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Growth and biomass of sunflower under different nitrogen levels and available water in the soil of a semi-arid region

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Abstract

The adequate water supply and nitrogen in the soil is essential for the growth and development of plants. Sunflower is the target of several studies of such factors due to the economic importance and the needs to expand in the semi-arid regions of Brazil. This work aimed to evaluate the growth variables, measured at 80 days after sowing (DAS), and the biomass obtained at 100 DAS of the Helio 253 sunflower hybrid under the effect of nitrogen and water levels. The experiment was conducted in a greenhouse in the city of Campina Grande- PB, in split-plot of a completely randomized design with four moisture levels in the soil (50, 75, 100 and 125% of available water) and four nitrogen rates (30, 60, 90 and 120 kg ha^{-1}). Among all levels of available water in the soil, the stem diameter (SD) ranged from 13.6 to 19.6 mm and the plant height (PH) from 93 to 107 cm. Plants with 100% AW showed a leaf area (LA) 45% greater than the treatment with higher water stress. The heads had an average diameter between 83 and 98 mm, the dry biomass of the heads (DBC) and total dry biomass (TDB) ranged from 45 to 55 g and of 65 to 101 g, respectively. The weight of a thousand seeds per head (W1000) obtained minimum and maximum of 49 and 66 g. The stem diameter ranged between 14.4 to 18.3 mm and the minimum and maximum plant height values were 93 and 110 cm, using applied N levels. The leaf area varied from 22 to 36 dm^2 and the heads had average diameter of 86 to 99 mm. With respect to the dry biomass of the heads, there was a variation of 38 to 68 g and TDB of 68 to 107 g and W1000 valued between 52 and 65 g under doses of N. There is considerable variation in all variables mainly due to increased water level in the soil and nitrogen fertilization.

Keywords: *Helianthus annuus* L., irrigation, nitrogen fertilization.
Abbreviations: DAS_days after sowing; N_nitrogen; WRC_water retention capacity; ETo_reference evapotranspiration; AW_available water; SD_stem diameter; PH_plant height; LA_leaf area; CD_head diameter; DBC_dry biomass of the head; TDB_total dry biomass; W1000_thousand seed weight; ABA_abscisic acid.

Introduction

Sunflower is native to North America and currently is grown on every continent, as it has wide adaptability to different environmental conditions and its income is little influenced by latitude, altitude and photoperiod (Zobiole et al., 2010). In Brazil, sunflower is an option preferred as the second crop in the summer (off-season). There are many prospects of cultivation and growth of sunflower in the country. It is mainly due to the production of biofuels and also to serve as a noble edible oil in the market, confectionery, bird foods, silage, meal for animal feed, ornamental production, honey production, and the possibility of export of grain and oil (Person, 2013; Silva et al., 2014). The need to increase production to meet Brazil's domestic demand requires not only the expansion of the agricultural area, but also increase of the crop productivity, depends to several factors such as adequate mineral nutrition of plants and favorable water conditions (Oliveira et al., 2010).

In Brazil, there are problems that limit the productivity of sunflower such as the irregular distribution of rainfall during the year (Silva et al., 2015) and the lack of nutrients in the soils, mainly nitrogen (Faria et al., 2015). The sunflower accumulates large amounts of nutrients, in which the nitrogen (N) is the major one. However, its response to fertilization is limited (Jardini et al., 2014), due to its deep root system which increases the operating capacity and utilization of natural soil fertility and also the fertilizing of the previous crop, with absorption of nutrients from deeper layers (Santos et al., 2013a). Moreover, Santos Jr. et al. (2014) reported that N is the largest nutritional limiting factor on sunflower productivity and absence of N provides a reduction of up to 60% in the potential for sunflower production.

