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# Production of Sunflower and Biomass Depending on Available Soil Water and Nitrogen Levels

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**Abstract:** In order to study the effects of nitrogen and available soil water levels on growth and yield components of sunflower (cv. Embrapa 122 / V-2000), an experiment was carried out from November 2009 to October 2010 in the Agricultural Engineering Department of the Federal University of Campina Grande, Campina Grande, Paraiba, Brazil. The treatments were arranged as a completely randomized design, in a 4×4 factorial experiment (four nitrogen levels and four available soil water levels), with three replications, totaling 48 experimental units. The nitrogen (N) levels in kg ha$^{-1}$ were: 0; 60; 80 and 100 added as urea; the available soil water (AW) levels were 55; 70; 85 and 100%. In conclusion, this study showed that the application of nitrogen fertilizer levels and available soil water levels led to significant increase in growth and production traits except for the dry weight of 1000 seeds.

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

## INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most important oil crops and its oil can be used for food and bioenergy. High content of unsaturated fatty acids, vitamin E content and lack of cholesterol in sunflower oil improves the quality of food. Several researchers have already demonstrated its use as an alternative energy source. Sunflower is an option for the production of good quality forage, as it features a high yield of silage per hectare as second crop, with low risk of failure because of its tolerance to drought and cold [1].

Since the state of Paraiba, Brazil, is located in a semi arid region and has limited rainfall or shortage of water for irrigation during the growing season, this can remarkably affect the development of the planting area and its yield increased due to reductions of growth, yield, as well as adaptation of the sunflower; especially in relation to drought stress. However, in certain tolerant-adaptable crop plants, such as sunflower, morphological and metabolic changes occur in response to drought. Nezami *et al*. [2] indicated that sunflower plant height, biological yield, stem diameter, head size, seed number per head and 1000-grain weight under dry and semi-dry conditions declined. Similarly, Soleimanzadeh *et al*. [3] showed that drought stress induced significant decrease in plant height, head diameter, seed number per head, 1000-grain weight, biological yield, grain yield, harvest index and oil yield. However, according to Abdel-Motagally and Osman [4], sunflower, tolerant to short periods of drought, is an important crop in semi-arid area with limited irrigation because this culture is adapted to a wide range of climate conditions.

Nitrogen is an essential element and important determinant of plant growth and development. Metabolic processes leading to increases in vegetative and reproductive growth and yield are totally dependent upon the adequate supply of nitrogen. The sensitivity of plant growth to nitrogen fertilization is of great importance in agriculture. Nitrogen is the second most required nutrient for the culture of sunflower; this is the element that most limits the production, providing up to 60% reduction in productivity as a result of its disability. Nitrogen deprivation reduces, for instance, leaf production,

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individual leaf area and total leaf area. On the other hand, an increase in nitrogen availability results in higher leaf nitrogen content. According to Cechin and Fumis [5], high nitrogen supply had a significant stimulatory effect on shoot dry matter production and photosynthetic activity of sunflower plants. Moreover, the higher rates of photosynthesis were accompanied by an increase in leaf dry matter, thus increasing the total assimilatory area.

However, studies related to the management especially those regarding nitrogen fertilization and water replacement, are necessary for a systematic expansion of cultivated areas in northeastern Brazil. Therefore, the aim of this experiment was to evaluate the growth and yield components of sunflower when grown under different levels of available water in soil and nitrogen fertilization.

## MATERIALS AND METHODS

The study was carried out from November 2009 to October 2010 in a semi-controlled greenhouse condition of the 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), with three replications, totaling 48 experimental units. Each experimental unit consisted of a plastic vase filled with 32 kg of Distrophic Argisol with the following physical and chemical characteristics [6]: sand = 841.5 g $kg^{-1}$; silt = 87.5 g $kg^{-1}$; clay = 71.0 g $kg^{-1}$; pH ($H_2O$) = 6.6; Ca = 1.85 cmolc $kg^{-1}$; Mg = 2.23 cmolc $kg^{-1}$; Na = 0.06 cmolc $kg^{-1}$; K = 0.28 cmolc $kg^{-1}$; H + Al = 0.79 cmolc $kg^{-1}$; OM = 8.4 g $kg^{-1}$; P = 28.5 mg $kg^{-1}$.

