shown by vertical bars.

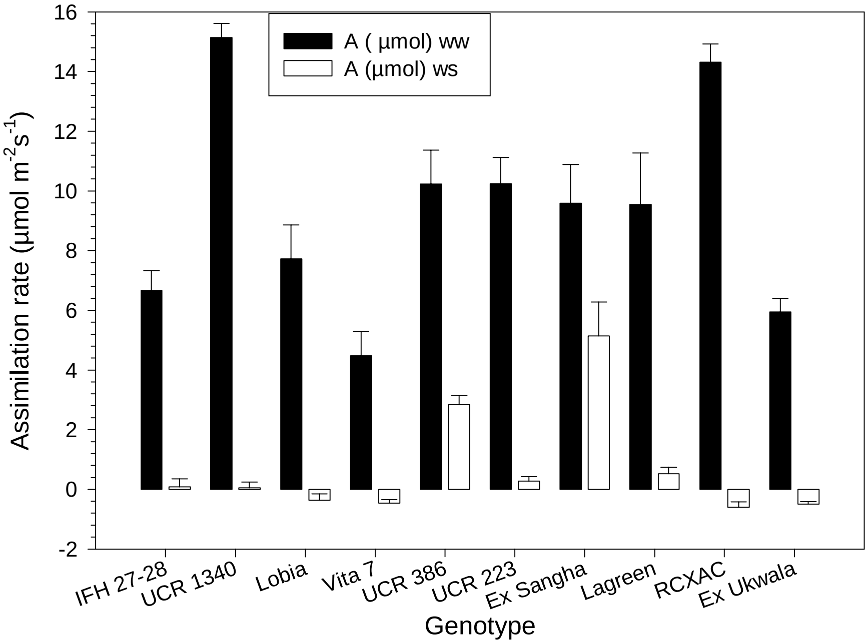

Figure 2a. The effects of water stress on assimilation rate of different cowpea genotypes. Data were collected on day 10 of maintained low soil water potential at -0.075 MPa. S.E is shown by vertical bars

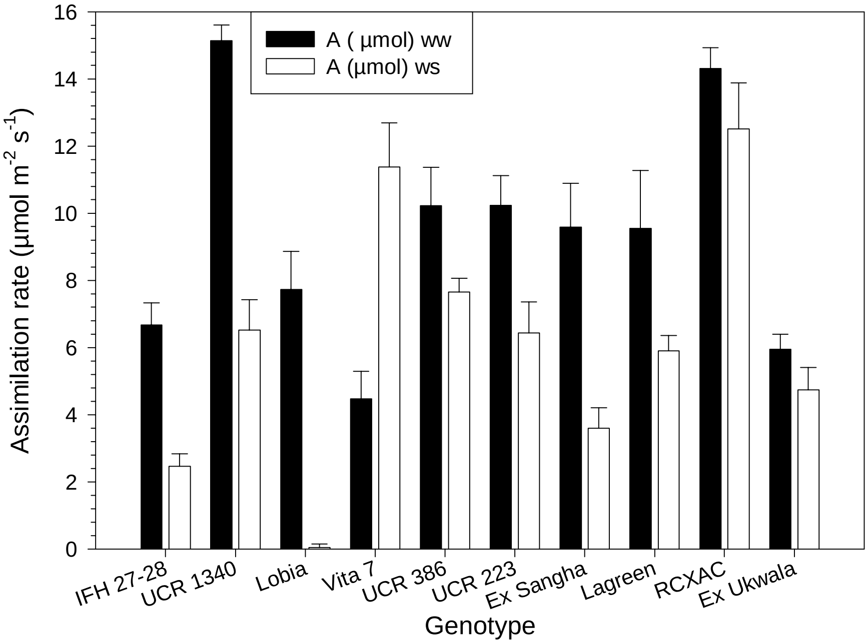

Figure 2b. The effects of water stress on recovery of assimilation rate of different cowpea genotypes. Data were collected on day 7 after stress release. S.E is shown by vertical bars.

