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Biometry and Water Consumption of Sunflower as Affected by NPK Fertilizer and Available Soil Water Content under Semiarid Brazilian Conditions

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Abstract

The present study evaluated the effect of NPK fertilization and available soil water levels on the biometric response and water use of sunflower cv. Embrapa 122-V2000. The experiment was conducted at the Agricultural Engineering Department of the Federal University of Campina Grande, Paraiba State, Brazil, during 2009 and 2010, in a semi-controlled greenhouse using the Eutrofic Regosol. The treatments were defined according to a Baconian matrix, with eleven doses of the nitrogen, phosphorus and potassium and four available soil water levels. The experiment was arranged in a complete randomized design, with three replicates, in a total of 132 sample units. No effect of N and K was observed on plant height. However, it increased significantly with P levels. The stem diameter and the leaf area were affected by the N and K and not by the P. The number of leaves increased significantly with the amount of N, P and K fertilizer. Available soil water content increased significantly in all the variables studied. The best sunflower performance and water consumption were obtained with the 100:120:120 kg·ha^{-1} NPK and 100% of the available soil water content treatment.

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Keywords

***Helianthus annuus* L., Mineral Nutrition, Water Management**

1. Introduction

Sunflower (*Helianthus annuus* L.) occupies a prominent place among oilseed crops as it contributes about 12% of the world edible oil production. Water and fertilizers application plays an important role in improving seed yield and oil quality of sunflower [1].

Nitrogen is an essential element and important determinant of plant growth and development. It is the second most required nutrient for the culture of sunflower. Metabolic processes leading to increases in vegetative and reproductive growth and yield are totally dependent upon the adequate supply of nitrogen.

Potassium is a nutrient that positively affects achenes production within sunflower crop (*Helianthus annuus* L.) and its proper management is indispensable for better economical employment of this element and for a less environmental impact.

The low soil available phosphorus content is one of the main limitations to the development of sunflower considering that influences the photosynthesis, respiration, storage and energy transfer, cell division, cell growth and several other processes in the plant. When there is no limitation of phosphorus, its uptake occurs until grain filling. The contribution of phosphorus remobilized from leaves and stems to the seeds in maturation varies from approximately 30% to 60%.

Application of NPK fertilizers increases sunflower growth and yield substantially [2]-[4]. However, application of nitrogenous, phosphoric and potassic fertilizer above or below the optimum level can adversely affect it [5] [6]. In sunflower crop, its deficiency causes nutritional disorder, being the nitrogen that most limits the yield, providing up to 60% of reduction in productivity as a result of their disability.

Sunflower is commonly regarded as a plant tolerant to drought that uses water efficiently. However, the crop consumes a large amount of water due to the fact that it produces high yields, a large vegetative bulk and it has a long growing period coinciding with the warm months of spring and summer. Thus, water stress on sunflower reduces plant height, root length and stomata number [7] [8] and causes early flowering, early maturity and seed yield reduction [9]. Drought adversely influenced leaf area, days to maturity, leaf diameter, 100-achene weight and achene yield per plant [10].

The present research aimed to investigate the biometry and water use of sunflower as affected by NPK fertilization treatments and irrigation regimes under semiarid Brazilian conditions.

2. Materials and Methods

The study was carried out from November 2009 to October 2010 at the Agricultural Engineering Department of the Federal University of Campina Grande, Campina Grande, Paraíba, Brazil. Temperatures ranged from approximately 32˚C during the day to 27˚C during the night.

The sunflower cultivar used was the Embrapa 122-V2000. It grown under semi controlled greenhouse conditions with 11 treatments on a completely randomized design generated by the Baconiana Matrix (**Table 1**) with four doses of N (0, 60, 80 and 100 kg·ha^{-1}), four of P_2O_5 (0, 80, 100 and 120 kg·ha^{-1}), four of K_2O (0, 80, 100 and 120 kg·ha^{-1}), five available soil water (ASW) levels (55%, 70%, 85% and 100%) and three replicates originating 132 experimental units. Urea was used as a source of N; triple super phosphate as P and potassium chloride as of K. All the treatments received 2 kg·B·ha^{-1} as boric acid.