The nitrogen (N) levels in kg $ha^{-1}$ were: 0; 60; 80 and 100 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 $P_2O_5$ $ha^{-1}$ (triple superphosphate); 80 kg $K_2O$ $ha^{-1}$ (potassium chloride) and 2 kg B $ha^{-1}$ (boric acid).

Ten seeds of sunflower (cv. Embrapa 122 / V-2000) were sown in plastic vases; 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 corresponding 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 corresponding to 100% of AW and from then extrapolated to other treatments 55, 70 and 85% of AW. Irrigation was performed daily.

When the experiment was finalized, the plants were collected and separated into leaves and stems and oven-dried at 65°C for 96 hours to a constant weight. The following parameters were measured: head diameter (cm); number of seeds; percentage of viable seeds (%); 1000-seeds weight (g). Using SISVAR-ESAL [7], the data were subjected to analysis of variance.

## RESULTS AND DISCUSSION

An increase in nitrogen levels led to significant increase in growth traits, i.e., stem, leaves and head fresh and dry matter were significantly affected by nitrogen levels. Stem fresh matter and stem, head dry matter and leaves were significantly affected by the available soil water. The results of the interaction between the factors N and AW were not significantly affected (Table 1).

Table 1: Analysis of variance for experimental growth traits

| | | Mean square | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fresh matter | | | Dry matter | | |
| Treatment | DF | Stem | Leaves | Head | Stem | Leaves | Head |
| Nitrogen levels (N) | 3 | 17.66** | 9.37** | 13.47* | 2.34** | 2.59** | 2.28** |
| Linear regression | 1 | 39.15** | 27.98** | 15.99** | 5.69** | 7.38** | 5.32** |
| Quadratic regression | 1 | 13.55** | 0.14$^{ns}$ | 18.79** | 1.25** | 0.35$^{ns}$ | 0.79* |
| Available soil water (AW) | 3 | 10.56** | 1.20$^{ns}$ | 10.53$^{ns}$ | 2.06** | 0.44** | 1.20** |
| Linear regression | 1 | 29.98** | 2.10$^{ns}$ | 24.08$^{ns}$ | 6.11** | 1.16** | 3.56** |
| Quadratic regression | 1 | 17.85** | 32.01$^{ns}$ | 79.72$^{ns}$ | 0.06* | 0.60$^{ns}$ | 0.05$^{ns}$ |
| N*AW | 9 | 0.98$^{ns}$ | 1.07$^{ns}$ | 5.34$^{ns}$ | 0.13$^{ns}$ | 0.17$^{ns}$ | 0.29$^{ns}$ |
| Error | 32 | 121.53 | 67.17 | 3.39 | 0.13 | 0.12 | 0.21 |
| C.V. | % | 16.51 | 25.82 | 33.43 | 11.90 | 13.41 | 15.81 |