Leaf *E* followed a pattern similar to that of *A* throughout the water stress cycle. Pre-stress *E* ranged from 1.09 to 3.51mmol m-²s-1 among the genotypes. Like was observed for *A*, there was a sharp decrease in *E* by more than 70% on day 10 of the maintained low soil water status (figure 3a). After rewatering, *E* of leaflets increased, which is in agreement with the relative recovery of *A* observed (figure 3b). The effects of water stress on g_s were similar to those of *E* (figure 4a and b). The relationship between *E* and g_s was high, also a strong *E* and g_s versus *LWP* relationship (data not shown) was found. Dingkuhn et al., (1999) also reported a robust gs versus LWP regardless of time of day.

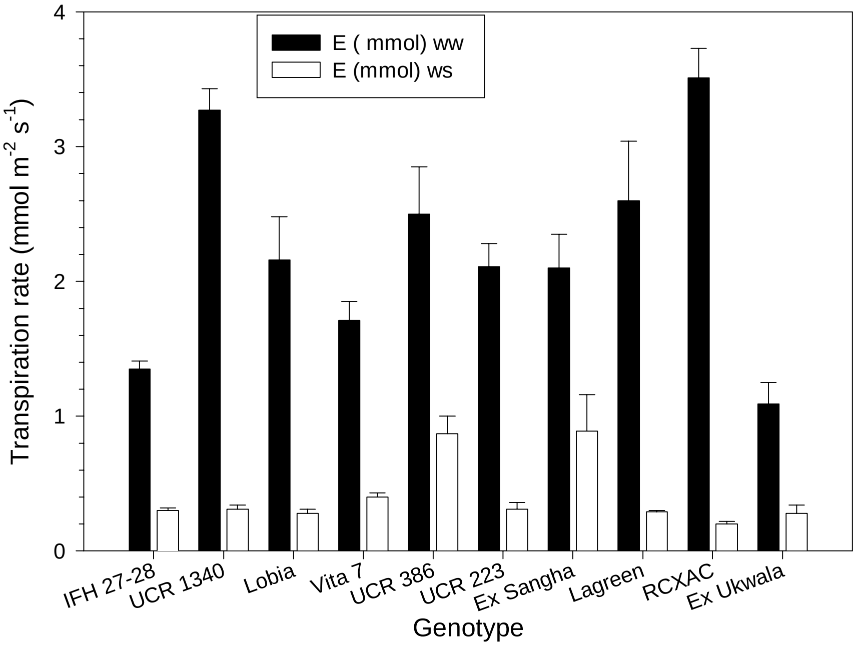

Figure 3a. The effects of water stress on transpiration rate of different cowpea genotypes. Data were collected on day 10 of maintained low soil water potential at -0.075 MPa. S.E is shown by vertical bars

