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**CENTRE D'ETUDE REGIONAL POUR
L'AMELIORATION DE L'ADAPTATION A LA
SECHERESSE**

**Comparative drought resistance of
cowpea and peanut genotypes.
A technical report**

Nwalozie M.C.
ABAI state Univ., Nigeria

Rapport final du 09/92 au 01/93
C.E.R.A.A.S. 1993



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INTRODUCTION

In parts of West Africa where cowpeas and peanuts are cultivated, drought periods are a major factor impeding plant growth, development and yield. Although many improved genotypes of these species are now available, there is even more **need** to further improve their performances under more severe droughts. However, the genetic improvement of crops for drought resistance faces such limitations as insufficient information on physiological mechanisms of resistance, and lack of efficient screening methods for resistance parameters.

The multitude of factors potentially involved in drought resistance makes it unlikely that any single measurement can provide an all-encompassing test of drought resistance. However, the importance of plant water for the maintenance of turgidity required for plant growth and survival during drought is widely recognized. Many workers, notably Conner and Tunstall (1968), Slatyer (1960), Sanchez-Diaz and Kramer (1971), and Levitt (1972) have demonstrated that drought resistant plants have smaller water deficit per unit decrease in leaf water potential than more drought susceptible plants. Similarly, Kirkham *et al.* (1980), Clarke and McCraig (1982), and Schonfeld *et al.* (1988) in evaluating the excised-leaf water retention capabilities or relative water content (RWC) of wheat during water stress, concluded that cultivars with higher RWC are more drought resistant. Similar results have been obtained with soybean (Carter and Patterson, 1985). Also stomatal conductance, a major factor controlling plant water loss, is considered as a **veritable** tool for assessing drought resistance. Loss of water from turgid leaf tissue in response to transpiration results in not only a **significant decline** in water potential, but also a decline in osmotic potential. A **decline** in osmotic potential can result from a simple passive concentration of solutes due to dehydration, or due to net solute accumulation (osmotic adjustment).

This report presents the results of comparative drought resistance studies on cowpeas and peanuts grown both in a glasshouse and field conditions. A comparative physiological study of two different species may reveal, (1) if genotypes of cowpea are indeed more drought resistant than those of peanut, as regularly claimed by researchers, **albeit** without **any** hitherto available empirical data, and (2) if there are attributes of drought resistance which are **common** to the genotypes of these species. **Such** attributes could be taken as important and effective for a better understanding of **crop** performance during drought.

As an addendum to my research fellowship at CERAAS, the onus of communicating our previous collaborative research efforts for publication in reputable plant science journals fell on me. Find listed in Appendix I, the manuscripts so communicated.

MATERIALS AND METHODS

a) Plant materials

Two species, *Vigna unguiculata* (cowpea) and *Arachis hypogaeae* (peanut), were studied. Five genotypes of each species were selected for the experiments (see Table 1).

Table 1 a Genotypes used for glasshouse studies

Cowpea	Tag	Peanut	Tag
IT84S2246-4	CV ₁	55-437	PV ₁
TVU 3000	CV ₂	73-30	PV ₂
B89-504	CV ₃	GC835	PV ₃

Table 1 b. Genotypes used in field experiments

Cowpea	Tag	Peanut	Tag
IT84S-2246-4	CV ₁	55-437	PV ₁
TVU 3000	CV ₂	73-30	PV ₂
IT82E-60	CV ₃	GC835	PV ₃
B89-504	CV ₄	57-422	PV ₄
Bambey 21	CV ₅	Fleur 11	PV ₅

b) Glasshouse studies

Culture conditions and treatments:

The plants were grown in a translucent glasshouse with temperature at 42.6° C + 3° C during the day, and 23.5° C + 1.4° C during the night. Humidity was 95% + 35% at 0300 h, and 19.8% + 4.1% at 1500 h. Natural light was not supplemented, and maximal irradiance generally reached > 800 micromoles m⁻²s⁻¹ at midday.

The seeds of three genotypes, for each of cowpea and peanut, were treated with a fungicide (deltamethrine, 12 g l⁻¹, applied in dust form. Four seeds were sown, for each of genotype, per pot (25 cm diameter x 40 cm height) containing 28 kg of top soil of known physical and chemical composition. A 5 g weight of N₆-P₂₀-K₁₀ compound fertilizer was applied 10 cm below soil level. The soil was thereafter irrigated to field capacity prior to sowing. After sowing, the seeds were allowed to germinate on stored soil moisture, after which daily irrigation with 200 cm³ of water per pot commenced (i.e 10 days after sowing, DAS).

The design was a randomized complete block, with five blocks (replications), two species x three genotypes x two watering regimes (irrigated and stressed); a total of 30 pots for each species. The border was also made up of two species x three genotypes x two watering regimes, replicated two times. The design was such that each treatment (i.e. species, genotypes, and watering regime) was represented in each block.

The plants were thinned down to two plants per pot on the 13th day after sowing (13th DAS). From the 23rd to the 30th DAS, each pot was irrigated with 400 cm³ of water every other day. From the 31st DAS the plants were irrigated with 400 cm³ of water daily. Soil moisture stress was applied to the pots labelled H₂ on the 32nd DAS, while irrigation continued for those labelled H₁ as previously described. Water stress was imposed by withholding irrigation for H₂ plants, and was terminated on the 50th DAS by resumption of irrigation. Water stress was terminated when the soil volumic humidity had attained 1.11 cm³ cm⁻³ + 0.38 cm³ cm⁻³ (or 87.4% less than the moisture content of the control). Water stress lasted for a total of 19 days. The soil moisture status during water stress is shown on Fig. 1

Data collection

On the 20th DAS, and at intervals of seven days thereafter, terminating on the 54th DAS, various measurements were taken. Leaf relative water content, and osmotic regulation were measured as previously reported (Nwalozie 1991). Protoplasmic resistance was determined according to Vasquez-Tello *et al* (1990). Total nitrogen was determined by the micro-Kjeldahl technique (Cataldo *et al*, 1974). Stomatal conductance was determined by porometry. Leaf specific weight was determined according to McCaig and Romagosa (1991). The rate of leaf initiation was calculated from values obtained on total number of leaf nodes observed per plant and per week. Soil moisture or volumic humidity was determined gravimetrically (Mulla, 1987). At harvest, the total dry weight of shoots (previously abscised leaves were collected in paper bags awaiting final harvest), and fruits were determined separately.

Data treatment:

All data were treated to an analysis of variance, performed on all dependent variables. Sources of variation were species, genotypes, soil moisture, replicates species x genotypes x irrigation interactions. Means were separated according to Duncan's multiple range test (DMRT).

c).Field studies

The total area of the field was 30 m x 8 m. A total of 30 plots were derived from the site, with each plot measuring 2 m x 2 m, and 1 m apart. Ten plots were marked out per row, all culminating to three rows (or blocks/replications). The field was sprinkler irrigated with 111.5 cm³ of water 53 cm⁻² of plot h⁻¹ for 3 h. Seeds (see Table 1 b) of cowpea and peanut were sown 24 h after the field was irrigated. Cowpea seeds were planted at 50 cm between lines, and 25 cm between plants. Peanut seeds were sown 50 cm between lines and 15 cm between plants. Two seeds were sown per pocket. Irrigation was repeated on the 5th and 15th DAS at the same rate as earlier stated, for 30 min., during each irrigation. Irrigation was thereafter discontinued. The border was made up of cowpea planted all around the main plots.

