Functioning of peanut (Arachis hypogea L.) under nutrient deficiency and drought stress in relation to symbiotic associations

Quilambo, Orlando António

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SUMMARY

Peanut is a common crop in the semi-arid tropics and for the majority of the population in southern Mozambique it is yet an irreplaceable constituent of the daily diet. The peanut yields, however, have decreased in the last years due to (i) low soil fertility, mainly low nitrogen (N) and phosphorus (P), (ii) growing of unimproved landraces, (iii) poor agricultural practices and, (iv) drought stress. Drought stress in particular has been recognised as the major constraint for the peanut production, due to the unpredictability of its occurrence, severity, timing, duration and to the interaction with other abiotic stresses, particularly extremes of temperature and variation in nutrient availability and with biotic stresses. These constraints have shifted peanut from a cash crop to a subsistence crop, so that the majority of the population has to rely on imported peanut seeds for agricultural production and human consumption. Therefore, any effort to attempt to increase peanut production is of great value, because it would bring nutritional benefits (peanut is rich in oil, protein content and vitamin B1) to the rural population, and increase their income.

A growth analysis experiment (chapter 2) showed that small-seeded cultivars (Falcon and Natal Common) had a higher relative growth rate (RGR) and root weight ratio (RWR), than the large-seeded cultivars (Local and Bebiano Branco). The dry matter allocation pattern showed substantial differences, the small seeded cultivars allocated more of their dry matter to the pegs and pods, while the large-seeded cultivars allocated more of their dry matter to the leaves and roots. Based on these differences in allocation pattern the cultivars Falcon (small-seeded) and Local (large-seeded) were used for subsequent studies on nutrient deficiency, drought stress and symbiotic associations.

This thesis deals with growth responses of selected peanut cultivars to controlled changes in soil fertility, especially low N and low P (chapters 3 and 4); drought stress (chapters 5 and 6) and symbiotic interaction between arbuscular mycorrhizal fungi (AMF) and peanut, under well-watered conditions (chapter 7) and under drought stress conditions (chapter 8).

Limitation of mineral nutrients was achieved by reducing the amount of the slow release fertiliser osmocote, while maintaining a constant amount of the other nutrients in the sand/vermiculite substrate. Drought stress was imposed by withholding irrigation until the moisture content of the pot soil reached 3 % (near the wilting point of the peanut cultivars).

N limitation resulted in symptoms of deficiency only at the reproductive stage. At the vegetative stage RGR was significantly reduced in cultivar Falcon, while relative leaf expansion rate (RLAER) was reduced in both cultivars at this growth stage (chapter 3). It was concluded that leaf expansion rate was more sensitive to N limitation than the other growth parameters. The high sensitivity of the cultivar Falcon, was ascribed to its high specific leaf area (SLA), since high SLA has been associated with high fertility demanding species, and this cultivar is originating from a high input breeding system, in Zimbabwe. Symptoms of N deficiency alone were found to be not a direct and adequate indication of the N requirement of the peanut cultivars, as these symptoms may result from other factors, such as low P or drought stress. Only small amounts of N are sufficient to allow normal growth of the peanut cultivars if nodulation is adequately present or completely absent as in the N limitation experiment, since peanut is a poor utiliser of fertiliser N.

P limitation (chapter 4) resulted in a reduced leaf area, leaf area ratio (LAR), SLA and leaf area to root dry weight ratio at the reproductive stage, in both cultivars. Similarly, root dry weight and root volume were increased at this stage. RGR was only reduced at the vegetative stage, but relative leaf expansion rate (RLAER), was reduced in both cultivars at both growth stages. It was therefore concluded that, P limitation although not reducing yield, represents, particularly under field conditions, a constraint of certain importance for the growth and production of the peanut cultivars. RLAER and RWR were very sensitive growth parameters under low P.

Drought stress (chapter 5) resulted in differentiated responses at the vegetative stage. While cultivar Falcon did not show a significant growth reduction, cultivar Local reduced its leaf area, LAR and SLA, while increasing its RWR, maximum root length to leaf area ratio (MRLAR) and root shoot ratio (R/S). Dry matter content of both cultivars was not significantly reduced, suggesting a lower sensitivity of photosynthesis to drought stress than leaf expansion. N_2-fixation measured as the number of nodules was not reduced by drought stress at the vegetative stage in both cultivars.

It was concluded that the peanut cultivar Falcon possessed an osmotic adjustment mechanism which enables it to withstand short-term drought stress. A measurement of the cell membrane integrity, with polyethylene glycol test (PEG)-test, showed that the membranes of the cultivar Falcon were less injured, compared to those of the cultivar Local, under drought stress.

Additionally, proline was substantially more accumulated in this cultivar, than in

cultivar Local (chapter 6). Therefore, cultivar Falcon was classified as drought-tolerator and cultivar Local as drought-avoider. A continuous drought stress, however, resulted in a substantial reduction in leaf and root growth, and contrary to the vegetative stage also in reduction in dry matter content. Additionally and contrary to the low N and P experiments, yields were significantly reduced.

Drought stress, in this study, was found to be the major constraint for the production and yield of the peanut cultivars. Relative water content, cell membrane integrity, proline content, RWR, MRLAR and R/S were found to be drought stress indicators, loosing their significance as drought stress developed.

Inoculation (at a ratio of 5 % of the pot volume) of the peanut cultivars with self-produced inoculant (Soil Mozambique) and purchased inoculant (Hannover), resulted in increased root colonisation and growth, particularly for leaf area and leaf dry weight at the vegetative stage (chapter 7). At the reproductive stage, particularly in cultivar Falcon, an increased leaf area andleaf number was observed, while RWR was significantly reduced. The cultivar Falcon, a product of a high input agriculture system showed a higher dependence on AM inoculation and the cultivar Local, a landrace, was more compatible with the indigenous (Soil Mozambique) inoculant. This confirmed the high fertility demanding characteristic of cultivar Falcon, expressed by the high sensitivity to low N (chapter 3).

Inoculation (at a ratio of 10 % of the pot volume) under drought stress, particularly with the Soil Mozambique inoculant, resulted in the same growth as the control plants (chapter 8). An increase in leaf area, leaf number and a reduced RWR and R/S was observed in drought-stressed and inoculated plants of both cultivars. Clearly Soil Mozambique inoculant could alleviate drought stress effects in a non-sterilised soil. The indigenous inoculant was more adapted to the drought stress conditions than the purchased inoculant.

The present results have shown that under low input agriculture, the correct management of indigenous AMF, represent a real alternative to minimise the constraints in peanut production, since they are known not only to increase drought tolerance, as found in present study, but also to increase the uptake of other mineral nutrients such as N, P, potassium, sulphate, copper and zinc. Mycorrizal symbiosis could also help improving not only grain yield, but also soil physical, chemical and biological factors, enhancing the growth environment for other non-legumes.

Further research is needed to optimise the beneficial effects of the mycorrhizal symbiosis, under the Mozambican conditions, which include the determination of the host-fungus interactions, the specificity of the AMF, the competitiveness and mutualistic effectiveness of the AMF, under optimal and stress conditions, particularly under low N, low P, salinity and drought stresses.