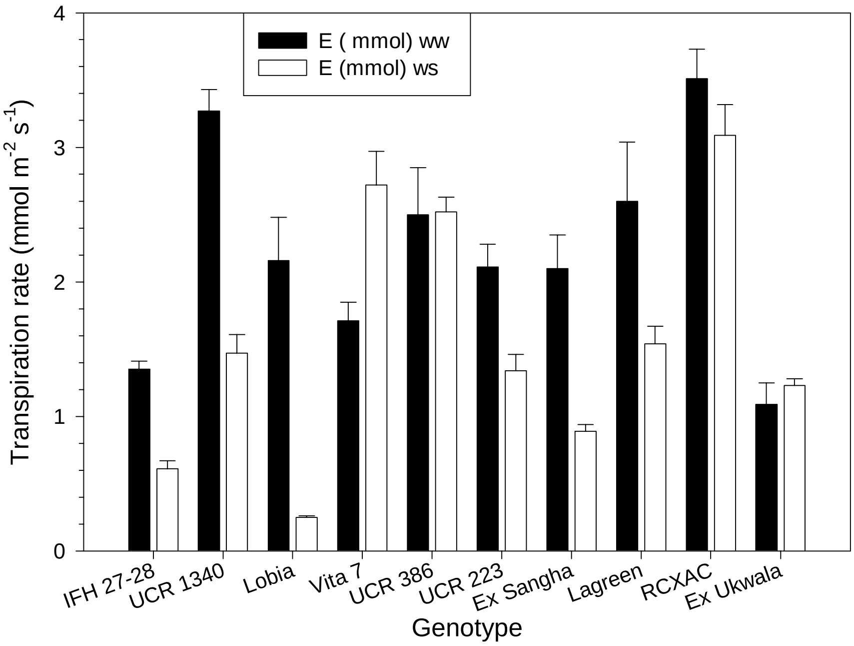

Figure 3b. The effects of water stress on recovery of transpiration rate of different cowpea genotypes. Data were collected on day 7 after stress release. S.E is shown by vertical bars.

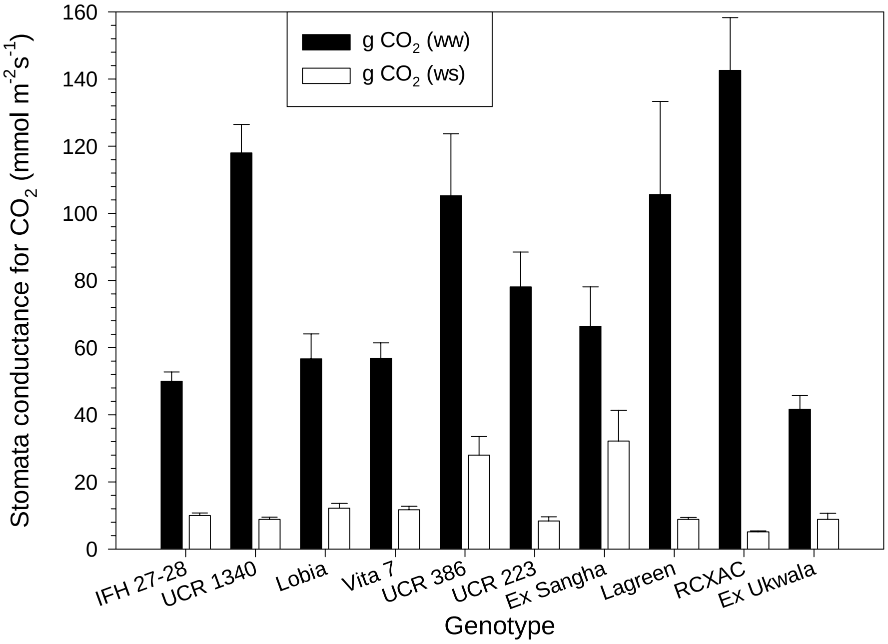

Figure 4a. The effects of water stress on stomata conductance for CO2 rate of different cowpea genotypes. Data were collected on day 10 of maintained low soil water potential at -0.075 MPa. S.E is shown by vertical bars.