This design was also completely randomized, two species x five genotypes x one soil moisture regime, replicated three times.

On the 25th DAS and at intervals of seven days thereafter, data was collected from the plants. Rate of growth, measured as percentage of soil cover, was determined with a sunfleck ceptometer (Decagon, Pullman Washington USA). Leaf Relative Water Content was also determined. Soil moisture was from samples collected at 40 cm and 70 cm depth. This experiment in the field could not be continued beyond the 53rd DAS because (a) several periods of precipitation were observed during the supposed dry period, and (b) soil moisture continued to be abnormally high, most probably because of the regularly irrigated trial 20 m away from the plots. It was reasoned that, because a trench was not dug to create a break between my trial and the regularly irrigated one, soil water may have moved in a continuum from the regularly irrigated trial to my plots, thus nullifying a supposedly soil drying treatment.

RESULTS AND CONCLUSION

Leaf relative water content (LRWC) in cowpeas and peanuts was significantly ($P < 0.01$) reduced by the water stress treatment (Fig. 2) from the 40th to the 47th DAS (or from the 12th to 19th day after stress), except in PV_1 of peanuts where reduction started earlier. Before the 26th day of the cycle in cowpeas, LRWC was generally between 78% and 80%. As growth progressed, LRWC became higher in control, and lower in stressed plants. Whereas LRWC in stressed cowpeas did not drop below 80.8% (see Fig. 2a to 2c) in any of the genotypes (during the stress period), the LRWC in stressed peanuts was reduced to as much as 57.3% in PV_1 . The least reduction in stressed peanuts was 66.3% in PV_3 (see Fig. 2d to 2f). In the cowpea genotypes studied, it was observed that when the LRWC fell below 78% during stress at flowering, the temporary wilting point (TWP), the leaves entered the phase of permanent wilting point (PWP), and never recovered even after the soil was rewatered. In peanuts, however, the PWP was below 55% LRWC. Leaves of the various genotypes of cowpea and peanut that had not reached PWP, however, regained full turgidity on rehydration by the 51st DAS. The rate of recovery in cowpea CV2 was, however, slower than the other genotypes.

During soil moisture stress, cowpeas held a relatively higher amount of water in their leaves, thus preventing the cells from experiencing significant dehydration. This mechanism is a drought avoidance strategy, since the living cells cannot successfully 'co-exist' with higher levels of dehydration. On the other hand, peanuts during drought, held much less water in their leaves, while metabolic activities continued; and LRWC appreciated rapidly on rehydration. This comportment in peanuts is a drought tolerance strategy; the cells co-existed with high levels of tissue dehydration.

Leaf specific weight (LSW) was not significantly affected by the water stress treatment in both species (Fig. 3). The determination of LSW was done in order to assess the total amount of dry matter per unit area of leaf tissue. In a further analysis, leaf total nitrogen (N) was measured soon after soil moisture stress was imposed, and at intervals of seven days, including the period of recovery. In cowpeas, generally, the amount of total N per unit weight declined as growth progressed (Fig. 4). Although higher amounts of N were observed in stressed cowpea CV_1 and CV_2 (see Fig. 4a and b) during peak moisture stress (47 DAS) and the days of recovery (between 50 and 54 DAS), the difference was not significant. Similarly, the lower total N observed in stressed CV, was not significant (see Fig. 4c). In peanut PV_1 there was no difference, between stressed and non-stressed plants, in the leaf total N (see Fig. 4d). The response in PV_2 and PV_3 was, however, different (Fig. 4e and 4f). There was a significantly lower amount of total N in stressed PV_2 and PV_3 by the 47th DAS (the peak of soil moisture stress), whereas

the increase in total N in these stressed plants over the controls, during recovery, was not significant. A significant accumulation of free amino acids, notably proline, has been variously reported during water stress in some species. These amino acids increase the total N pool, hence lowering the osmotic potential of the leaves. The lowering of osmotic potential by osmotic adjustment (OA) minimizes the opportunity for significant water loss to occur from leaf tissue. This factor, among others, may account for the higher LRWC observed in cowpeas than peanuts. Generally, however, both cowpeas and peanuts exposed to a prior soil moisture stress adjusted better to osmotic stress than those that were irrigated regularly (see Fig 5 and Fig 6). Measurements of OA taken on 40th and 47th DAS (second and third weeks of stress respectively) indicated a significantly higher ($P < 0.05$) OA in cowpeas than peanuts (compare Fig. 5a to 5c with Fig. 5d to 5f, and Fig. 6a to 6c with Fig 6d to 6f). While this pattern of OA may explain the higher LRWC in cowpeas than peanuts and their consequent ability to avoid drought, protoplasmic resistance measurements taken during this study had no consistent pattern, and therefore unreliable. Perhaps, if more painstakingly done, further knowledge of drought tolerance between cowpeas and peanuts may be gained from protoplasmic studies.

Stomatal conductance was significantly reduced during drought (Fig. 7). As soon as irrigation was withheld, the stomata generally behaved more sluggishly, and finally closed as stress persisted. In spite of the very low leaf relative water content in peanut PV₁, complete stomatal closure was delayed for seven days (compare Fig. 7a, 7b, 7c, 7e and 7f with 7d). Stomatal conductance resumed normally in stressed peanuts on rehydration. In cowpeas, however, stomatal conductance in recovering plants was significantly ($P < 0.05$) higher than the controls (see Fig. 7a to 7c) within the period of rehydration. The tendency to open the stomata more widely in cowpeas may stem from the potential need for higher gas exchange (notably the uptake of more CO₂) to enable the plants complete their cycle more successfully; however, higher stomatal transpiration occurring therefrom, may lead to a rapid depletion of soil moisture, and in the event of a second drought, the plants may therefore be at a further risk.

The number of leaf nodes was significantly reduced by stress (Fig. 8). Soon after the onset of soil moisture stress, the rate of leaf initiation (Fig. 9) began to decline significantly in all the genotypes. The rate of decline was much higher in cowpeas than in peanuts (compare Fig. 9a to 9c with 9d to 9f). Leaf initiation in stressed cowpeas stopped after the third week in CV₁ and CV₃, and after the 4th week in CV₂. In stressed peanuts, new leaves were continually being initiated throughout the period of this experiment. This among other factors, may account for the higher yield potentials of peanuts (Fig. 10b and 10d) than cowpeas (Fig. 10a and 10c) during soil moisture stress (Fig. 10). For example, above ground yield (excluding fruits) in stressed cowpea was 79.7% for CV₁, 90.8% for CV₂, and 72.8% for CV₃ (percentage of the controls). The yield in stressed peanuts, on the other hand, was 89.9% for PV₁, 81.8% for PV₂, and 83.7% for PV₃. Similarly, fruit yield in stressed cowpea was 8% for CV₁, 71.7% for CV₂, and 39.4% for CV₃, whereas stressed peanuts had 76.5% for PV₁, 63.9% for PV₂, and 65.0% for PV₃, thus further confirming a better ability in peanuts to resist drought.