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

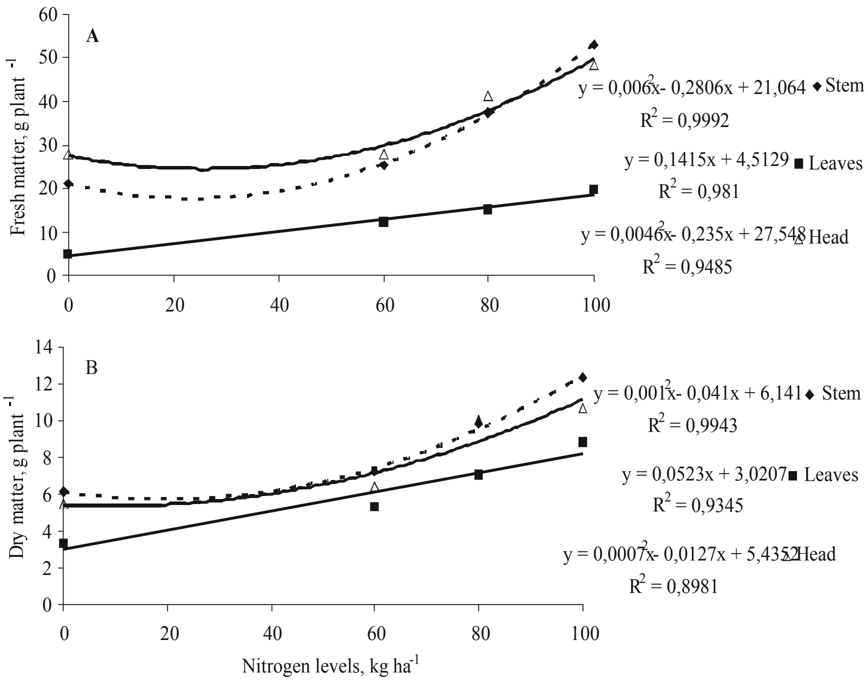


Fig. 1: Stem, leaves and head fresh and dry matter of plants grown versus nitrogen supply.

A polynomial relationship between nitrogen and fresh weight of stem represents the contribution of N fertilizer on fresh matter of stem (Figure 1A). A similar relationship was observed with available soil water in the fresh weight stem (Figure 2A).

An increase from 0 to 100 kg ha$^{-1}$ of nitrogen fertilization and from 55 to 100% of available soil water led to an increase of 165 and 125% of fresh weight of stem, respectively. The sensitivity of plant growth to available soil water has been demonstrated in many studies. Santos *et al.* [8] in his experiment on sunflower also came to similar results.

Nitrogen is an essential element and important determinant of leaf growth and development. Therefore, the fresh weight of leaves showed increases of approximately 300% between the levels from 0 to 100 kg ha$^{-1}$ of nitrogen fertilization. In this case, the relationship between N levels and fresh weight of leaves was described by a linear equation (Figure 1).

The head fresh matter was significantly affected by nitrogen fertilizing; increasing N levels from 0 to 100 kg ha$^{-1}$ resulted in additions around 85% of the head fresh matter (Figure 1A).

In general, the increase in fresh biomass as a function of increased nitrogen fertilizing is important, since it is used for animal feeding and for the production of sunflower silage.

The dry weight of stem was significantly affected by the amount of nitrogen fertilizer (Figure 1B) and available soil water (Figure 2B). Increasing nitrogen fertilization from 0 to 100 kg ha$^{-1}$ and available soil water from 55 to 100% resulted in an increase of about 117 and 100% in stem dry weight, respectively.

The large difference in leaf dry matter between low and high N-grown plants is a result of the effect of nitrogen on final leaf production per plant and in individual leaf dry mass. The dry weight of leaves showed increases of 200% from the levels of 0 to 100 kg ha$^{-1}$ of nitrogen fertilization (Figure 1B); however, increasing the levels of available soil water from 55 to 100% raised leaf dry weight approximately 40% (Figure 2B). According to Trapáni *et al*. [9] the leaf size is very responsive to nitrogen supply. The leaf size is largely a result of cell production and cell expansion. However, Roggatz *et al*. [10] demonstrated that the effect of nitrogen deficiency depends on the developmental status of the leaf when nitrogen stress is imposed. Deprivation of nitrogen in the earlier stages of leaf development, when cell division still taking place resulted in greater reduction in final leaf size and consequently, reduction of dry weight of leaves [5].

Head dry matter showed expressive results from the dose of 80 kg N ha$^{-1}$, however, raising N levels from 0 to 100 kg ha$^{-1}$ resulted in additions around 100% of head dry