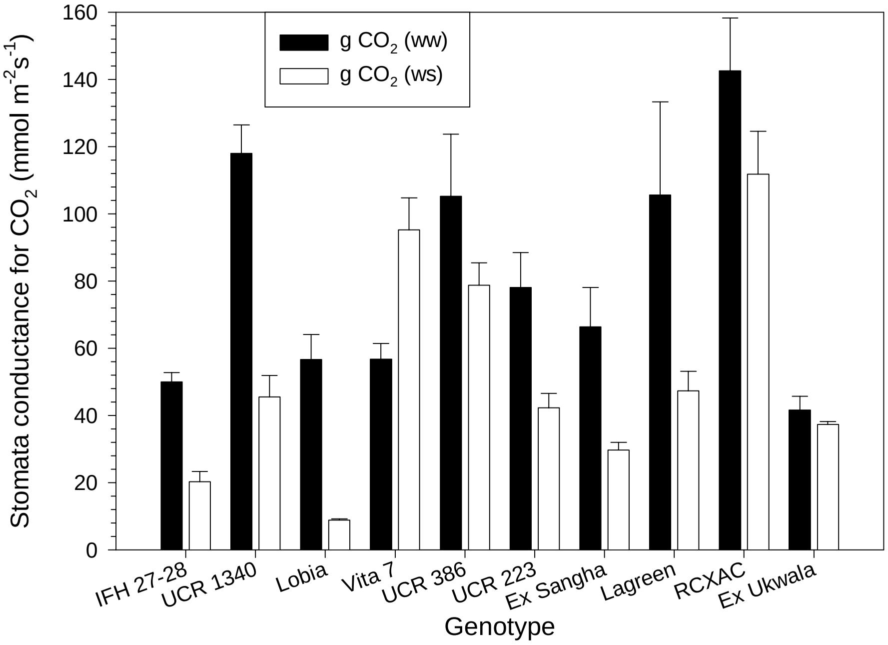

Figure 4b. The effects of water stress on recovery of stomata conductance for CO2 of different cowpea genotypes. Data were collected on day 7 after stress release. S.E is shown by vertical bars.

IWUE did not follow a particular order in the genotypes as was observed for *A*, *E* and g_s as the water stress progresses. As the soil dried out to about -400hPa, a slight increase in the *IWUE* was observed in some genotypes while others decreased or maintained pre-stress levels (data not shown). But as the magnitude of stress intensified, a general decrease in *IWUE* was noticed, though some genotypes remained stable (figure 5a). The *IWUE* under stress remained considerably high in 2 genotypes while it was reduced more or less strongly in the others. This suggest a certain resistance by these two genotypes under the imposed stress. A full recovery of *IWUE* was shown by 6 genotypes after stress release while it was moderate in the others except for Lobia which could not recover 7 days after stress release (figure 5b). Turk and Hall (1980) reported that *WUE* increased slightly with moderate reductions in water use but dropped sharply with more drastic reductions in water availability. Here we have considered a wider range of genotypes and found similar results in some of the genotypes while others reacted differently. High *WUE* under water stress could lead to stable yield under water stress conditions. Other studies (Hall et al 1997) did not consider gas exchange as effective in detecting genotypic differences in cowpea. However, the differences observed here indicates that cowpea genotypes react differently under water stress. Perhaps the stress intensity and duration may play a very important role. Under conditions of mild to moderate water stress, the *WUE* of most genotypes is increased or unaffected. This is to be expected since the stomata is very sensitive to the slightest changes in soil water. According to Passioura (1996), the root is the first organ to recognise water deficit, it sends a signal to the leaves which then regulate water loss from the plant. In the present study, we found a positive relationship between *A* and *WUE*, while on the other hand a weak association was observed between *E* and *WUE*. This suggest that the gain in *WUE* under water stress observed here was due primarily to some degree of assimilation under the low soil water potential maintained.