Fig. 1: Volumic humidity of soil ($\text{cm}^3\text{cm}^{-3}$) taken on the 8th and 15th days after commencement of soil moisture stress. Each bar is a mean of 30 replicates + SD Shaded bars represent irrigated soil, open bars represent dry soil. Means followed by different lowercase letters are significantly ($P < 0.01$) different according to DMRT

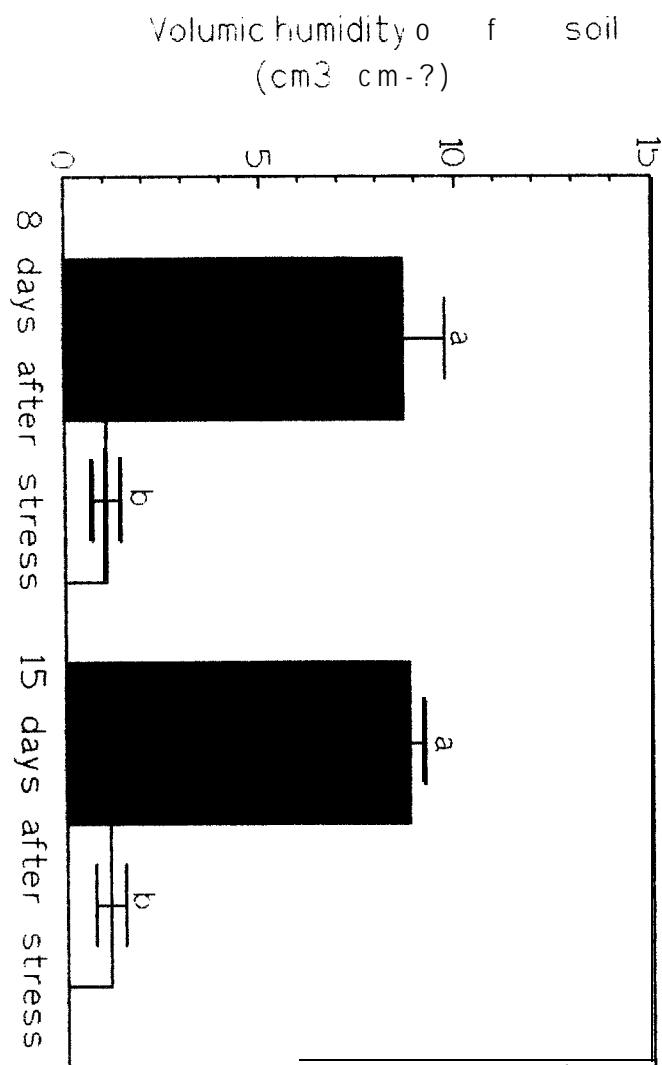


Fig. 2: Leaf relative water content (%) in cowpea, CV₁ to CV₃ (a to c), and peanut, PV₁ to PV₃ (d to f) are represented for stressed (unshaded squares), and irrigated (shaded squares). Each point is a mean of five replicates + SD.

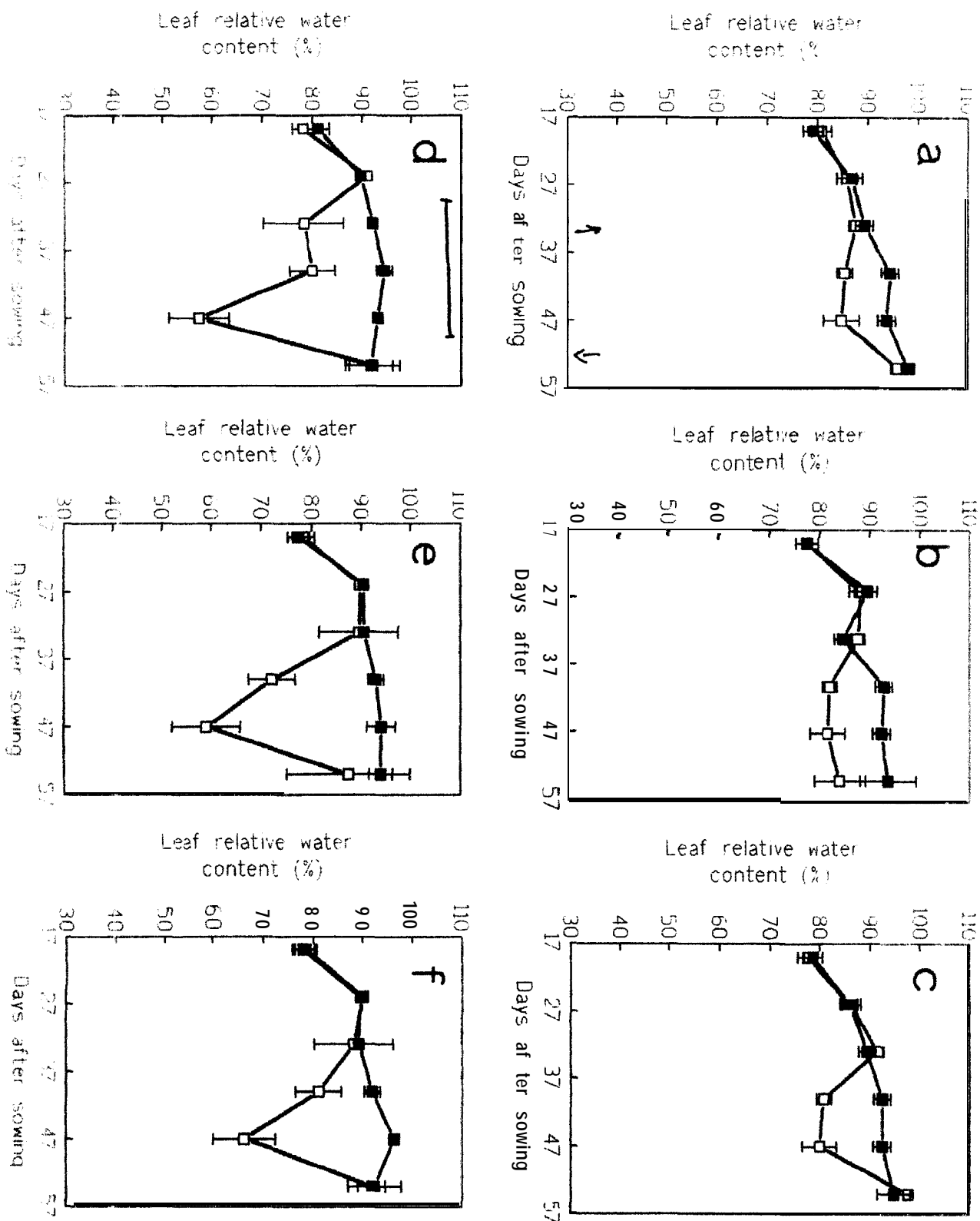


Fig 3 Leaf specific weight (g) in cowpea, CV₁ to CV₃ (a to c), and peanut PV₁ to PV₃ (d to f) are represented for stressed (unshaded squares), and irrigated (shaded squares),. Each point is a mean of five replicates + SD.