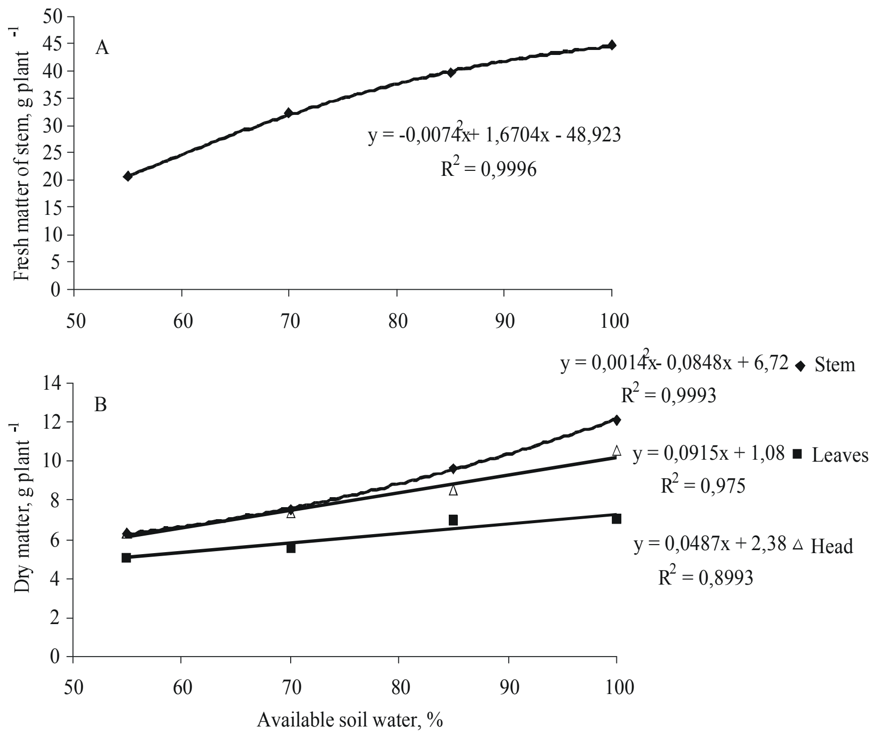


Fig. 2: Stem, leaves and head fresh and dry matter of plants grown versus available soil water

matter (Figure 1B). Increasing available soil water from 55 to 100% resulted in approximately 43% of head dry matter (Figure 2B).

In general, an increase in the quantity of nitrogen favored the growth of sunflower plants. According to Malavolta *et al.* [11], nitrogen deficiency is associated with reduced production of chlorophyll, causing changes in chloroplasts. Other researches reported that the great importance of nitrogen is not only for growth but also for cell division.

The data presented in Table 2 indicate that the variables which influence seed yield, except for the dry weight of 1000 seeds, were significantly affected by N fertilization and available soil water. The interaction between these factors was significant only on seed viable percentage.

Significant difference in terms of head diameter could be noticed due to the variations in N level and available soil water level. Increasing N fertilizer and available soil water level resulted in increased head diameter. A polynomial relationship between head diameter and N fertilizer represents the contribution of N to head diameter, the variation of N fertilizer from 0 to 100 kg N $ha^{-1}$ resulted in variation of about 4 cm in head diameter (Figure 3A). Ivanoff *et al.* [12] reported that adequate nitrogen fertilizing can provide increments of 16% in the head diameter. Fatih Killi [13] and Abdel-Motagally and Osman [4] concluded that increasing N levels resulted in increased head diameter. According to these authors, the increase in head diameter may be due to the ability of the plant to increase their photosynthetic metabolites on account of nitrogen fertilization. Biscaro *et al.* [14] observed that the N application resulted in a quadratic effect with increase in head diameter, the maximum level of 44.9 kg N $ha^{-1}$, resulted in a head diameter of 11.9 cm. This higher value, compared with the present paper (Figure 3A) is probably due to different cultivars of sunflower, i.e., H 358.

The linear relationship between head diameter and available soil water level has shown a variation of about 2.5 cm, from 55 to 100% of available soil water (Figure 4A) according to Silva *et al.* [15]. Also, Razi and Asad [16] and Soleimanzadeh *et al*. [3] demonstrated that irrigation resulted in greater head diameter. The lowest available soil water levels reduced plant growth due to the low assimilation of products of photosynthesis and, consequently, reduced the head diameter.

The seed number is an important and efficient component in yield. Referring to Soleimanzadeh *et al*. [3], the potential number of flowers which is determined during the plant growth period causes changes in seed number per head. In this study, seed number per head was