The maximum production of sunflower has been achieved with N rates between 80 to 90 kg ha^{-1}. However, with doses of N between 40 and 50 kg ha^{-1} it is possible to obtain 90 % of maximum relative production, which is equivalent to the amount of the nutrient economically efficient (Lobo et al., 2013). Santos et al. (2010) observed that the sunflower exported 71 % of N of the cumulative total. Santos et al. (2013b) reported that the excess of nitrogen is also harmful, as it causes excessive growth of sunflower, causing sensitive leaves, favorable for the incidence of pests and diseases. In turn, this affects production of grains, as well as problems with lodging and decrease in percentage of oil. Therefore, the amount of N to be applied needs to be determined for each type of soil, area and crop. The amount of water required for the crop is also not well-defined, but in the majority of the cases, 400 to 500 mm of the water evenly distributed throughout the cycle, result in yields close to the maximum potential (Silva et al., 2014). Despite the sunflower is commonly cultivated as a rained crop, it is not a tolerant plant to drought. However, it can be cultivated in soils with little moisture because usually the root system of this crop reaches the depth around two meters, which increases its water absorption. Dutra et al. (2012) evaluated the growth of sunflower plants in different water retention capacity (WRC) and observed that leaf area, number of leaves, the dry matter of the stem, root and leaf have lower values in 60 % of the WRC. Silva et al. (2012) found that the irrigation equivalent to 50% of ETo committed the morphology and sunflower biomass production.

The objective of this work was to evaluate the final growth and the biomass of the Helio 253 sunflower hybrid subjected to different levels of nitrogen fertilization and water in the soil.

Results and Discussion

Analysis of variance

The results of analysis of variance indicated that there was significant difference at 1% probability of error for the growth variables and production between treatments with irrigation and also for nitrogen doses. However, there was no interaction between these factors for any of the variables (Table 1).

Stem diameter

The stem diameter ranged from 13.6 to 19.5 mm to the level of 50 to 100% of available water in the soil, respectively (Fig. 1A), whereas the nitrogen fertilization promoted variation in the diameter of the rod between 14.4 to 18.3 mm with N doses equal to 30 and 120 kg ha^{-1}, respectively (Fig. 1B). These results are confirmed by Leite et al. (2005), which reported that cultivars reached on average from 10 to 80 mm of stem diameter. According to the authors, the sunflower should get high stem diameter at the end of the cycle to resist lodging and sustain production of heads with many achenes. Biscaro et al. (2008) also reported that increased stem diameter in sunflower are a feature considered desirable to facilitate the implementation of management and cultivation practices. These authors evaluated sunflower plants submitted to N doses and measured the maximum stem diameter of 18.4 mm, achieved with N dose equal to 47.8 kg ha^{-1}. However, the wide range of diameters may be associated with genetic and phenotypic characteristics. Smiderle et al. (2005) observed a significant difference between the stem diameters of different cultivars.

Nezami et al. (2008) reported that the reduction of the stem diameter due to reduced water availability in the soil is mainly due to growth of the main stem and suppression of side branches and; therefore a lower closed partition of dry matter in the stem. Taiz and Zeiger (2009) noted that the growth of the stem is influenced by the same principles that govern the restricted growth of leaves, before the drought.

Plant height

The plant height in irrigated treatments ranged from 93 (50% AW) to 107 cm (100% AW), with an average of 101 cm (Fig. 1C). In treatment whose level of water replacement in the soil was 100 % of available water, the plants showed greater height, while the curve adjustment tended to be higher in the treatment with 125 % of the AW. Freitas et al. (2012) also evaluated the sunflower under different levels of irrigation with well-watered and sewage, but observed linear effect of water favorable on plant height, with increments of 17 and 23% between the minimum and maximum limit of irrigation depth provided for well-watered and sewage, respectively. The lower growth of plants subjected to smaller water depths may be related to the production of abscisic acid (ABA), since this is considered a hormone that retards plant growth and increased in stressed plants by lack of water (Sharp, 2002). The ABA is signaled by the roots and causes a reduction in the rate of transpiration of the plant by stomatal closure, influencing nutrient absorption rate and consequently the physiology and morphology of plants under water stress (Taiz and Zeiger, 2009).

Regarding crop response to different levels of nitrogen fertilization, there was minimum and maximum plant height of 93 cm and 110 to the levels of 30 and 120 kg ha^{-1} N, respectively (Fig. 1D). This significant effect of nitrogen doses on plant height is consistent with the results obtained by Biscaro et al. (2008) that also observed similar response in sunflower height depending on the doses of N. However, Freitas et al. (2012) and Ribeiro et al. (2015) did not find significant effects of nitrogen fertilization on sunflower growth. Ivanoff et al. (2010), reported that application of N must be divided and provided as close to the stage of development, when plant needs or can use it. Zagonel and Mundstock (1991) described that the plant height is a reflection of the nutritional conditions during the stem elongation period. It has been verified that the application time was more important to stem elongation than the amount of nitrogen applied.