Each experimental unit consisted of a plastic pot filled with 32 kg of an Eutrofic Regosol with the following attributes: sand = 841.50 g·kg^{-1}; silt = 87.50 g·kg^{-1}; clay = 71.0 g·kg^{-1}; pH (H_2O) = 6.6; Ca^{2+} = 1.85 cmol$_c$·kg^{-1}; Mg^{2+} = 2.23 cmol$_c$·kg^{-1}; Na = 0.06 cmol$_c$·kg^{-1}; K^+ = 0.28 cmol$_c$·kg^{-1}; H^+ + Al^{3+} = 0.79 cmol$_c$·kg^{-1}; organic matter = 8.4 g·kg^{-1}; P = 28.5 mg·kg^{-1}. The analyses procedures used were those recommended by [11].

Soil water content was monitored daily at three depth intervals: 0 - 10, 10 - 20 and 20 - 30 cm, through a Frequency Domain Reflectometry segmented probe, inserted into the ground through an access tube installed in the pots with 100% of available soil water (ASW). With the use of the soil water retention curve the volume of water replacement corresponding to 100% of ASW was calculated and extrapolated to the other treatments: 55%,

Table 1. Nitrogen (N), phosphorus (P_2O_5), potassium (K_2O) and available soil water levels generated by the Baconian matrix.

Treatments	N ($kg·ha^{-1}$)	P_2O_5 ($kg·ha^{-1}$)	K_2O ($kg·ha^{-1}$)	Available soil water* (%)			
1	0	0	0	55	70	85	100
2	0	80	80	55	70	85	100
3	80	80	80	55	70	85	100
4	100	80	80	55	70	85	100
5	60	0	80	55	70	85	100
6	60	100	80	55	70	85	100
7	60	120	80	55	70	85	100
8	60	80	0	55	70	85	100
9**	60	80	80	55	70	85	100
10	60	80	100	55	70	85	100
11	60	80	120	55	70	85	100

*Each treatment of fertilization was tested on the four levels of available soil water. **Reference level used by the sunflower growers at the State of Rio Grande do Norte, Brazil.

70% and 85% of ASW. Irrigation was performed daily.

Twenty days after sown a thinning was conducted leaving one plant per pot.

The variables evaluated were plant height, stem diameter, number of leaves and leaf area at 40 and 60 days after the sowing (DAS). The results were analyzed statistically through the analyses of variance (ANOVA) described by [12], using the SAEG software [13].

3. Results and Discussion

No effect of N and K was observed on plant height (PH). However, it increased significantly, in a linear shape, with P_2O_5 levels (**Figure 1(a)** and **Figure 1(b)**) and available soil water, ASW (**Figure 1(c)**) at 40 and 60 DAS. The maximum plant height at 40 and 60 DAS (81.87 and 110.47 cm, respectively) were observed for the plants fertilized with 120 $kg·ha^{-1}$ P_2O_5.

Increasing the ASW in the soil from 55% to 100% produced a plant height increment of 22.34% and 19.00% at 40 and 60 DAS, respectively. Aziz and Soomro [7] showed that all growth and yield components (plant height, days to maturity, head diameter, seed yield and oil content) of sunflower were significantly affected by different irrigation frequencies. The results are in agree with those obtained by [14] who found that phosphorus addition, in general, result in significant height growth of sunflower. Similar findings were also reported by [15] and [6].

The stem diameter was afected by the N and K and not by the P. It increased significantly with nitrogen levels at 40 and 60 DAS (**Figure 2(a)**) and by potassium at 60 DAS (**Figure 2(b)**). The increase of diameter with the nitrogen resulted in a superiority of 19.7% for the highest dose of nitrogen (100 $kg·ha^{-1}$) compared to the control. At 60 DAS it was detected a linear fit with increasing N rates, providing with 100 $kg·ha^{-1}$ of N an stem diameter 29.05% superior when compared to control. Abbadi *et al.* [16], using nitrogen fertilizer in cultivation of sunflower in pots, found that stem diameter was greater in the fertilizer treatments compared to control. Ayub *et al.* [17] found no significant interference of different sources and doses of potassium in stem diameter different. This difference in response may be due to differences in the genetic characteristics of the cultures used by the researchers.