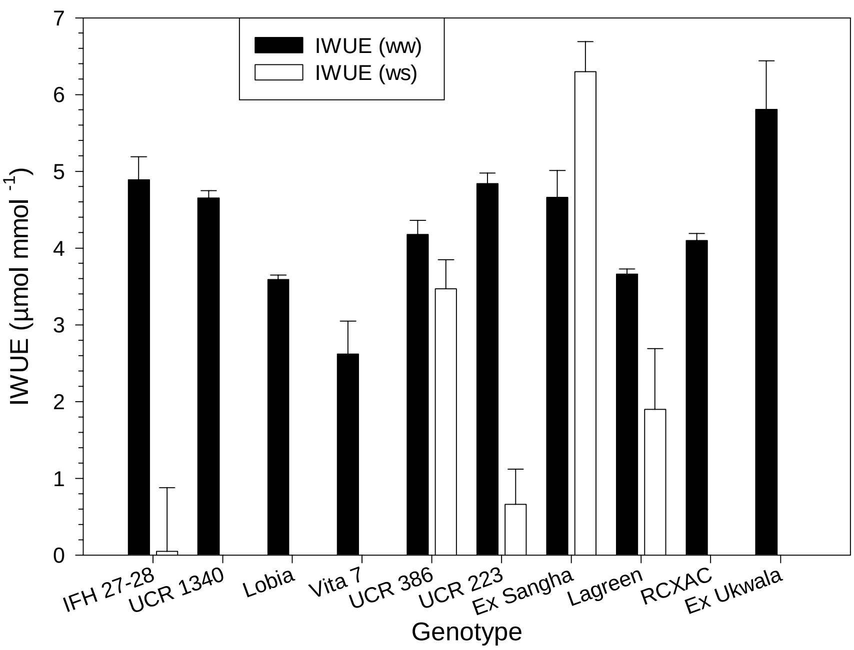

Figure 5a. The effects of water stress on instantaneous water use efficiency of different cowpea genotypes. Data were collected on day 10 of maintained low soil water potential at -0.075 MPa. Negative *IWUE* values resulting from negative *A* values were assumed to be 0. S.E is shown by vertical bars.

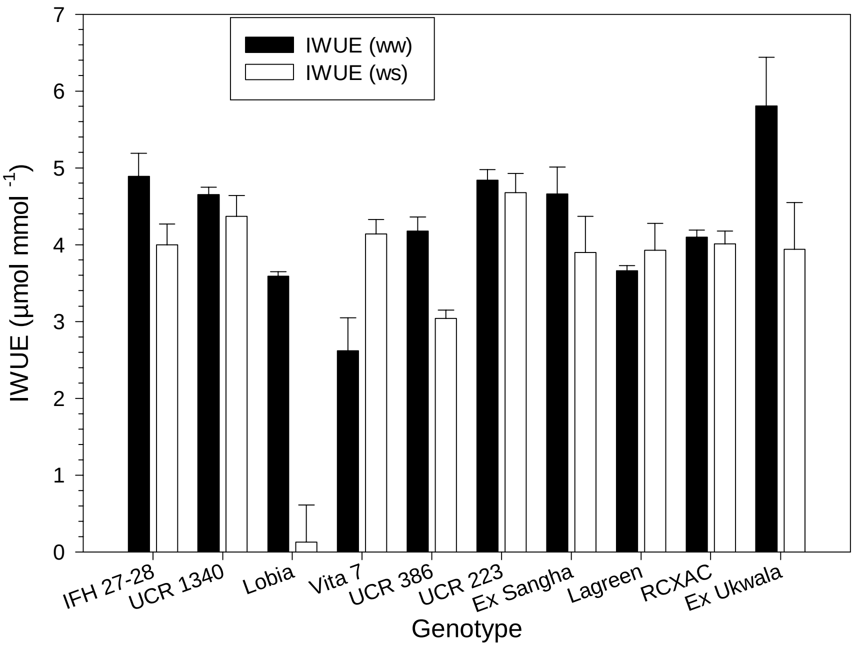

Figure 5b. The effects of water stress on recovery of IWUE of different cowpea genotypes. Data were collected on day 7 after stress release. S.E is shown by vertical bars.

In conclusion, water stress results in sharp decreases in water potential and gas exchange in cowpea, however genotypic differences do exist. Some genotypes are able to regain fully their gas exchange capability after a short term water deficit. The genotypic variation observed here may be useful in detecting differences in cowpeas which can be exploited for possible improvement. Therefore we suggest that measurements of leaf gas-exchange is important when evaluating cowpea cultivars for yield ability in dry environments

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