Leaf area

The plants with 100% AW showed leaf area 45% greater than the treatment with higher water stress and 11% more than treatment with moisture above the field capacity (125% AW). There was a quadratic culture with the increase in soil moisture (Fig. 1E). Dutra et al. (2012); however, measured higher leaf area when sunflower plants subjected to flooding, finding linear crop response with a water availability of the soil. Freitas et al. (2012) did not find reduction in the number of leaves with decreasing water availability. They suggested that reduction of leaf area may have been an adaptive defense strategy of the plant to tolerate drought.

Fageria (1989) reported that in drought stress conditions, most vegetables search for alternatives to reduce water consumption, especially reducing transpiration. Within adaptations, the leaf area reduction by decreasing the amount of leaves is widely-known. Taiz and Zeiger (2009) reported that the effects of water stress not only limit the size of individual leaves (cell growth), but also the number of leaves, as they decrease the growth rate of the branches. As the leaf expansion is as low as the production assimilated by photosynthesis, it reflects the production of biomass. The reduction of photosynthesis causes significant growth reduction as few metabolic are produced. Photosynthesis products are essential to nurture and ensure the perpetuation of the species, and not leaving sufficient quantities to be stored, reflected in the low plant growth (Ribeiro et al., 2015). The leaf area as a function of N doses also showed a quadratic fit, despite not having decrease in the adjustment curve, in which the values ranged from 22 to 36 dm^2 at doses of 30 and 120 kg ha^{-1} N, respectively (Fig. 1F). Fagundes et al. (2007) also showed that the increase of nitrogen fertilizer

Table 1. Summary of the analysis of variance for the growth variables at 80 days after sowing (DAS); stem diameter (SD), plant height (PH), leaf area (LA) and head diameter (CD); and variable production to 100 DAS: dry biomass of the head (DBC), the total dry biomass (TDB) and thousand seed weight (W1000) of the sunflower submitted to levels of available water in the soil and nitrogen doses.

Sources of variation	Test F						
	SD (mm)	PH (cm)	LA (dm^2)	CD (mm)	DBC (g)	TDB (g)	W1000 (g)
Blocks	ns	ns	ns	ns	ns	ns	ns
Available Water (AW)	**	**	**	**	**	**	**
Nitrogen (N)	**	**	**	**	**	**	**
Interaction (AW x N)	ns	ns	ns	ns	ns	ns	ns
CV (%)	6.3	7.3	16.8	8.4	8.9	12.5	15.1

CV - coefficient of variation; ns, * and **: not significant and significant at 5 and 1%, respectively.