Similarly to that observed for plant height, available water affected estatistically the stem diameter growth at 40 and 60 DAS, resulting in higher values with the treatment of 100% available soil water (**Figure 2(c)**). Other studies have also found a reduction of stem diameter in response to water deficit, thus, [8], studying the effect of water stress on stem diameter of sunflower under controlled conditions, found that a reduction in the soil water

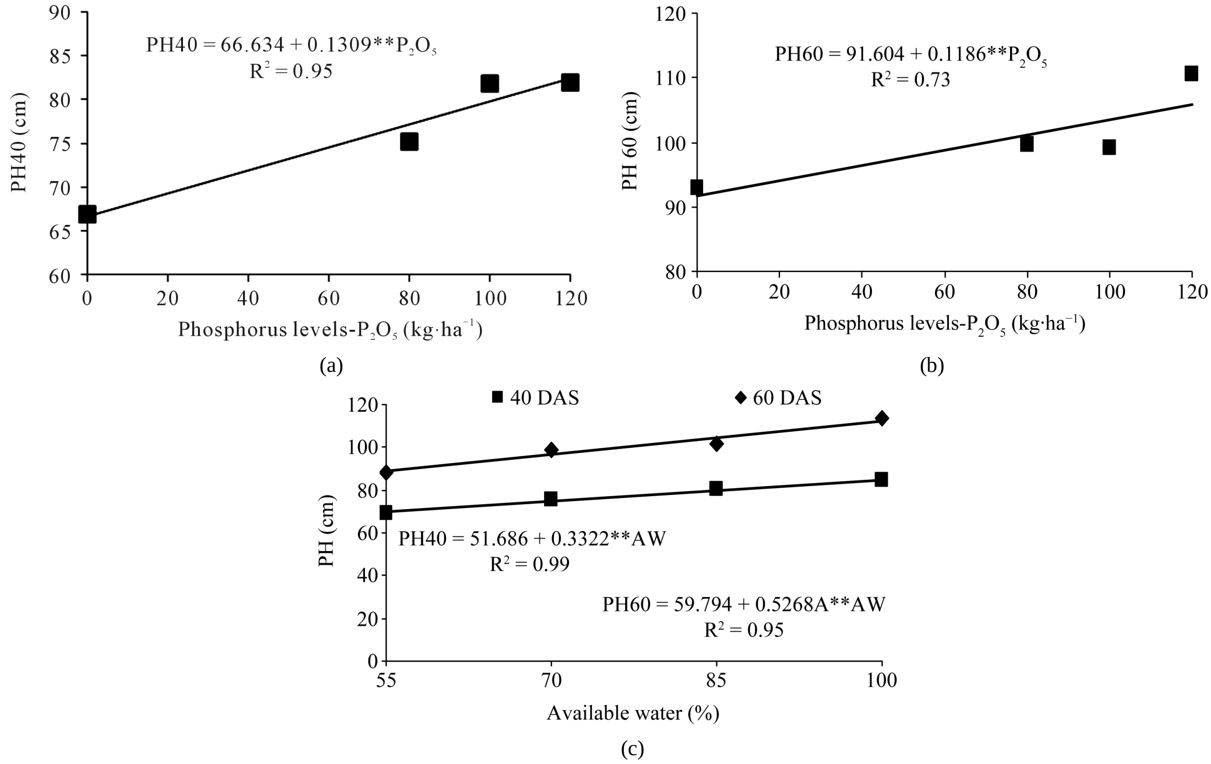

Figure 1. Plants height (PH) of sunflower cv. Embrapa 122-V2000 at 40 e 60 DAS in fuction of P_2O_5 levels (a) and (b) and available soil water (c).

