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Response of Sunflower to Nitrogen Application and Water in Northern Brazil Alfisol

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Abstract: Decline in crop yield has been a problem in Northern Brazil region due to inherent low fertility status of the soils and water deficit of different crops. In order to study the effects of nitrogen and available soil water levels on growth and yield components of sunflower, an experiment was carried out from March to June 2010 in a semi-controlled greenhouse condition of the Federal University of Campina Grande, Paraiba, Brazil using Alfisol soil. The treatments were arranged as a completely randomized design, in a 4×4 factorial experiment (four nitrogen levels and four available soil water levels), in triplicates, total of 48 experimental units. The nitrogen levels in kg/ha were 0; 60; 80 and 100 which was added as urea; the available soil water levels were 55; 70; 85 and 100%. The results of this research indicate that nitrogen had a significant effect only on leaf area at 40 DAS and % achenes viable. The effect of available soil water on sunflower cv. Embrapa 122/V-2000 biometry and the yield showed that there were significant differences, on average, in all growth traits (stem height and diameter) at 40 and 60 DAS, in leaf number at 40 DAS, in leaf area at 40 and 60 DAS and in all production traits. The biometry and yield response to available soil water of different crops is of major importance in production planning. In this study, the maximum biometry and yield response factor of sunflower was determined at 100 % of available soil water.

Key words: Irrigation; *Helliantus annuus* L.; Nitrogen fertilizer

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most important oilseed crops in the world which is naturally higher in nitrogen than other crops. Nitrogen is one of the major nutrients which enhances the metabolic processes that lead to increase in vegetative, reproductive growth and yield of the crop.

In sunflower crop, its deficiency causes nutritional disorder, being the nutrient that most limits the yield as a result of disability of the plant, provides up to 60% reduction in productivity [1].

The number of achenes per head is a reflection of action of nitrogen in critical stages of floral that occurs in early stages of development of sunflower. The potential number of flowers is determined very early which affects the number of achenes and consequently affects the head diameter [2].

The head diameter is one of the morphological characteristics which most affected by addition of nitrogen. It shows an increase even with small doses of nitrogen (25 kg/haN). However, this increase does not continue with an increase of N.

According to Guedes Filho *et al*. [3], the nitrogen application affected the growth and yield of sunflower except for dry weight of 1000 achenes. However, Biscaro *et al*. [1] showed significant effect of nitrogen levels in dry weight of 100 achenes. This resulted in increased average weight of achenes until the maximum dose of 44.9 kg/ha N was obtained. The maximum weight was also reached to 7.19 g for the mass of 100 achenes, which reflected in income.

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Unfortunately, with the advancement of agriculture, soils are being degraded at Na alarming rate by wind and water erosion, desertification and salinization because of misuse and improper farming practices. Growing of crops one after another without giving consideration to nutrient requirement has resulted in decline in soil fetility, especially in nitrogen.

Maintaining soil quality at a desirable level is a very complex issue due to involvement of climatic, soil, plant and human factors and their interactions. This issue is even more challenging in case of dry land agriculture.

Among different problems faced by crop plants, water stress is considered to be the most critical one [4]. Shortage of water, the most important component of life, limits plant growth and crop productivity, particularly in arid regions more than any other abiotic environmental factor.

Water shortage and the increasing competition for water resources between agriculture and other sectors compel the adoption of irrigation strategies in semi arid regions which may allow saving irrigation water and still maintain satisfactory levels of production.

Sunflower is commonly regarded as a plant that is tolerant to drought and it uses water efficiently. Nevertheless, the crop consumes a large amount of total water due to the fact that it produces high yields and a large vegetative bulk. It also has a long growing period coinciding with the warm months of spring and summer.

Sunflower is capable of enduring drought but its yield will be lower in that case because the plants are forced to take up less available forms of water from the soil. Sunflower is the most susceptible to soil water deficiency at flowering; fertilization and grain fill, whereas at the start and end of the flowering period the sensitivity is not so evident.

Due to the advancement of sunflower in terms of cultivated area in semi-arid region, its growth, development and production have been studied by many researchers in many different soil types that make up this region. Alfisol in the semi arid region occupied approximately 107 thousand Km^2, which accounts for 89 % of Alfisol in Northeast Brazil region [5]. The information about such soil is limited and dispersed in some studies. Considering these factors, this study aims to investigate the biometry and the yield of sunflower, cv. Embrapa 122/V-2000, grown in an Alfisol with increasing nitrogen doses and levels of available water in soil.