Table 2: Analysis of variance for experimental production traits

| | | Mean square | | | |
|---|---|---|---|---|---|
| Treatment | DF | Head diameter | Seed number | % Seed viable | 1000-seed weight |
| Nitrogen levels (N) | 3 | 0.94** | 260.27** | 0.44** | 1.87$^{ns}$ |
| Linear regression | 1 | 2.29** | 698.72** | 0.53** | 0.46$^{ns}$ |
| Quadratic regression | 1 | 0.33* | 55.19* | 0.11** | 1.58$^{ns}$ |
| Available soil water (AW) | 3 | 0.42** | 106.73** | 1.99** | 2.07$^{ns}$ |
| Linear regression | 1 | 1.21** | 222.32* | 0.70** | 3.56$^{ns}$ |
| Quadratic regression | 1 | 0.02 $^{ns}$ | 77.63** | 0.40** | 1.67 $^{ns}$ |
| N*AW | 9 | 0.08$^{ns}$ | 41.44$^{ns}$ | 0.17** | 4.25$^{ns}$ |
| Error | 32 | 0.06 | 9.73 | 0.02 | 0.83 |
| C.V. | (%) | 8.68 | 31.85 | 8.81 | 19.58 |

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

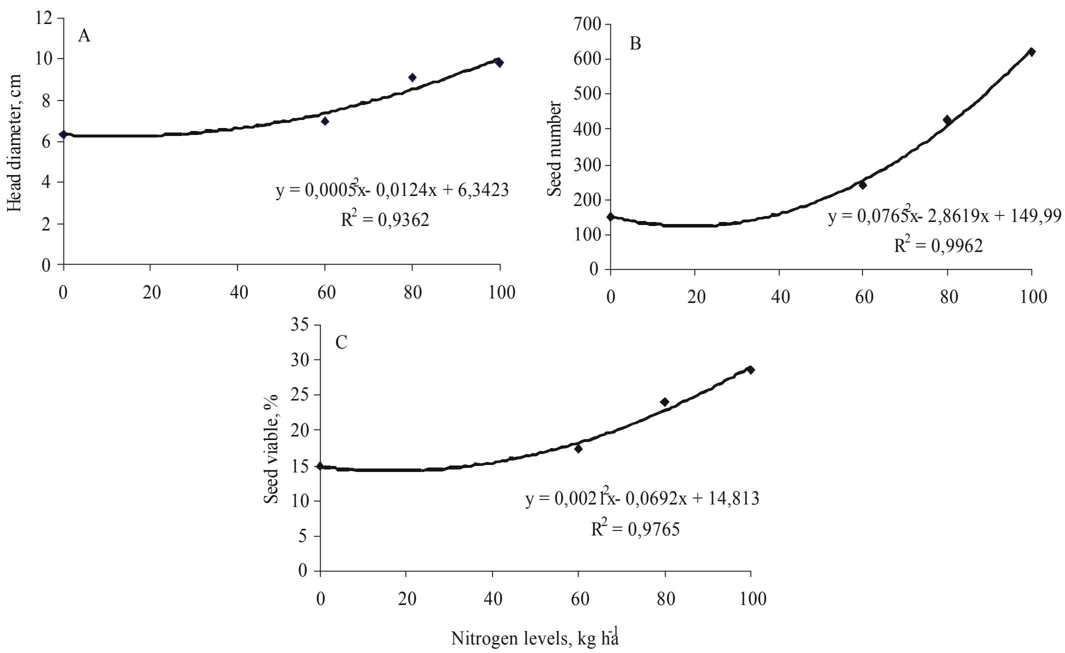


Fig. 3: Head diameter, seed number and seed viable of plants grown versus nitrogen supply

significantly affected by N fertilization and available soil water treatments (Table 2). Increasing N levels from 60 to 100 kg ha$^{-1}$ resulted in additions above 200% of the produced seed number (Figure 3B). This was probably influenced by the increased nutrient availability and then a reflection of head diameter. However, the levels of available water presented different results only for the 100% AW level (Figure 4B). Biscaro *et al*. [14] studying N fertilization in irrigated sunflower also came to similar results. Ghani *et al*. [17], Fatih [13] and Abdel-Motagally and Osman [4] reported that N treatments significantly increased seed number per head. Increased N application significantly increased seed yield of rapeseed [18], one of the oil seed crops like sunflower plant. Similarly, increasing N increased the seeds of pinto bean [19] and grains of maize yield [20].