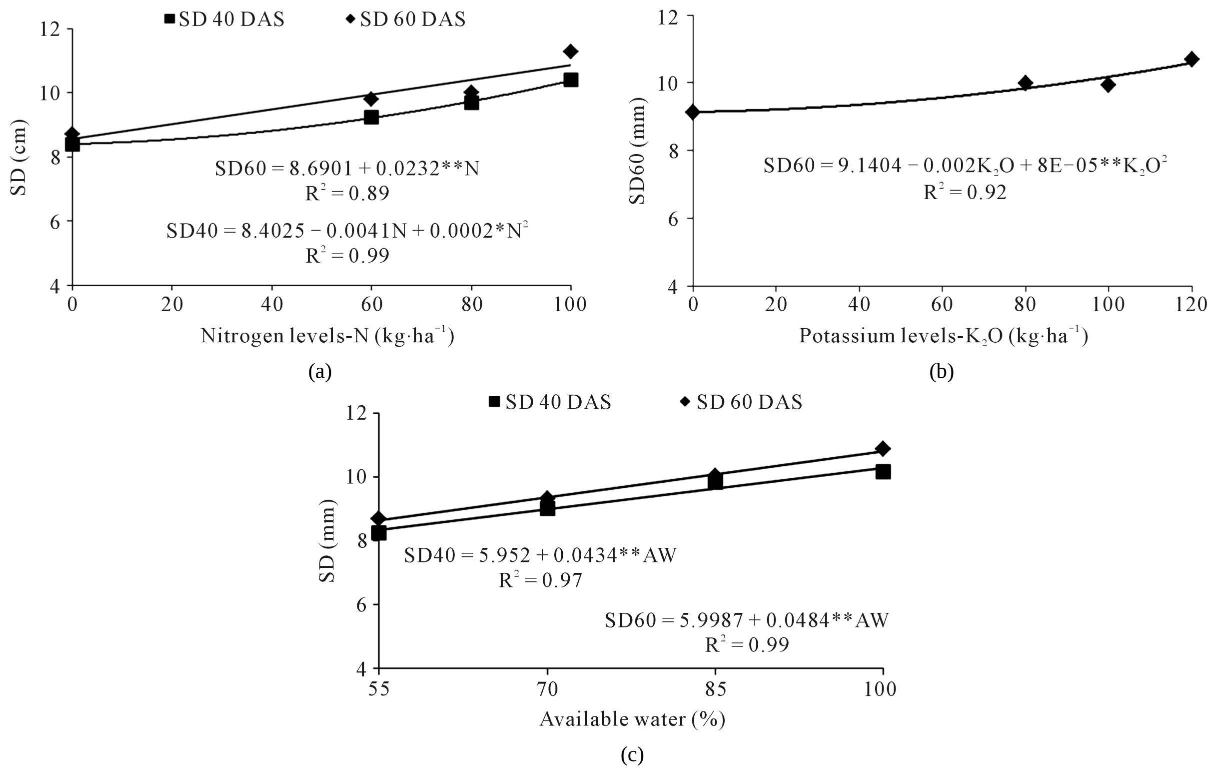

Figure 2. Stem diameter (SD) of sunflower cv. Embrapa 122-V2000 at 40 e 60 DAS in function of N (a), K_2O (b) levels and available soil water (c).

content from 60% to 30% of field capacity, resulted in a decrease of 20.46% of stem diameter. Assessing the influence of irrigation and nitrogen on yield and agronomic behavior of sunflower, [18], achieved significant results of nitrogen fertilization on stem diameter of sunflower, however not interaction between irrigation frequency and nitrogen was found.

The number of leaves of sunflower at 40 DAS increased exponentially with the amount of nitrogen applied, however, at 60 DAS this adjustment was linear. At 40 DAS the number of leaves was maximum (16 leaves) for an estimated dose of 71.22 kg·ha^{-1} of N (**Figure 3(a)**). The number of leaves was superior at 40 DAS was greater than at 60 DAS probably due to the fact that during the development of sunflower, the older leaves cease to photosynthesize over time and fall. As the number of leaves at 60 DAS in the treatments with nitrogen, phosphorus levels also increased the variable. Phosphorus addition resulted in a maximum number of leaves (15) with the dose of 120 kg·ha^{-1} of P_2O_5 (**Figure 3(b)**). No significant effect was found at 40 DAS.

Potassium affected significantly the number of leaves at 60 DAS, until the estimated dose of 78.6 kg·ha^{-1} of K_2O, providing the number of leaves maximum of 15 units (**Figure 3(c)**).

The available water contents contributed significantly to increase the number of leaves at 40 DAS (**Figure 3(d)**). In research conducted in Pakistan by [5], with sunflower subjected to NPK fertilization they found that the largest number of leaves per plant was obtained with the 120-90-60 Kg·ha^{-1} treatment. Data from the depressive effect of water stress on the number of leaves of sunflower corroborate with those found by [19] and [10].

