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Response of Cowpea (*Vigna unguiculata* L. Walp.) to Water Stress and Phosphorus Fertilization

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Abstract: This study was conducted in the experimental college of agriculture and forestry, in Maputo-Mozambique, in order to evaluate the response of cowpea (*Vigna unguiculata* L. Walp.) to irrigation and phosphorus and test the hypothesis that high levels of phosphorus improves the tolerance of plants to water stress. We used a variety IT 18 of cowpea, short cycle and ended. The experiment was subdivided into building plots complete block design with five repetitions, the irrigation factor was fixed at the main plot with two levels (with irrigation and without irrigation) and phosphorus factor in sub-plots with 3 levels (0, 20 and 40 kg ha^{-1} of phosphorus). The fertilization strongly influenced the yield and the number of pods per plant in both irrigation conditions. The effect of fertilizing phosphorus was higher under irrigation. The interaction was significant only for grain yield and number of pods, which means that the effect of phosphorus in these two variables has not been the same for the two levels of irrigation, high levels of phosphate fertilizer (P_2O_5) have improved the tolerance of cowpea when not irrigated.

Key words: Drought, legume, grain yield, water deficits, mozambican soils, nutrients

INTRODUCTION

Cowpea is one of the important food legumes in hot-dry tropics and subtropics in Sub-Saharan Africa. Plays a substantial role by serving as grain and vegetable crop mainly for the rural people in the east, west, south and central parts of Africa (Lemma *et al*., 2009). The cowpea (*Vigna unguiculata* L. Walp.) is cultivated in tropical and subtropical regions of Africa, America and Asia under a variety of ecological conditions. Cowpea is a more important legume in regions where water stress is the major constraint for its production (Santos, 2000). Water stress reduces photosynthesis and become scarce availability of carbohydrates for pod filling, which can cause the same drop (Zimmermann *et al*., 1988).

In Mozambique, cowpea is an important food crop that ensures food security and improves the quality of the diet of rural populations mainly because it is rich in proteins more accessible and of high biological value because it contains high levels of lysine and tryptophan (Santos, 2000). However, the food crop cowpeas can be consumed in the form of grain or dried and cooked green leaves, it can also be used for animal feed and as a cover crop (Rodriguez, 1985). Despite the importance demonstrated by the many uses and their contributions to food security, production and productivity remain below the genetic potential of cultivated varieties (Santos, 2000). Plant growth rate is dependent on the interaction of many complex processes, which are influenced by both genetic and environmental factors. Nutrients are required by plant in adequate quantities for metabolic regulation, production of new tissues as well as development. They are structural components of metabolic and protoplasm structure (Adelusi and Aileme, 2006).

Several factors contribute to low productivity, among which is particularly intense biotic pressure by insects and other pests, soil problems especially low or high pH, high amounts of aluminum, low fertility, soil salinity, high temperatures, water, inadequate management and poor plant protection, soil physical properties, a mixture of cultures and hydrological stress (Singh and Rachie, 1985).

Water stress has been reported to be one of the factors limiting the productivity of cowpea, because not only affects the production of the grain, even as the whole process of growth of all organs of the plant and its metabolism (Zimmermann *et al*., 1988).

Although, adverse the accretion, operating and production, water stress can be relieved by fertilizing with phosphorus. For example, Chiulele (2003) reported that plants fertilized with high levels of phosphorus survived successive periods of drought. These took root growth that allowed them to explore the large amount of water existing in the root zone in addition to possessing a greater capacity to extract water due to greater hydraulic

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conductivity of roots. Thus, it is necessary to evaluate the response of cowpea to water stress and conditions of limited availability of water. Therefore, this study was conducted to evaluate the response of cowpea, IT-18 variety to water stress and its response when fertilized with phosphorus.

MATERIALS AND METHODS

Location and characteristics of the study area: The test was conducted between October 2005 and January 2006 in the experimental college of agriculture and forestry, in Maputo, Mozambique, with the following geographical coordinates of latitude 26°20' S and 32°41' E, located 15 m from mean sea level (Augusto, 1996). The type of soil is sand with 0.3% organic matter (Augusto, 1996). The test occurred under field conditions and precipitation recorded in the period of the test is shown in Fig. 1.