MATERIALS AND METHODS

The study was carried out from March to June 2010 in a semi-controlled greenhouse condition of Agricultural Engineering Department of the Federal University of Campina Grande, Campina Grande, Paraiba, Brazil. Temperatures ranged from approximately 32°C during the day to 27°C during the night.

The treatments were arranged as a completely randomized design, in a 4 × 4 factorial experiment (four nitrogen levels and four available soil water levels), in triplicates, total of 48 experimental units. The nitrogen (N) levels in kg/ha were 0; 60; 80 and 100 which was added as urea; the available soil water (AW) levels were 55; 70; 85 and 100 %. Before the nitrogen addition, the soil was fertilized with 80 kg $P_2O_{5/ha}$ (triple superphosphate); 80 kg K_2O/ha (potassium chloride) and 2 kg B/ha (boric acid).

Each experimental unit consisted of a plastic vase filled with 32 kg of Alfisol with the following chemical characteristics [6]: pH (H_2O) = 5.3; Ca = 1.05 cmolc/kg; Mg = 3.15 cmolc/kg; Na = 0.52 cmolc/kg; K = 0.30 cmolc/kg; H + Al = 1.12 cmolc/kg; OM = 11.0 g/kg; P = 15.5 mg/kg.

Ten seeds of sunflower (cv. Embrapa 122 / V-2000) were sown in plastic vases; at 20 days after sowing (DAS) there was a thinning aiming to produce one plant per vase.

The soil water content along the experimental period was monitored daily through a segmented probe using Frequency Domain Reflectometry (FDR), which was inserted into the ground through a tube access installed in the vases with treatments, corresponds to 100% of available water (AW) in three depth ranges: 0-10, 10-20 and 20-30 cm. The data were compiled into spreadsheets according to the equation of the soil water retention curve into previously programmed mathematical functions to calculate the volume of replacement corresponds to 100% of AW and from then extrapolated to other treatments 55, 70 and 85% of AW. Irrigation was performed daily.

Stem height and diameter and leaf number and area were evaluated at 40 and 60 days after sowing (DAS). Leaf area was calculated according to methodology proposed by Maldaner *et al*. [7] using the formula: $LA = 0.1328 \times L^{2.5569}$, where L is the length of the central rib of each leaf of the plant. When the experiment was finalized, plants were harvested and measured parameters such as: head diameter (cm), percentage of viable achenes (%) and 1000 achenes weight (g).

Using SISVAR-ESAL [8] data were subjected to analysis of variance.

RESULTS AND DISCUSSION

Plant development usually responds to nitrogen fertilizer. However, nitrogen level applied in sunflower did not affect significantly the stem height and diameter at 40 and 60 DAS (Table 1). Similar results were reported by Killi [9] in evaluation of the effects of different nitrogen level (0 to 120 kg/ha) in the productivity of sunflower. Unlike the results observed in this experiment, Ali *et al*. [10] observed that the stem height gradually increased with increase of nitrogen rates.

The nitrogen supply is related to carbohydrate utilization, when N supplies are adequate and conditions are favorable for growth. However, when N supplies are insufficient, carbohydrates are deposited in vegetative cells causing them to thicken affecting plant growth. In this experiment, N supply was insufficient or the N content in the soil was already suitable for the development of plants.

The available soil water linearly increased the stem height and diameter of sunflower (cv. Embrapa 122 / V-2000) at 40 and 60 DAS (Figure 1). These results are in agreement with those findings reported by Tan *et al*. [11] who observed that irrigation applied significantly increased vegetative growth particularly plant height in sunflower. The stem diameter is a very important characteristic in sunflower allowing the plant occurs less lodging and facilitates its management, treatment and harvesting.

Nitrogen level applied in sunflower did not affect significantly the leaf number at 40 and 60 DAS, but at 40 DAS the leaf area significantly increased (Table 2). However, according to Nasim *et al.* [12], leaf area index gradually increased and achieved its maximum value at 60 DAS. Leaf area growth at 40 DAS was observed in the N-treated plants, probably because of the N applied was sufficient to correct the initial N deficiency in the soil or because of this period the leaves reached to the maximum growth.