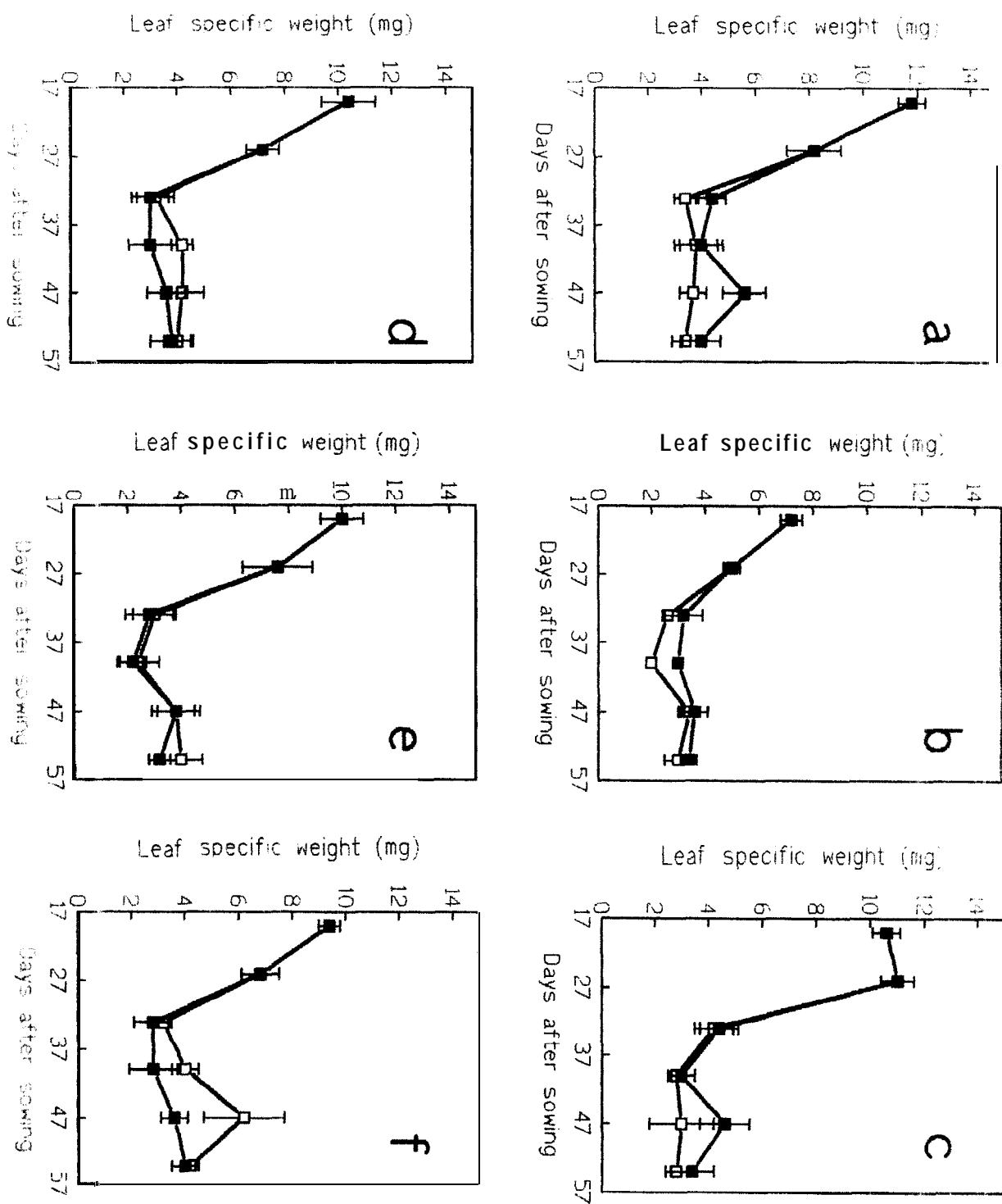


Fig 4: Leaf total nitrogen (% of dry matter) in cowpea, CV₁ to CV₃ (a to c), and peanut, PV₁ to PV₃ (d to f) are represented for stressed (unshaded squares), and irrigated (shaded squares). Each point represents five pooled samples from each block. Standard deviations are therefore not represented.

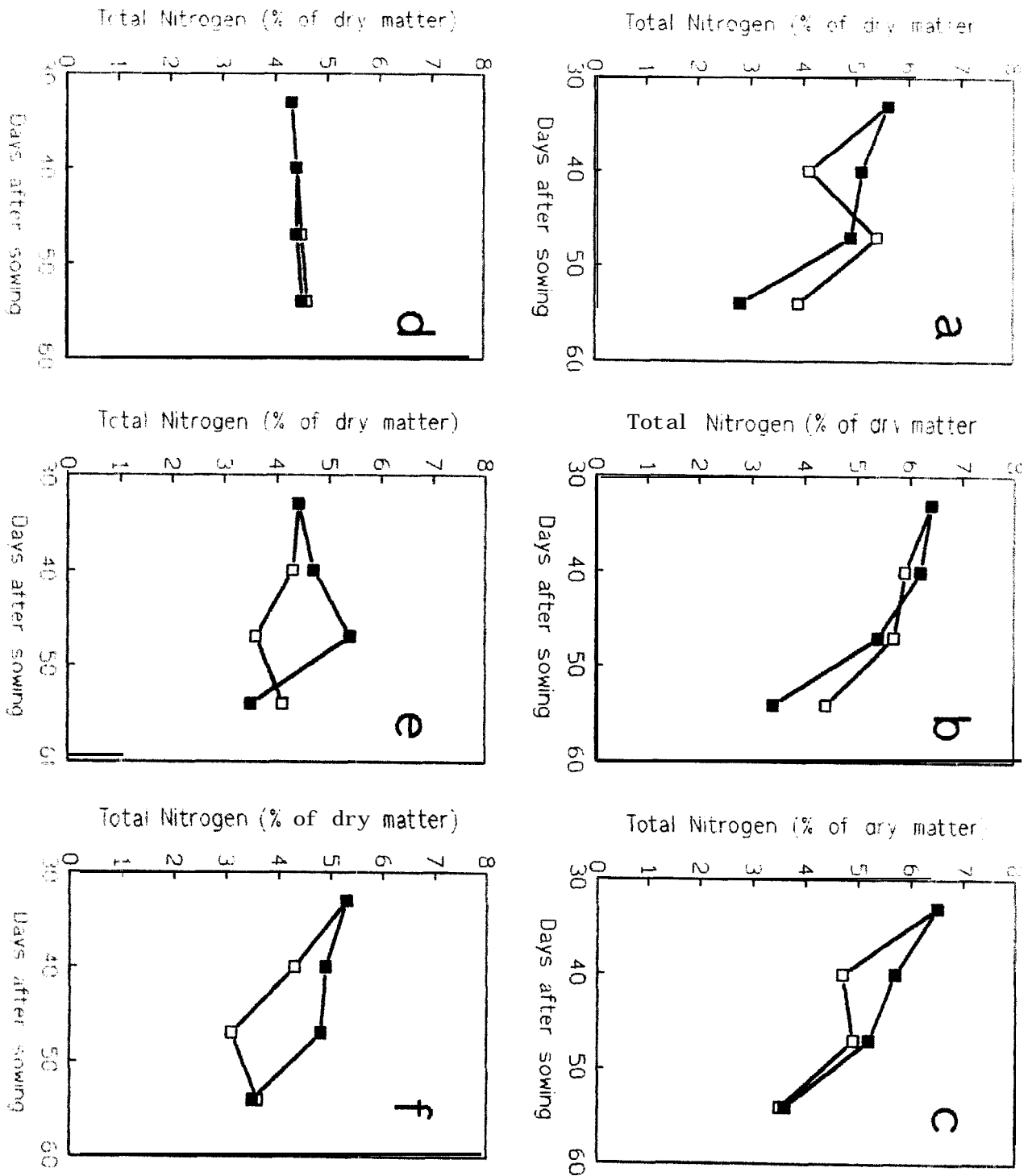


Fig. 5: Osmotic adjustments (% of leaf relative water content, LRWC) in cowpea, CV₁ to CV₃ (a to c), and peanut, PV₁ to PV₃ (d to f) are represented for stressed (unshaded squares), and irrigated (shaded squares). Measurements taken on 40th DAS (second week of stress). Each point is a mean of five replicates + SD.