The leaf area was affected statistically, both at 40 and at 60 DAS by the nitrogen, potassium and available water treatments. It increased linearly with the levels of nitrogen. Treatments without N addition at 40 and 60 DAS had leaf areas 336.33% and 81.55% lower than plants supplied with 100 kg·N·ha^{-1}, respectively (**Figure 4(a)**). For the potassium, the leaf area at 60 DAS, was adjusted to a quadratic regression model. In both study periods the highest leaf areas 1286.68 and 1181 cm^2 at 40 DAS and 60 DAS, respectively were obtained with a dose of 120 kg·ha^{-1} of potassium (**Figure 4(b)**). Similar to nitrogen, available water content increased the leaf area of sunflower following a linear model (**Figure 4(c)**). The plants with the lowest soil water had the lower leaf area, both at 40 (670.54 cm^2) and at 60 DAS (495.65 cm^2). The highest leaf areas, at both period of about

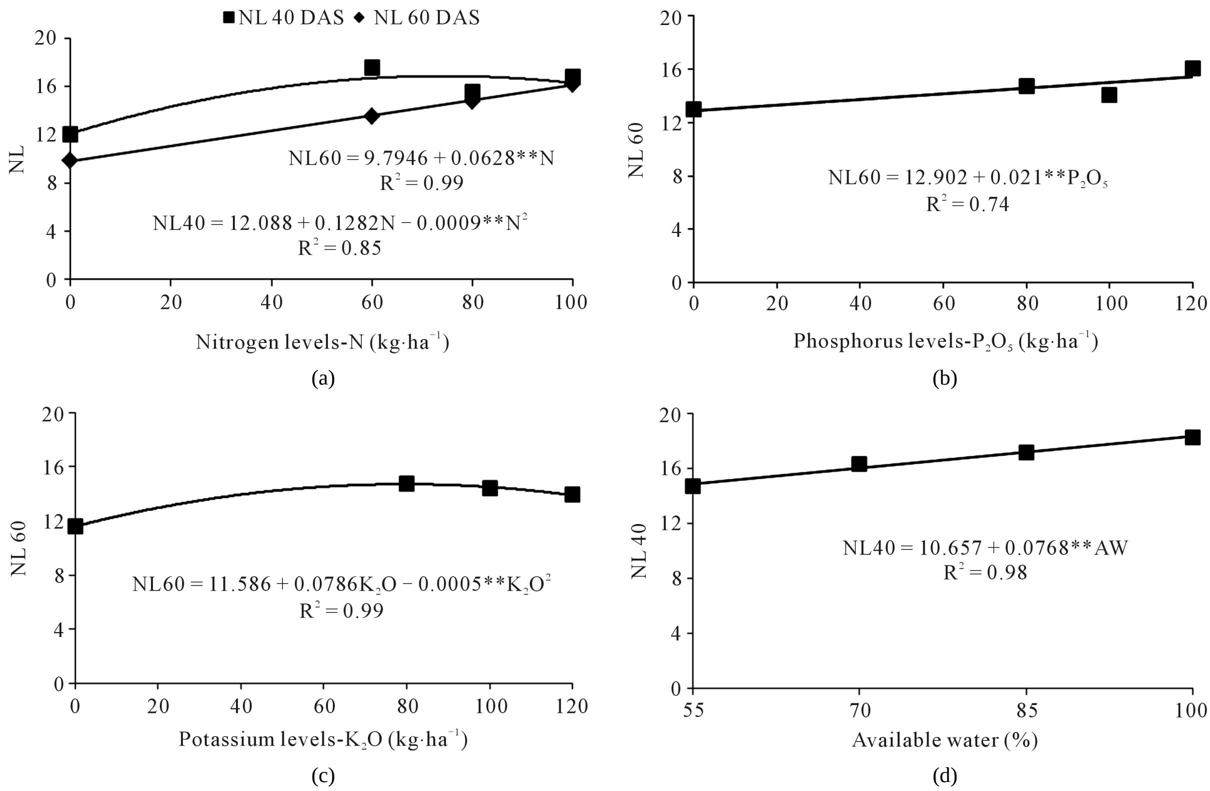

Figure 3. Number of leaves (NL) of sunflower cv. Embrapa 122-V2000 at 40 and 60 DAS in function of N (a), P_2O_5 (b), K_2O (c) levels and available soil water (d).