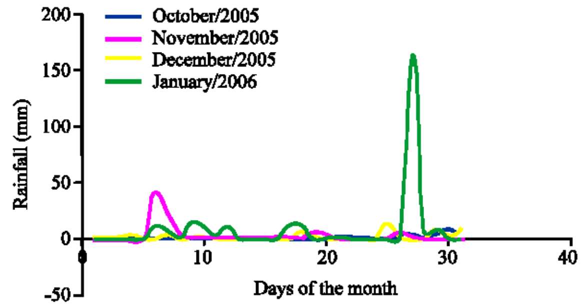

Fig. 1: Total daily rainfall during experimental period Oct/2005 to Jan/2006. Station: Maputo/ Observatory, Element: Total daily rainfall (9 a.m. to 9 h in mm), Source: INAM (National Institute of Meteorology)

General test for the assembly: For the test were used seeds of cowpea, IT-18 variety (It is a prostrate variety, short cycle, with approximately 70 days, with broad leaves and indeterminate). Test was applied to the soil after weeding, Basamid to combat nematodes, the compass was used 1×0.25 m, the test occupied an area of 15×5 m in length and width, respectively. To this end three seeds were sown by lair and then thinned to one plant per lair 15 days after the emergency. Interruption of irrigation was imposed in the post-emergency phase (15 days later) while the well-watered control was irrigated regularly at field capacity. Irrigation and weed control was done manually. Metric tape was used, single superphosphate (P_2O_5), dimethoate to combat aphids, cypermethrin to combat the caterpillars, spades, spray the back, tags for identification of treatments to balance the weighing of grain yield, plastic bags for collection and separation of pods per treatment and hand watering.

Test experimental treatments: Consisted of two factors (irrigation and phosphorus), the irrigation factor with two levels (with irrigation and without irrigation) and phosphorus factor with three levels (40 kg ha^{-1} of P_2O_5 as high level of phosphorus, 20 kg ha^{-1} of P_2O_5 middle level and low level 0 kg ha^{-1} as applied in the form of superphosphate).

Experimental design: The experiment was subdivided into plots, where the factor was set at irrigation plots and the main factor in phosphorus dub plots with five blocks. Each block consisted of 2 plots (irrigation and no irrigation) at 1 m apart and each block was composed of 3 crop rows, each with different level of phosphorus fertilizer according to the randomization scheme, where a line had dimensions 1.25 m long and 1 meter spacing. Each line consisted of 5 plants spaced at 0.25 cm between plants. Each block was about 30 plants, each row within the plot was a treatment. In each treatment was examined 1 central plant and the two sides served as the border. So, 6 plants were studied in each block. The test data were analyzed using the statistical package SAEG. The analysis of variance was made and for the significant variables was used the Scott Knott test to compare averages.

Variable measures

Grain yield in each treatment: For determining the yield of grain, became based on weighing the dried grains from the threshing of all pods in the area useful, expressed in kg ha^{-1}.

No. of pods per plant: The number of pods was determined by counting them in each treatment in random samples of 3 plants to the determination of the number of pods per plant, made to harvest the pods of the plants in each treatment and then had to count beans, dividing by the number of plants in the area useful

Floral initiation: Floral initiation (No. of plants flowered) was determined through a frequent observation and counting of plants that flowered 30 days after sowing.

Statistical analysis: All data were submitted to Analysis of Variance (ANOVA) of variables measures, following the outline of subdivided plots used the statistical package SAEG 05.