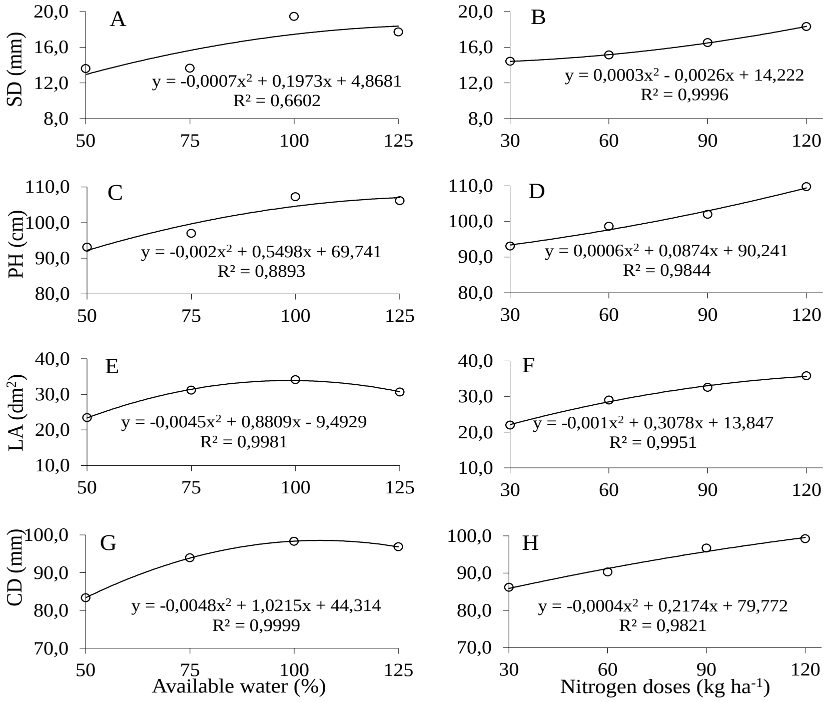

Fig 1. Data of stem diameter (SD), plant height (PH), leaf area (LA) and head diameter (CD) of sunflower at 80 days after sowing (DAS) at levels of available water in the soil and nitrogen doses.

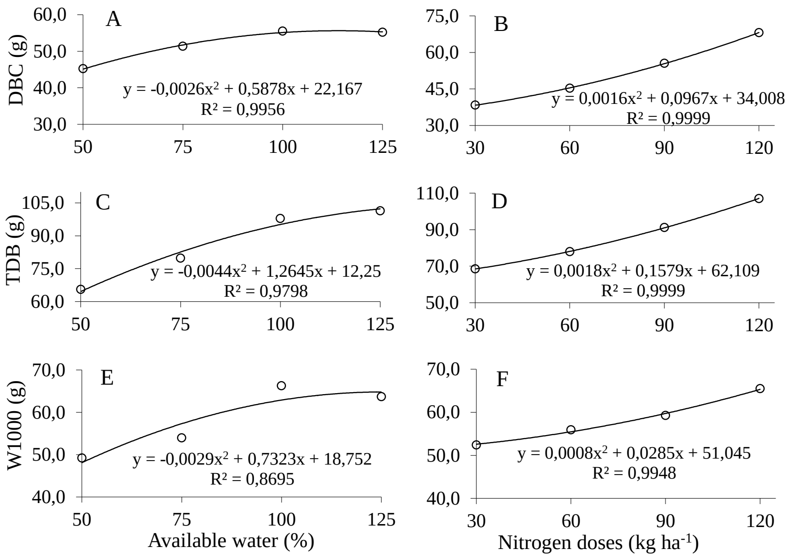

Fig 2. The dry biomass of the head (DBC), the total dry biomass (TDB) and thousand seed weight (W1000) at 100 days after sowing (DAS) in function of levels of available water in the soil and nitrogen doses.

provides a quadratic increase in sunflower leaf area. As Fernandez et al. (1994), the nitrogen not only affects the rate of expansion, but also cell division, determining the final size of the leaves and it is one of the determining factors of biomass accumulation rate.

Head diameter

The heads had an average diameter of between 83 and 98 mm in the treatments of 50 and 100% of available water, respectively, while the nitrogen afforded variation from 86 to 99 mm for doses of 30 and 120 kg ha^{-1}, respectively. These values were lower than those found by Freitas et al. (2012), which measured average diameter of 14.6 and 16 cm using well-water and sewage, respectively. Biscaro et al. (2008) also observed maximum diameter of the head equal to 11.9 cm with 44.9 kg N ha^{-1}. Freitas et al. (2012); however, measured the head diameter of 15 cm with 75 kg N ha^{-1}.

According to Zagonel and Mundstock (1991), the nitrogen acts in the critical stage of flower differentiation, which affects the amount of achenes for each head, and consequently the head diameter. Souza et al. (2010) reported that the head diameter is one of the most sensitive components of production to the presence of nitrogen. However, Biscaro et al. (2008) suggested that the good growth of head diameter does not need a high amount of nitrogen fertilizer, which may warrant finding a maximum point for the dose.

Dry and total biomass of the heads

The biomass of the heads (Fig. 2A) and total (Fig. 2C), produced by plants to different levels of water replacement, ranged from 45 to 55 g and from 65 to 101 g, respectively. Regarding the biomass produced according to the nitrogen fertilization, there is the change from 38 to 68 g (Fig. 2B) and a total of 68 to 107 g (Fig. 2D) for the lowest and highest dose of N, respectively. The adjustment of regression for biomass formation was increased with increasing N doses rather than water level, although the coefficient of determination in equation (R^2) have varied between 0.97 and 0.99, values considered very high as Cargnelutti Filho and Storck (2007).