Table 1: Analysis of variance for experimental growth traits

		Mean square			
		Stem height		Stem diameter	
Treatment	DF	40 DAS	60 DAS	40 DAS	60 DAS
Nitrogen levels (N)	3	0.234 ns	0.148 ns	0.0383 ns	0.0492 ns
Available soil water (AW)	3	3.030**	4.946**	0.4174**	0.5850**
Linear regression	1	8.552**	14.193**	1.224**	1.667**
N * AW	9	0.151 ns	0.190 ns	0.023 ns	0.0188 ns
Error	32	0.372	0.187	0.014	0.0149
C.V.	%	7.35	4.29	3.52	3.51

ns, * and ** ; Non significant and significant at 5 and 1 % levels of probability, respectively

Table 2: Analysis of variance for leaf number and leaf area

		Mean square			
		Leaf number		Leaf area	
Treatment	DF	40 DAS	60 DAS	40 DAS	60 DAS
Nitrogen levels (N)	3	0.0827 ns	0.2660 ns	182.30**	87.371 ns
Available soil water (AW)	3	0.6269**	0.1760ns	265.10**	255.025**
Linear regression	1	1.828**	-	759.08**	728.733**
N * AW	9	0.0923 ns	0.1115 ns	85.86 ns	72.929 ns
Error	32	0.0675	0.0691	38.74	36.522
C.V.	%	6.12	5.88	14.01	13.85

ns, * and ** ; Non significant and significant at the 5 and 1 %levels of probability, respectively

Table 3: Analysis of variance for experimental production traits

		Mean square			
Treatment	DF	Head diameter	Achenes number	% Achenes viable [1]	1000- Achenes weight
Nitrogen levels (N)	3	3.35^{ns}	100.97**	29.36**	0.45^{ns}
Linear regression	1	0.18^{ns}	14.11ns	22.59**	0.03^{ns}
Quadratic regression	1	9.67^{ns}	2.88**	32.66**	0.55^{ns}
Available soil water (AW)	3	19.62**	163.99**	75.97**	9.87**
Linear regression	1	58.65**	426.96**	159.69**	26.12**
N*AW	9	0.61^{ns}	25.30^{ns}	6.52**	0.51^{ns}
Error	32	1.14	11.36	0.47	0.78
C.V.	(%)	10.67	14.59	14.20	10.82

ns, * and ** ; Non significant and significant at the 5 and 1 % levels of probability, respectively; [1] the values of % achenes viable were transformed by the function arccosine v x.

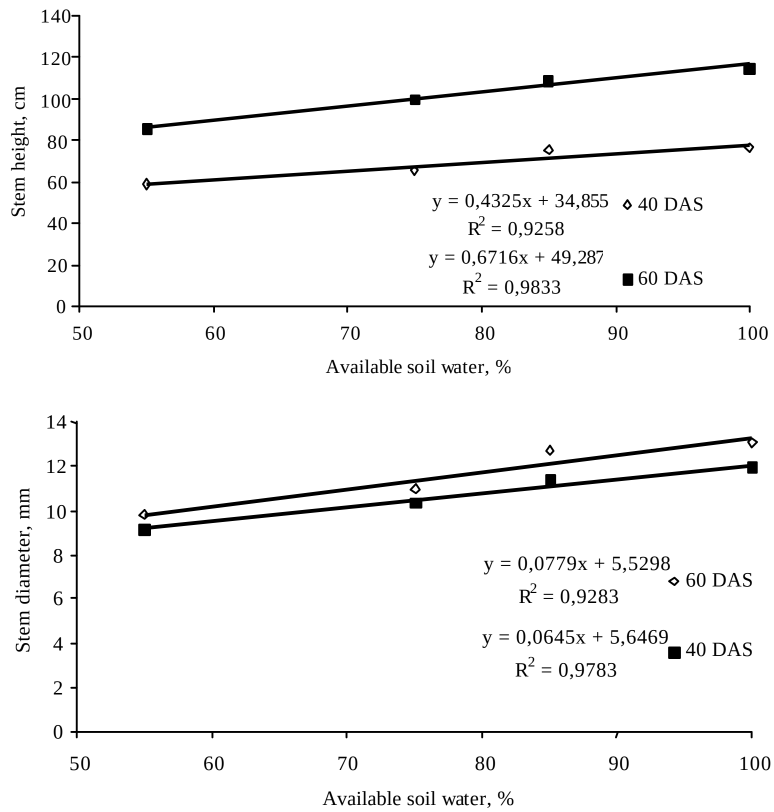

Fig. 1: Stem height and diameter of plants grown versus available soil water

The available soil water linearly increased with the leaf area at 40 and 60 DAS and the leaf number increased with available water only at 40 DAS. The effect of water is related to plant growth and consequently the development of the leaves number and leaf area as was reported by Pejiƒ *et al*. [13].

An increase in nitrogen levels led to no significant increase in production traits, except for achenes number and viable percentage which was significantly affected by N fertilization [3]. The improvement in the achenes viable may be accredited to more vegetative growth due to fertilizer. These head diameter, achenes number and viable percentage and dry weight of 1000 achenes were significantly affected by the available soil water. The results of the interaction between the factors N and AW were significantly affected only on achenes and number viable percentage and dry weight of 1000 achenes (Table 3).