RESULTS

Yield of grain: Yield was positively affected by a linear increase in phosphorus factor. The test, the maximum

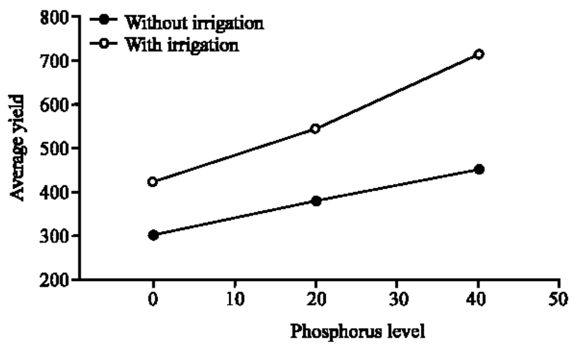

Fig. 2: Average yield of cowpea in conditions of irrigation and without irrigation

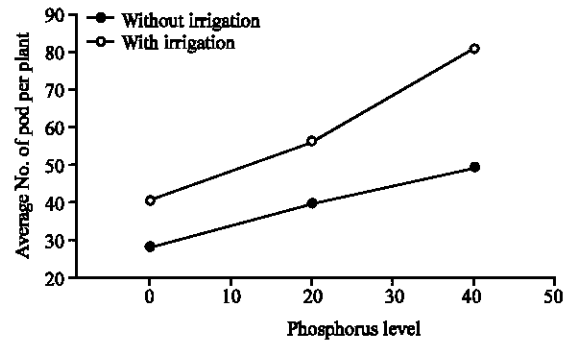

Fig. 3: Average No. of pods per plant in conditions of irrigation and without irrigation

yield was achieved 900 kg ha^{-1} obtained when applied 40 kg ha^{-1} of phosphorus in irrigation conditions compared with treatments without irrigation (Fig. 2).

The results show that the phosphorus strongly influences the yield of beans cowpea in both conditions without irrigation and watering, the fertilizing effect of phosphate was higher in conditions of irrigation. Plants fertilized with P level 40 kg ha^{-1} with irrigation and without irrigation achieved higher yields than those with level 0 and 20 kg ha^{-1} P under the same conditions, which comes out to reveal the fact that phosphorus promoted a rapid development system root giving greater tolerance of plants to water stress, because they can get nutrients from the deep.

Under irrigation, the irrigation effect was more remarkable when compared with treatments without irrigation, there was a fast vegetative growth of plants, higher yields and much leaf production

No. of pods per plant: The analysis of variance shows a strong interaction between phosphorus and irrigation in the production of pods for the plant. Due to the existence of water and high levels of phosphate, there was a major development, the greater leaf expansion and consequently high photosynthetic rate, allowing the plants allocate large amounts of carbohydrates in the reproductive areas and increase the production of pods (Fig. 3).

In a similar study, Greenway *et al.* (1969) showed that the absorption of phosphorus was reduced when the water potential of roots was reduced to -2 bars and decreased linearly as the potential was reduced. These results clearly suggest that the reduction in growth observed as a result of water shortage may partly arise from poor nutrition. The sensitivity of leaf area expansion due to deficiency of phosphorus causes a reduction in carbon available for leaf and allocation of biomass to heterotrophic tissues, which will have direct effect in the formation of pods per plant (Lynch *et al.*, 1991).

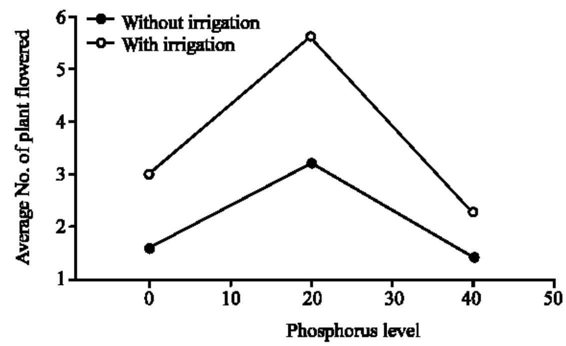

Fig. 4: Average No. of plants that flowered 45 days after emergence of plant as a function of levels of phosphorus

Floral initiation: Among the treatments that were in the irrigated plots in different blocks, plants flowered over the treatment which was under high doses of phosphorus and less in the treatment was subjected to low doses of phosphorus. Plants under high doses of phosphate showed that phosphorus addition increased vegetative growth and the assimilative capacity of the plants by increasing the leaf area or photosynthetic activity (Fig. 4).