Weight of thousand seeds per head

The weight of a thousand seeds per head showed quadratic fit with water levels, with minimum and maximum of 49 and 66 g for the treatments with 50 and 100% of available water in the soil, respectively (Fig. 2E). For the nitrogen, there was a higher adjustment regression with values observed between 52 and 65 g for the N doses equal to 30 and 120 kg ha^{-1}, respectively (Fig. 2F). The reduction of total dry biomass and heads to increased water and N doses can theoretically be a reflection of the values observed especially for leaf area and plant height in response to decreased photosynthesis. It leads to the conclusion that exposure to the tested levels cause low production of achenes and make production in areas with low water availability and N unfeasible or uneconomical (Andrade and Abreu, 2007; Ribeiro et al., 2015).

Silva et al. (2012) observed that the sunflower biomass is significantly affected when the water deficit occurs in different phenological phases. Therefore, the appropriate water supply in the vegetative phase is essential to promote vigorous growth of the plants and, consequently, high biomass production.

Materials and Methods

Characterizationof area

The experiment was conducted from March 10 to June 10, 2012 in a greenhouse, in the Academic Unit of Agricultural Engineering (UAEAg) of the Federal University of Campina Grande (UFCG) in Campina Grande- PB. The region climate, according to Köppen climate classification, is the type Csa, mesothermal, sub humid, with periods hot and dry (4 to 5 months) and rainy from autumn to winter. The average annual precipitation in the region is 804 mm (Macedo et al., 2011).

Treatments

The design was split-plots in completely randomized with the treatments consisted of four levels of moisture in the soil (50, 75, 100 and 125 % of available water) and four nitrogen doses (30, 60, 90 and 120 kg ha^{-1}). Each experimental unit consisted of a plastic vase with volumetric capacity of 30 L, with 20 kg of soil to grow a sunflower plant until 100 days after sowing. The soil used (Entisol Eutrophic of sandy loam texture) was collected in São José da Mata -PB in the surface layer 0-20 cm.

Plants materials

The cultivar studied was the hybrid Helio 253, which stands out for precocity (average growing cycle of 100 days). The sowing was done manually by placing seven seeds per hole. The thinning was performed 10 days after sowing (DAS) leaving three plants per pot, and 20 DAS is only one plant per pot. The soil was fertilized as recommended by Novais et al. (1991). The nitrogen was applied to cover in the form of urea, 40 % at planting, 40 % to 20 DAS and the rest at 30 DAS. The daily handling of irrigation was performed with the aid of sprinklers and graduated cylinder, wherein the water requirements of the culture were determined by the water balance in the soil by weighing vessels method. Before planting, the soil was irrigated bringing the water content to field capacity to promote seed germination.

Traits measured

The growth variables (stem diameter, leaf area, plant height and head diameter) were measured at 80 DAS. At 100 DAS, the production variables (total dry biomass, heads and thousand seeds weight) were obtained. The plant height was measured from the plant neck to the base of the youngest leaf and the stem diameter measurement was performed with a caliper, with the readings being made in the cervical region of each plant. The measurement of the sunflower head diameter was held with the aid of a graduated ruler at harvest. The calculation of the leaf area (LA) calculated according to Maldaner et al. (2009), whose formula is $AF = 0.1328 \times C^{2,5569}$, wherein 'C' is the length of the leaf midrib, and the total sum of the areas per leaves provides the value of the total leaf area of the plant. The dry biomass was obtained after drying the material circulating air oven at 60 °C until constant weight and then weighed on precision balance.

Statistical analysis

The growth variables and yield per plant were subjected to analysis of variance by test F ($p \leq 0.05$) and when significant, the regression studies to water levels and nitrogen fertilization were performed.

Conclusion

The nitrogen fertilization and available water in the soil increased all growth variables and sunflower biomass. With the increasing levels of treatments the growth variables enhanced. The smaller performances were obtained in the treatments with 50% of available water and 30 kg ha^{-1} N, while the best performances were obtained at 100 % of available water and 120 kg ha^{-1} N. However, there was no interaction between these factors according to the statistical analysis.

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