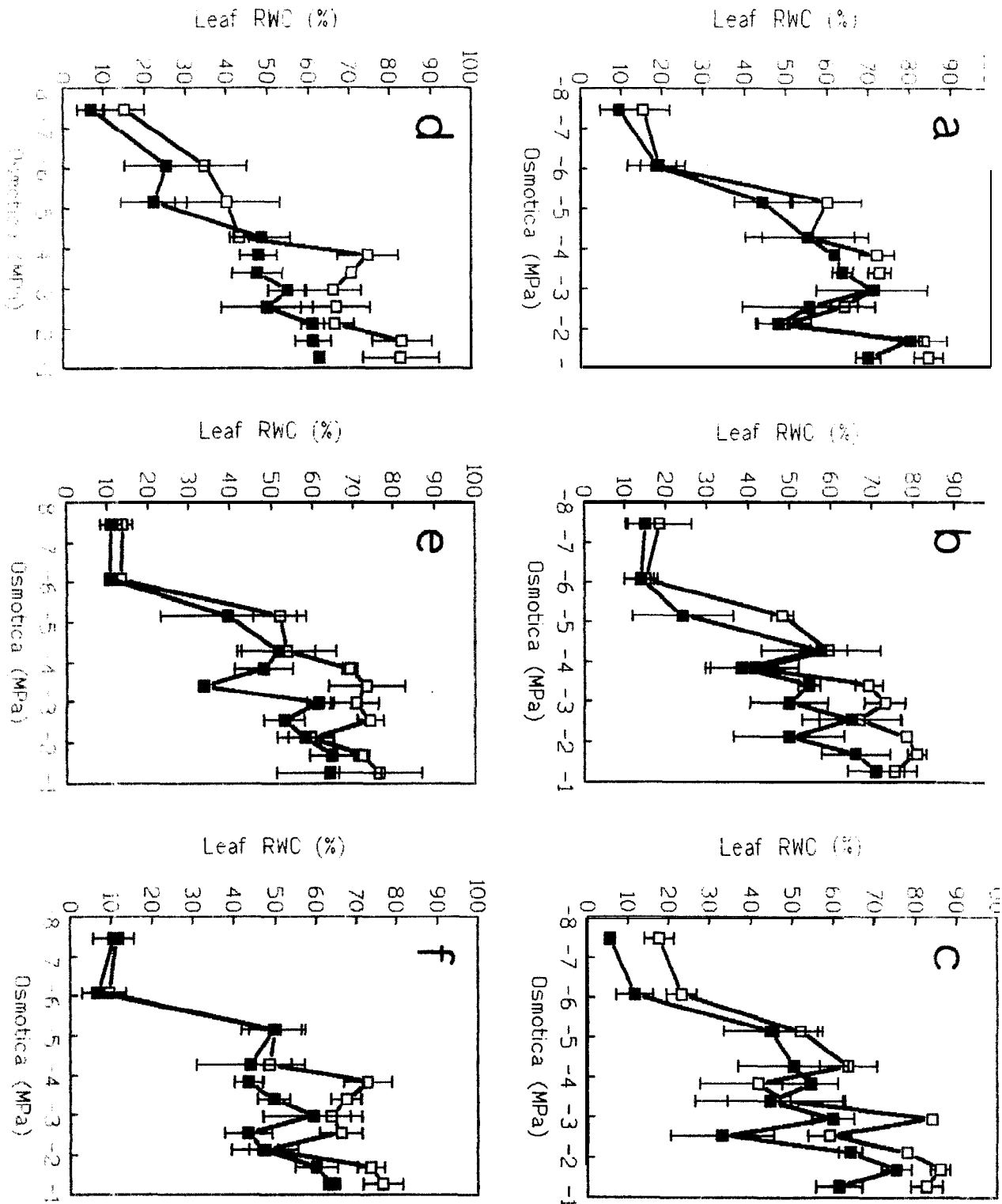


Fig 6. Osmotic adjustments (% of LRWC) in cowpea, CV1 to CV3 (a to c) and peanut, PV1 to PV3 (d to f) are represented for stressed (unshaded squares) and irrigated (shaded squares) Measurements taken on 47 th DAS (third week of stress). Each point is a mean of five replicates \pm SD.