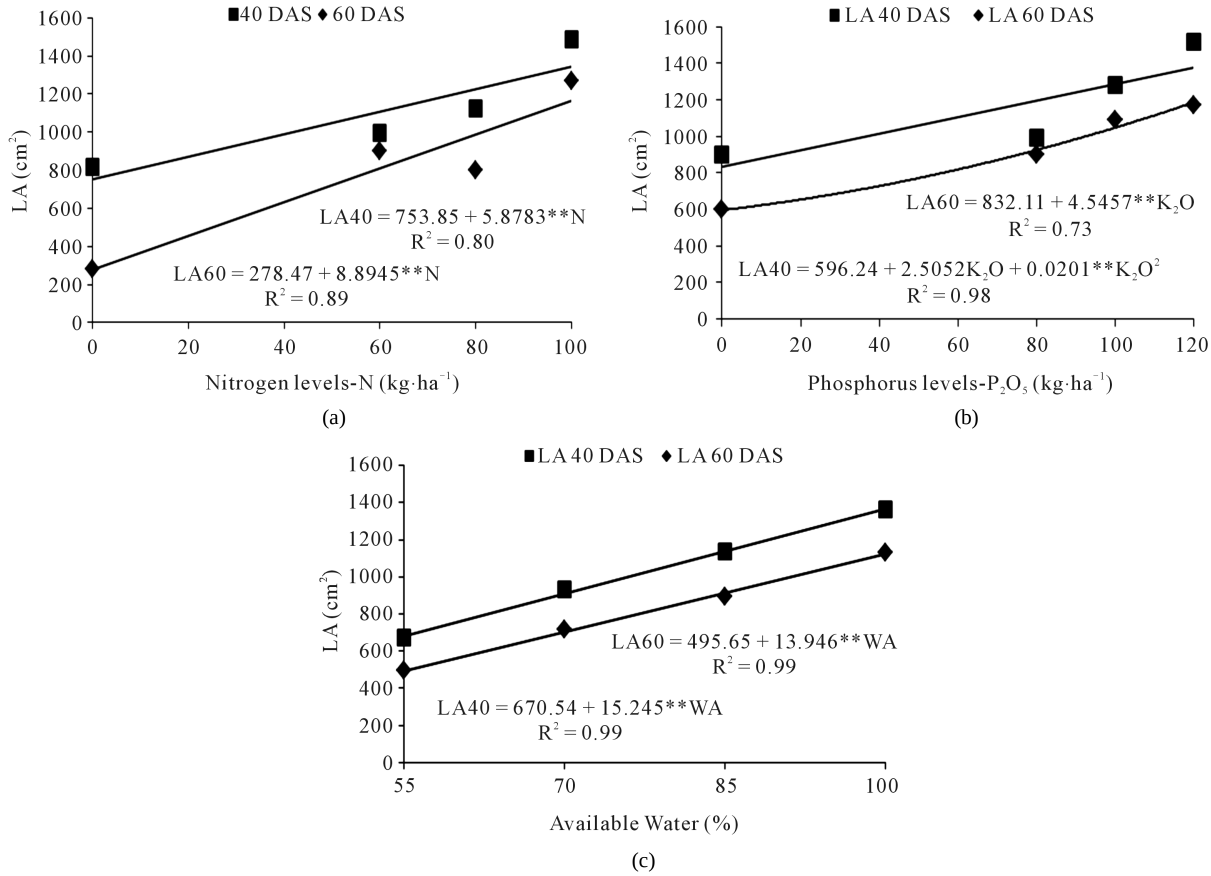

Figure 4. Leaf Área (LA) of sunflower cv. Embrapa 122-V2000 at 40 and 60 DAS in function of N (a), K_2O (b) a available ware levels (c).

evaluation, were found in the treatments with 100% water available.

Fagundes *et al.* [4] [20] [21] showed that leaf area is very sensitive to the supply of nitrogen. Murad *et al.* [22] concluded that the increasing levels of N increased the leaf area. Roggatz *et al.* [23] demonstrated that the effect of nitrogen deficiency depends on the plant development stage. The results obtained in the present study are also in agreement with those reported by [2] [3] [6] [24] [25].

On **Figure 5(a)**, **Figure 5(b)** and **Figure 5(c)** it is observed that nitrogen, phosphorus and potassium treatments increased water consumption, obtaining with the highest treatment level water consumptions 72.30%, 32.11% and 33.81% higher than those obtained with the control, respectively. Water consumption increased, linearly, 8.44 mm per unit increase of available soil water.

The results corroborate those found in the bibliography. In relation to nitrogen, increase of water consumption was obtained with the nitrogen, as evidenced in the literature for some oilseeds such as the colored cotton [26] and castor bean [27]. Aguiar Neto *et al.* [28], in an study conducted with phosphorus fertilization and liming on sunflower cultivation in Areia County, Paraíba State, Northeast Brazil, reported an increase in water consumption of sunflower with increasing doses of phosphorus. The increase of water consumption with the available soil water is discussed by [29] working with castor bean.