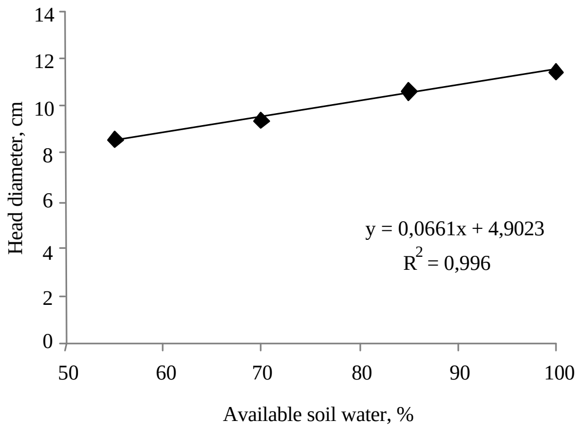

Fig. 2: Head diameter of plants grown versus available soil water

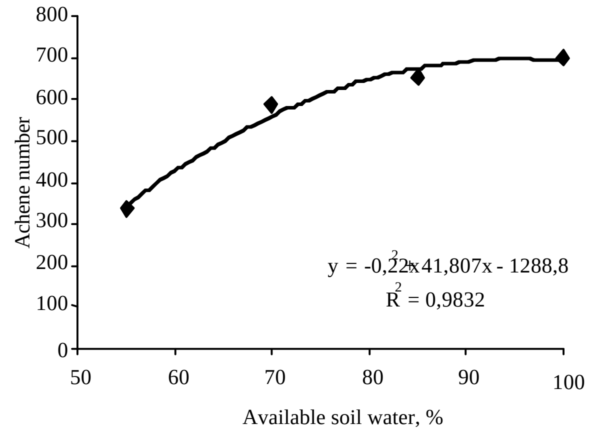

Fig. 3: Achene number of plants grown versus available soil water

The irrigation in semi-arid conditions can be supplementary in character, provided optimal soil moisture levels are secured for the period from flowering to pollination, which is the most sensitive stage of sunflower growth and development. Drought at flowering stage results in poor pollination and reduced number of florets in the central portion of the head, which leads to a decline in total seed weight per head and 1000-seed weight, bringing about major yield losses [13].

Despite nitrogen levels had no significant difference in the head diameter, the maximum and the minimum head diameters, produced with 100 kg N/ha and 0 kg N/ha, were 12.1 cm and 11.1 cm, respectively. The improvement in head diameter may be accredited to more vegetative growth due to fertilizer. These results confirm the findings by Nasim *et al*. [12] and Iqbal and Ashraf [14] that have also the evidence regarding positive effects of nitrogen on head diameter of sunflower crop.

The results of the head diameter influenced by the factor percentage of available soil water can be described by a linear regression equation (Figure 2). It was also observed that the results varied up to 3 cm when contrasted values in plants submitted to 55 and 100% of available water in the soil. Similar behavior was detected by Silva *et al.* [15], which studied the performance of sunflower cultivars subjected to different water level at State Ceara, Brazil. He has noted that cultivar EMBRAPA 122/V-2000 showed that linear behavior increased when it was subjected to increase levels of water. However, these researchers observed the values of head diameter on the order of 16.88 cm for the highest level of water replacement. These results are well above those found in the present work, which for 100% of available water were approximately 11.5 cm. This difference is related to the fact that plants grown in pots have more restrictions to root growth and nutrient absorption. Other researchers [3, 16, 17], in similar research also developed in the greenhouse, found values around 7.5 cm for the head diameter. These results were lower than those observed in this study.

The achene numbers per head is an important and efficient component in achene yield [12]. Embrapa 122 / V-2000 showed significantly mean high and minimum values of the achene numbers (659 and 391) with 60 and 80 kg N/ha, respectively. According to Nasim *et al*. [12], increasing N levels were significantly in achene number per head, i.e., 0 and 180 kg N/ha produced statistically mean minimum and as high as 573 and 887 achene, respectively.

In this study, achene number per head was significantly affected by drought stress, according to Soleimanzadeh *et al*. [18]. Increasing drought stress resulted in decrease achene numbers per head. Therefore, maximum and minimum achene numbers per head were 700 and 337 in 100 and 55 % of available soil water, respectively (Figure 3).