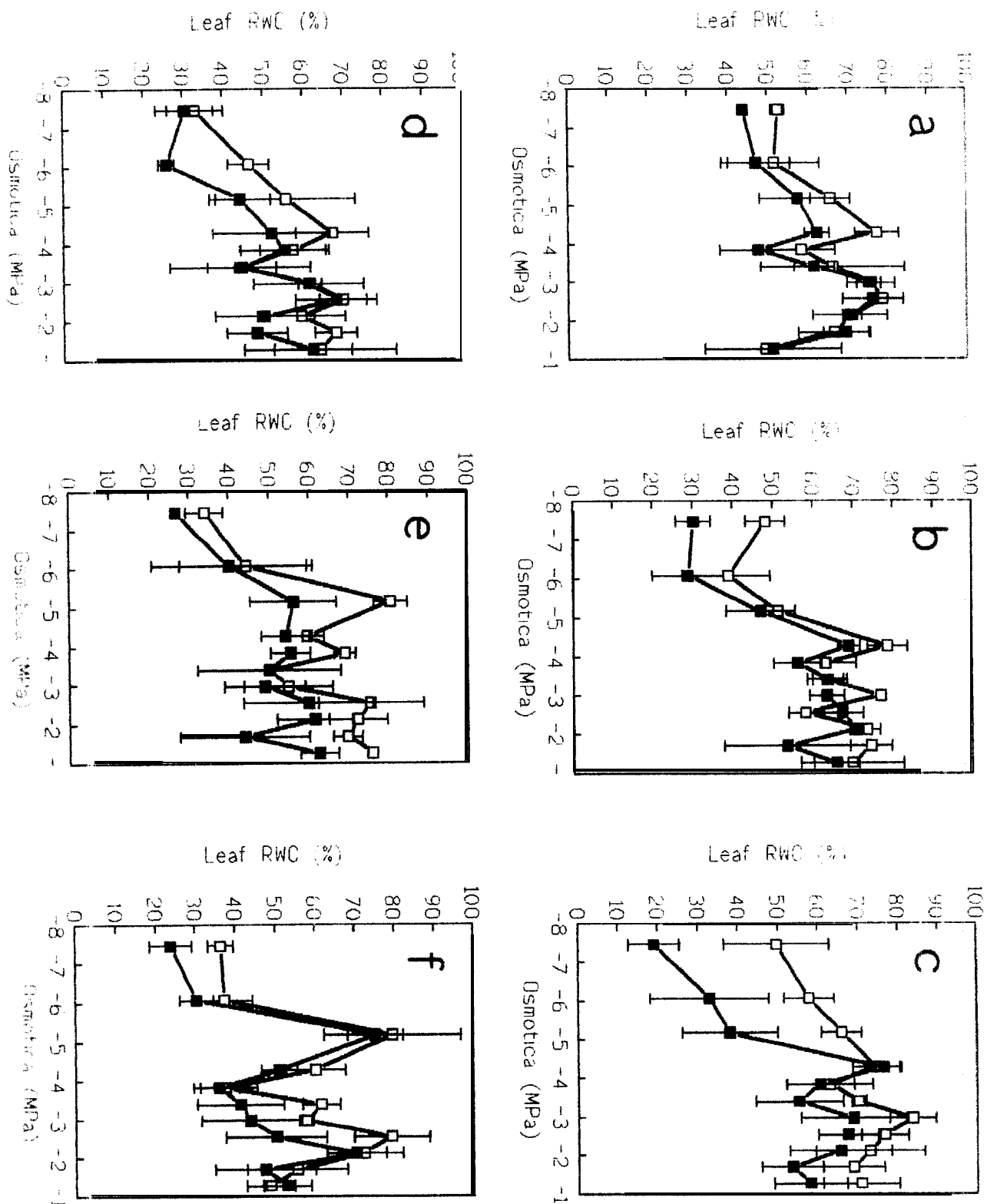


Fig 7: Stomatal conductance (cm s^{-1}) in cowpea, CV₁ to CV₃ (a to c), and peanut, PV₁ to PV₃ (d to f), are represented for stressed (unshaded squares), and irrigated (shaded squares). Each point is a mean of five replicates + SD.

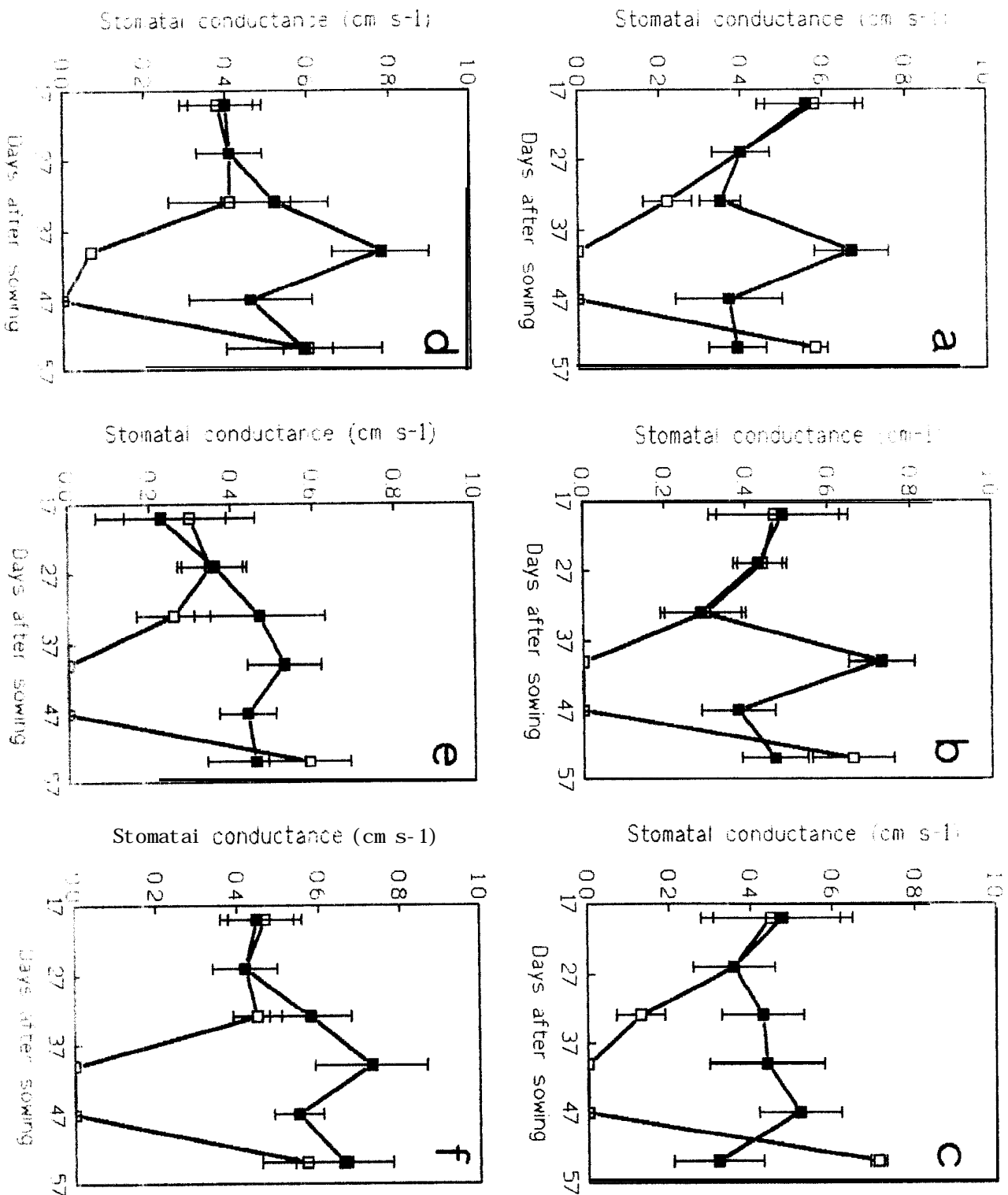


Fig. 8: Number of leaf nodes per plant in cowpea, CV₁ to CV₃ (a to c), and peanut, PV₁ to PV₃ (d to f) are represented for stressed (unshaded squares), and irrigated (shaded squares). Each point is a mean of five replicates + SD.