4. Conclusions

No effect of N and K was observed on the sunflower plant height. However, it increased significantly with P levels.

The stem diameter and the leaf area, different from what was observed for plant height, were affected by the N and K and not by the P.

The number of leaves increased significantly with the amount of N, P and K fertilizer.

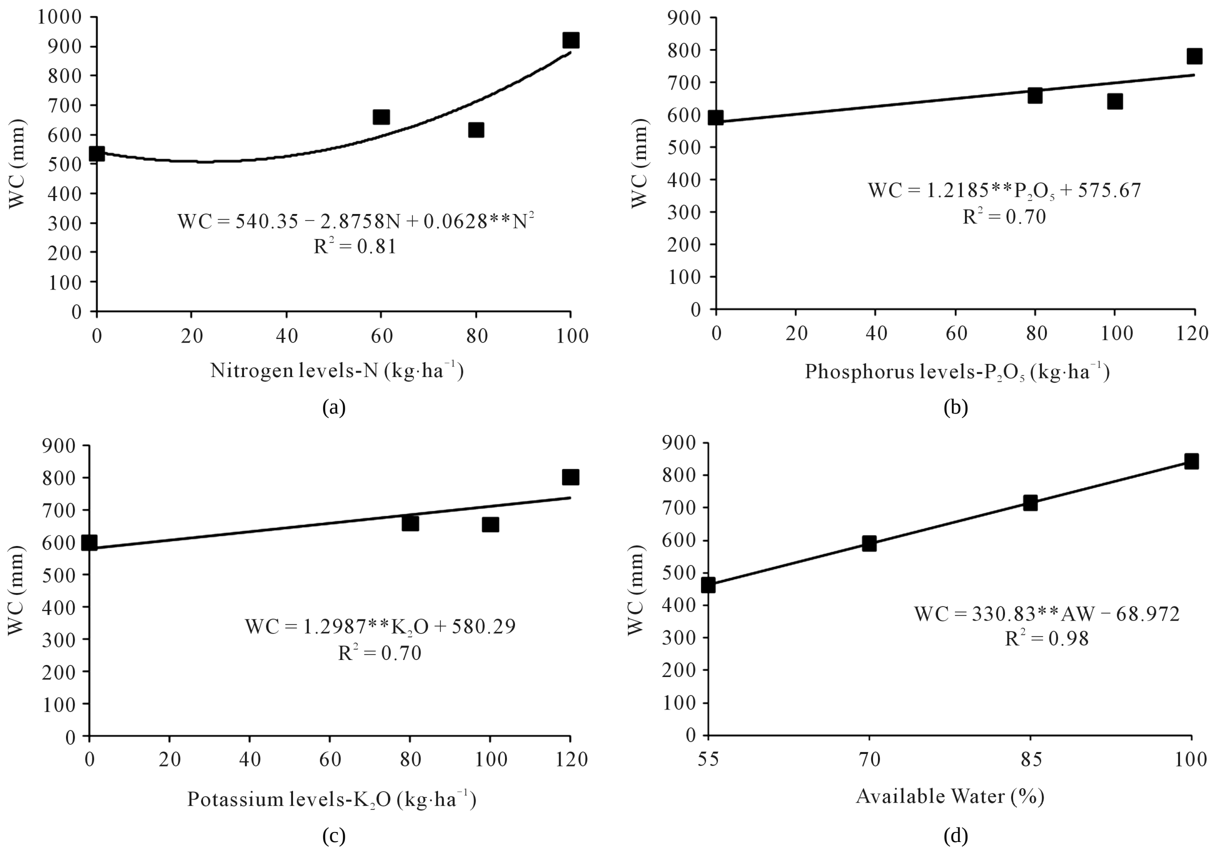

Figure 5. Water Consumption (WC) of sunflower cv. Embrapa 122-V2000 in function of N (a), P_2O_5 (b), K_2O (c) levels and available soil water (d).

With the exception of the number of leaves at 40 DAS, the available soil water content contributed significantly to increasing all the variables studied.

For the conditions studied, the doses 100, 120 and 120 kg·ha^{-1} of NPK and 100% of the available soil water content resulted in the highest growth rates.

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