Nitrogen increases achenes yield by influencing the % achenes viable. This result is quite in line with the Abdel-Motagally and Osman [19] have found that the number of filled achenes increased with an increase in nitrogen application; that might be due to its important role during fertilization. Moreover, with N, the metabolites translation from source to sink might be increased resulted in more filled seeds [19].

Besides the effect of nitrogen on the % achenes viable, this parameter is related to time of application of boron in the soil; boron was applied to 28 DAS, i.e., too late. Due to the low mobility of boron in plants, there was

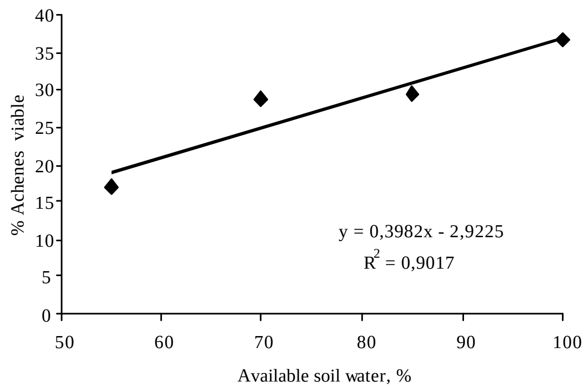

Fig. 4: Percentage achene viable of plants grown versus available soil water

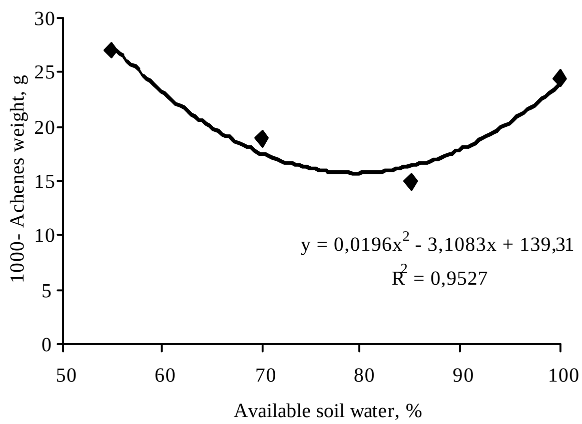

Fig. 5: Thousand achene weight of plants grown versus available soil water

not enough time for plants to take advantage this element. According to Souza *et al*. [20], sunflower boron requirement is high when compared with other crop species. However, its absorption from the soil is inefficient and can have lost 15 – 40 % when grown in soil with low boron content.

Likewise for other production traits, the available soil water had a significant effect on % achene viable (Table 3) as shown in Figure 4.

The average thousand achene weights is critical yield contributing factor, which take up an important role in representing the potential yield of sunflower. Despite the increase in % achenes viable of the sunflower as a function of N levels, the 1000- achenes weight did not vary significantly. On an average, heavier achenes were recorded from 100 % available soil water (83.16 g) which is statistically followed by 85 % available soil water (74.34 g) and minimum achene weight (49.02 g) was observed from 55 % available soil water (Figure 5).

A decrease in the thousand achene weight is due to a decline in water and nutrient absorption by plants and decrease assimilation an assimilate transport to grains. Banziger *et al*. [21] have demonstrated that delay in leaf aging and availability of foodstuff at grain filling period increase grain weight. Braz and Rossetto [22] have evaluated the thousand achene weight of cv Embrapa 122 / V-2000. They found that it averaged 53.66 g, a value lower than that found by Silva *et al*. [15] which was an average of 71.49 g with irrigation corresponding to 150% of crop evapotranspiration (533.7 mm). In present study, it is around 83 g to 100% of available water. In relation to nitrogen levels, the mean maximum and minimum 1000 achene weight (70.10 g and 62.81 g) was produced in N treatments of 100 and 0 kg N/ha, respectively. An increase in achene weight of sunflower in response to N fertilization has also been reported by Anwar-ul-Haq *et al*. [23] and Nasim *et al*. [12].

Generally, irrigation water increased seed yield per plant. The high seed yield per plant was attributed to desired head diameter, number of seed per head, high 1000-seed weight and less empty seeds.

CONCLUSIONS

The results of present research indicate that nitrogen had a significant effect only on leaf area at 40 DAS and % achenes viable. The effect of available soil water on sunflower cv. Embrapa 122/V-2000 biometry and the yield showed that there were significant differences, on average, in all growth traits (stem height and diameter) at 40 and 60 DAS, in leaf number at 40 DAS, in leaf area at 40 and 60 DAS and in all production traits. The biometry and yield response to available soil water of different crops is highly important in production planning. In this study, the enhanced biometry and yield response factor of sunflower was determined at 100 % of available soil water.

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