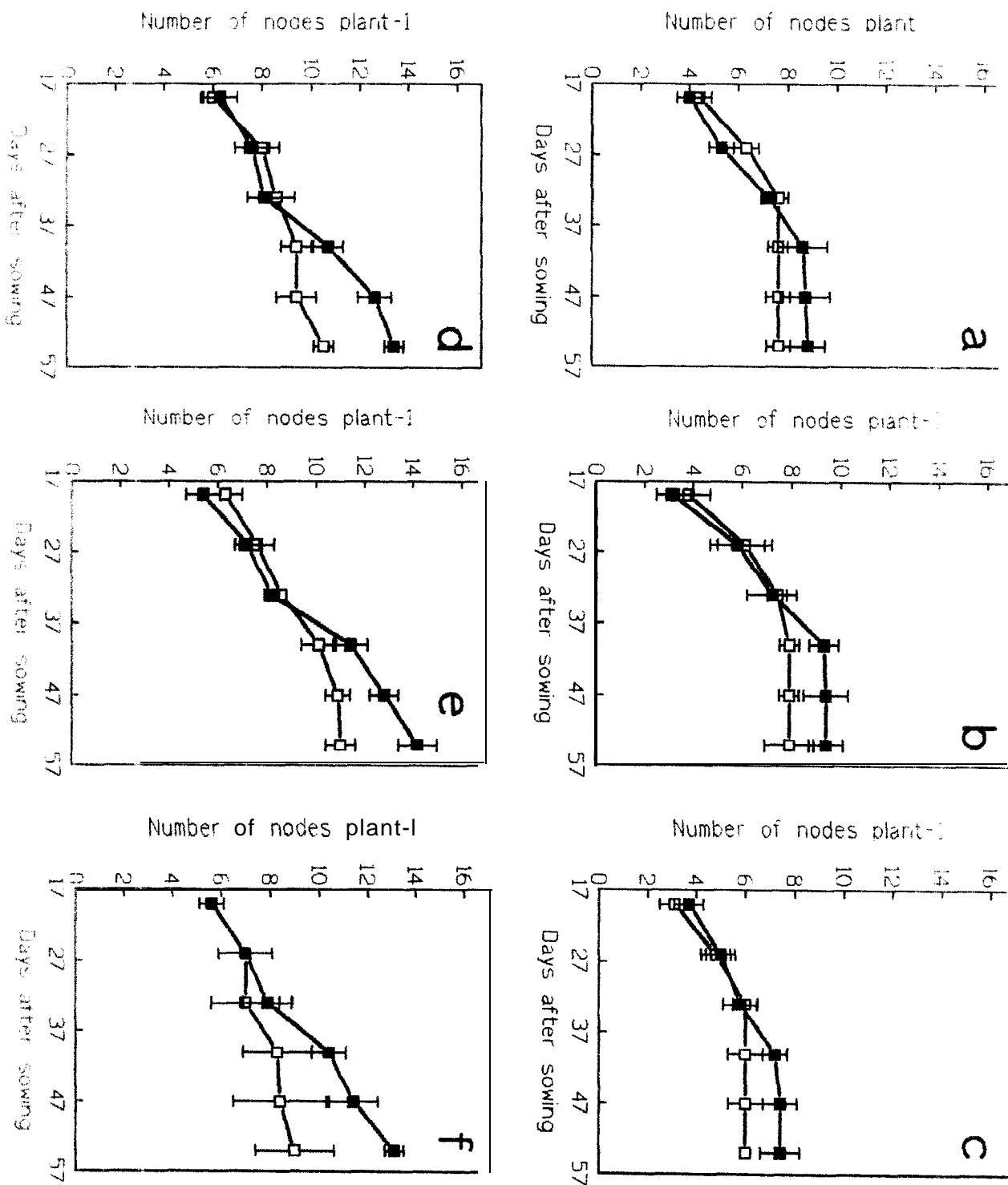


Fig 9. Rate of leaf Initiation per plant (mean number of new leaves emerging per weeh) in cowpea, CV₁ to CV₃ (a to c), and peanut, PV₁ to PV₃ (d to f) are represented for stressed (unshaded squares), and irrigated (shaded squares). Each point was calculated based on observed mean number of new leaf nodes per week. Standard deviations are therefore not represented.

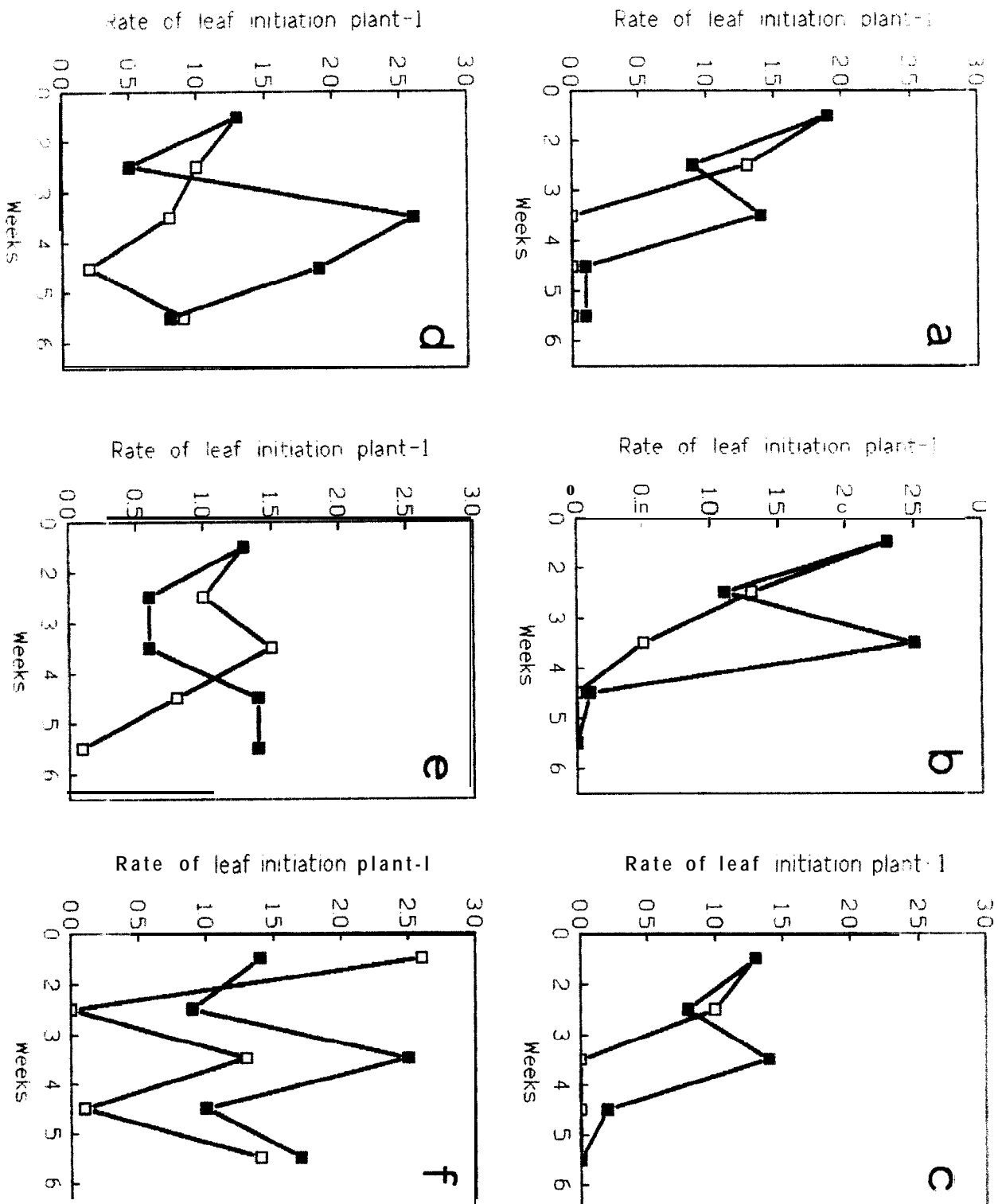
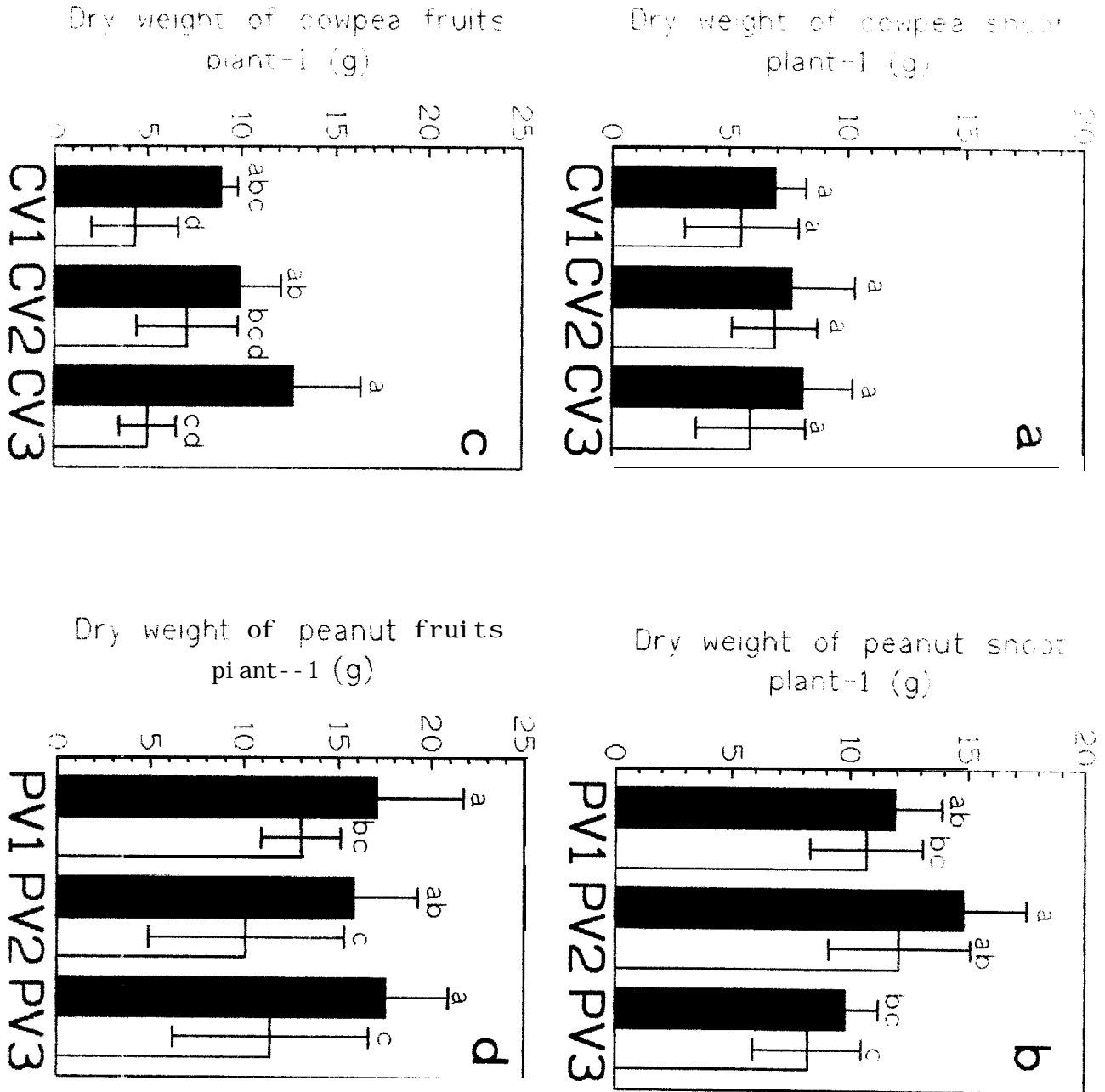