The percentage of viable seed was significantly affected by N fertilization, available soil water and interaction between these factors (p <0.01). Increasing N levels from 60 to 100 kg ha$^{-1}$ resulted in additions around 65% of the produced viable seed (Figure 3C). However, increasing the levels of available soil water from 55 to 100% prompted an increase of approximately 100% of viable seeds, influencing seed quality (Figure 4C). Besides the influence of nitrogen, several factors affect head development, determining the potential number of flowers and, therefore, the number of viable seeds. These factors are sowing time, crop management, plant density, different crops, nitrogen rates and frequency of pollinators [15].

Despite the increase in head diameter and seed number of the sunflower as a function of N levels, the 1000-seed weight did not vary significantly.

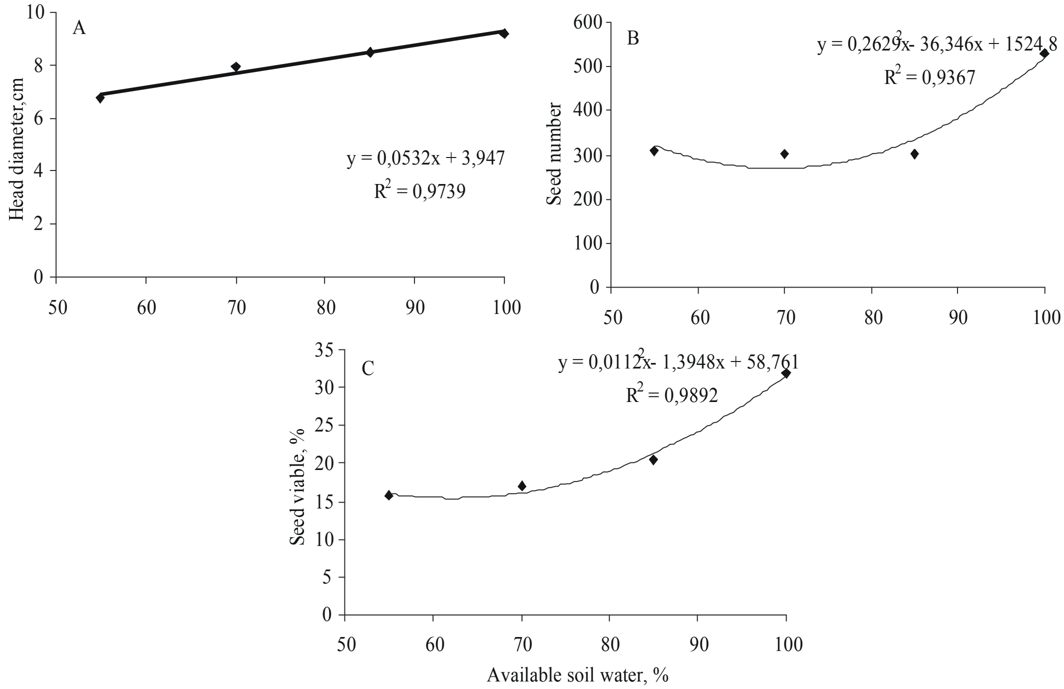


Fig. 4: Head diameter, seed number and seed viability of plants grown versus available soil water

In general, plants produced around 21 to 62 grams of 1000-seeds weight as a function of increasing levels of nitrogen and available soil water. These results are in harmony with those obtained by Abdel-Motagally and Osman [4], Soleimanzadeh *et al*. [3] and Castro *et al.* [22]. These last authors showed that seed yield was around 27.4 to 49.94 grams depending on the N levels (0 to 90 kg $ha^{-1}$). According to Biscaro *et al*. [14], increasing N levels resulted in increased average weight of seeds, with maximum level of 44.9 kg N $ha^{-1}$, the maximum weight of 7.19 g was reached for the mass of 100 seeds. The seeds weight is the result of capacity plant to supply nutrients to the potential limit established for each cultivar.

Probably, the N fertilizer and available soil water level used were not sufficient to transport the non-building carbohydrate stored in the stems to grains after flowering.

## CONCLUSIONS

In summary, it is concluded that nitrogen application and available soil water levels affected the growth and yield of sunflower except for the dry weight of 1000 seeds. The crop had a high requirement for N fertilizer and soil water and 100 kg N $ha^{-1}$ and 100 % of available soil water produced highest growth and production traits. Thus, providing sufficient nitrogen and soil water application are important to produce higher sunflower yield in semi-arid region, Paraiba State, Brazil.

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