The same observation was made by Ferreira (2004) in a similar study, where increments of phosphorus allowed the growth of roots which resulted in increased number of leaves, while Stewart *et al.* (1977) found that phosphorus deficiency reduces plant growth by inhibiting leaf expansion and photosynthesis. These results can be explained, because the phosphorus addition stimulates the growth of the root zone allowing the plant to get nutrients and water to distant areas of metabolic activity, resulting in rapidly escalating and initiation of early flowering, while plants in low doses, has no nutrients sufficient for metabolic activity.

DISCUSSION

The Analysis of Variance (ANOVA) of the variables studied proved to have a significant effect of watering and fertilization on yield of grain (Table 1).

The interaction was significant only for grain yield and number of pods per plant. This means that the effect of phosphorus in these two variables has not been the same for the two levels of irrigation. For example, Singh *et al.* (1997) found that plants under low levels of phosphorus in dry soils obtained low yields because plants showed severe symptoms of water stress and many died followed by drying and senescence of many leaves. While plants fertilized with high levels of P, not only survive, were able to hold great potential leaf extract water from deep soil, allowing satisfactory returns. Tyiem and Chieng, 2003 in a similar study reported that Statistical analyses of yield and P uptake gave a positive response of the crop to added fertilizer and irrigation water. Application of 70 kg ha^{-1} P_2O_5 produced the highest yields under all irrigation schedules. Irrigating too frequently was found to be detrimental; maximum yield under P fertilization was obtained with irrigations scheduled at half the design interval and with half the design irrigation depth. Uptake of P increased with yield. Many other experiments made with phosphorus showed that there is usually a linear relationship between increments of phosphorus and yield of plants (Cooke, 1982) Phosphorus application adds the assimilative capacity of the plants by increasing the leaf area or photosynthetic activity, ensuring an effect on the roots. Recent studies also showed that the nutrition information on phosphorus has strong effects on photosynthesis (Sivak and Walker, 1986). Another study made by Buerkert *et al.* (2001) to see the efficient phosphorus application strategies for increased crop production in Sub-Saharn west Africa, time trend analisyses showed that P-induced total dry matter increases between 28 and 72%. This was confirmed in 119 on-farm trials revealing P placement as a promising strategy to overcome most limiting growth to legumes.

Another field experiment was carried out by Matteucci and Carvalho, 1998 on a distrophic red yellow latosol text to in the state of Bahia, Brazil to see the effect of phosphorus and plant density on yield components of cowpea showed that phosphorus levels had significant and positive effects on those variables.

This study shows that the yield of cowpea in conditions without water increases as the phosphorus levels increase, this suggests that the tolerance of plants to water stress increases when fertilized with phosphorus and increments of phosphorus applied improved the tolerance of plants to water stress when compared with treatment of low level of factor. There was a linear effect of phosphorus on increments of income for both plants in conditions of irrigation and without irrigation and highest yield was observed with treatment with high dose of phosphorus and irrigation (900 kg ha^{-1}) against 200 kg ha^{-1}. The phosphorus and irrigation had an effect on the number of pods per plant as well as floral initiation and the level of 40 kg ha^{-1} of phosphorus allowed to obtain the greatest number of pods and larger floral initiation.

Table 1: Interaction between phosphorus and irrigation on grain yield, number of pods per plant and flowring

	Observed variables		
Source of variation	Grain yield	Pods per plant	Flowering initiation
Phosphorus	**	**	**
Irrigation	**	**	**
Phosphorus×Irrigation	**	**	ns

**Values significant at 5% probability by F-test. ns: Not significant

We can see in this study that water is vital for plant growth and development. Water deficit-stress permanently or temporary limit the growth and distribution of natural vegetation and performance of cultivated plants more than any other environmental factors do and this can be minimized with phosphorus supplement (Shao *et al*., 2008). Although, research and practices aimed at improving water-stress resistance and water-use efficiency have been carried out for many years, the mechanism involved is still not clear. Further understanding and manipulating plant-water relations and water stress tolerance at the scale of physiology and molecular biology and phosphorus supplement can significantly improve plant productivity and environmental quality.

Currently, post-genomics and metabolomics are very important to explore anti-drought gene resource in different life forms, but modern agricultural sustainable development must be combined with plant physiological measure in the field.

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