Fig. 10: Yield (y) per plant in cowpea (a and c), and peanut (b and d) are represented for stressed (open bars), and irrigated (shaded bars). Each bar is a mean of five replicates \pm SD. Means followed by different lowercase letters are significantly ($P < 0.05$) different according to DMRT.



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REFERENCES

- Carter, J.E.Jr., and R.P. Paterson,** 1985. Use of relative water content as a selection tool for drought tolerance in soybean. p. 77 In *Agronomy Abstract Agronomy Society of America*, Madison, WI.
- Cataido, D.A., L.E. Schrader, and V.L. Youngs,** 1974. Analysis by digestion and colorimetric assay of total nitrogen in plant tissues high in nitrate *Crop Sci* 14: 854-856
- Clarke, J.M., and T.N. McCraig,** 1982. Excised-leaf water retention capability as an indicator of drought resistance of *Triticum* genotypes. *Can. J. Plant Sci* 62:571-578.
- Conner, D.R., and B.R. Tunstall,** 1968. Tissue water relationships for brigalow and mulga. *Aust. J. Bot.* 16:487-490.
- Kirkham, M.B., E.L. Smith, C. Dhanasobhon, and T.I. Drake,** 1980. Resistance to water loss of winter wheat flag leaves. *Cereal Res. Commun.* 8:393-399.
- tevitt, J.** 1972 Responses of plants to environmental stresses. *Academic Press* New York.
- McCraig, T.N., and I. Romagosa,** 1991. Water status measurements of excised wheat leaves: position and age effects. *Crop Sci.* 31: 1583-1 588.
- Mulla, D.J.,** 1987. Measurement and characterization of soil water relations In *Soil, Crop and Water Management in the Sudan-Sahelian Zone*. A publication of the *International Crops Research Institute for the Semi-arid Tropics* (ICRISAT). pp 75-83.
- Nwalozie, M.C.,** 1991. Adaptation of cowpeas to drought: physiological aspects Technical report of *CERAAS*, Bambey, Senegal.
- Sanchez-Diaz, M.F. and P.J. Kramer,** 1971. Behavior of corn and sorghum under water stress and during recovery. *Plant Physiol.* 48:613-616.
- Schonfeld, M.A., R.C. Johnson, B.F. Carver, and D.W. Momhinweg,** 1988. Water relations in winter wheat as drought resistance indicators. *Crop Sci.* 28:526-531
- Slatyer, R.O.** 1960. Aspects of the tissue water relationships of an important arid zone species (*Acacia aneura* F muell.) in comparison with two mesophytes. *Bull. Res. Counc. Isr. Sect. D.* 8:159-168.
- Vasquez-Tello, A., Y. Zuily-Fodil, A.T. Pham Thi, and J.B. Viera Da Silva,** 1990. Electrolyte and Pi leakages and soluble sugar content as physiological test for screening resistance to water stress in *Phaseolus* and *Vigna* species. *Journal of Expt. Bot.* 41:827-832.

APPENDIX

Papers communicated for publication

- 1 **Nwalozie, M.C., C.I. Ogbonnaya, J.-L. Khalfaoui, and D.J.M. Annerose.** Water management, protoplasmic resistance and osmotic adjustment in two cowpea genotypes grown under two soil moisture regimes. *Agronomie (France)*
- 2 **Nwalozie, M.C., N. Cisse, J.-L. Khalfaoui, and D.J.M. Annerose.** Root comportment in two cowpea varieties during water stress. *Journal of Experimental Botany (United Kingdom).*
- 3 **Labare, K., S. Dossou-Yovo, M.C. Nwalozie, and D.J.M. Annerose** Patterns of root growth in five sorghum genotypes during moisture stress early in the cycle *Crop Science (U.S.A.).*
- 4 **Labare, K., S. Dossou-Yovo, M.C. Nwalozie, and D.J.M. Annerose.** Water status, gas exchange and yield in five genotypes of sorghum subjected to water stress at panicle development. *Crop Science (U.S.A.).*