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Sunflower response to nitrogen doses

Resposta do girassol a doses de nitrogênio

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ABSTRACT

The sunflower is an oilseed species, rustic, cultivated in different agroecosystems. The responses of cultivars to nitrogen fertilization vary according to the cultivar and environment. Therefore, this research aimed to evaluate the response of biometric characters of sunflower cv. Embrapa 122-V2000 under N doses. The experiment was carried out in a randomized block design with five treatments (0, 40, 80, 120 and 160 kg N ha^{-1}) and four blocks. All characters were influenced ($p<0.05$) by N doses, fitting to the quadratic model. The maximum values of plant height (1.68 m), stem diameter (22.71 mm), leaf area (423.41 cm^2), capitulum diameter (15.22 cm), dry biomass yield (6,075.13 kg DM ha^{-1}) and grains (2,982.89 kg ha^{-1}), N use efficiency from biomass (80.3 kg kg^{-1}) and grains (43.27 kg kg^{-1}) close to 90 kg N ha^{-1}, this dose being recommended for the edaphoclimatic conditions of the Agreste Meridional Region of Pernambuco, Brazil.

KEYWORDS: *Helianthus annuus* L.; nitrogen use efficiency; semiarid region.

RESUMO

O girassol é uma espécie oleaginosa, rústica, cultivada em diferentes agroecossistemas. As respostas dos cultivares às adubações nitrogenadas variam de acordo com o cultivar e o ambiente. Portanto, esta pesquisa objetivou avaliar a resposta de caracteres biométricos do girassol cv. Embrapa 122-V2000 sob doses de N. O experimento foi conduzido no delineamento em blocos casualizados com cinco tratamentos (0, 40, 80, 120 e 160 kg N ha^{-1}) e quatro blocos. Todos os caracteres foram influenciados ($p<0,05$) pelas doses de N, ajustando-se ao modelo quadrático. Os valores máximos de altura da planta (1,68 m), diâmetro do colmo (22,71 mm), área foliar (423,41 cm^2), diâmetro do capítulo (15,22 cm), produtividade de biomassa seca (6.075,13 kg MS ha^{-1}) e de grãos (2.982,89 kg ha^{-1}), eficiência do uso do N da biomassa (80,3 kg kg^{-1}) e dos grãos (43,27 kg kg^{-1}) próximo aos 90 kg N ha^{-1}, sendo esta dose recomendada para as condições edafoclimáticas da região Agreste Meridional de Pernambuco, Brasil.

PALAVRAS-CHAVE: *Helianthus annuus* L.; eficiência no uso de nitrogênio; região semiárida.

INTRODUCTION

Sunflower (*Helianthus annuus* L.), belonging to the Asteraceae family, is an annual species co-responsible for the Brazilian grain harvest, contributing with 59.1 thousand tons produced in 31.7 thousand hectares, highlighting the State of Goiás, with 66.7% of National production. Between the 2020 and 2022 harvests, there was an increase of 27.5% in national production (CONAB 2022).

It is a C_3 crop (photosynthetic metabolism), adapted to the temperate climate (HAWORTH et al. 2016). However, it is considered rustic and can produce optimally under different agroecological conditions (AKPOJOTOR et al. 2019). According to SANTOS et al. (2021), is a species little affected by latitude, altitude and photoperiod, allowing its cultivation in the semiarid region, with irrigation or non-irrigation regime. For this reason, research was developed to select sunflower cultivars adapted to the Brazilian Northeast, in which the cultivars were selected for grain production (MG 2, BRHS 01, M 734, 'Paraíso 20' and 'Hélio 358'; CARVALHO et al. 2012) and to severe water stress, with greater water use efficiency ('Hélio 251' and 'BRS 387'; CARVALHO et al. 2020).

In Brazil, the semiarid region presents variation in edaphoclimatic conditions (CARVALHO et al. 2012), with precipitation between 500 and 1,500 mm, irregularly distributed during the year, promoting water deficit that, when associated with high temperatures, overcoming the 40 ºC (CORREIA et al. 2011), reduces the productive potential of agricultural species. According to ANDRADE et al. (2020), the Agreste Meridional, located in the semiarid, is made up of six microregions and 71 municipalities, with a dry climate, average altitude of 400 to 800 m a.s.l, average precipitation of 500 mm year^{-1}, humidity between 10 to 80% and average temperature of 18 ºC and 37 ºC, depending on the region.

Sunflower triglycerides are rich in fatty acids important for human health, especially oleic (49.0%) and linoleic (45.4%) acids, whose relationship varies with the climate of the producing region (CORREIA et al. 2014). According to these authors, when the oil is subjected to high temperatures, it requires a high concentration of oleic acid to have a high degree of oxidative stability, being indicated for cultivation in the Northeast region. However, when cultivated in the Southeast region, there is a higher concentration of linoleic acid, which can be used to produce hydrogenated products due to its high degree of unsaturation. Furthermore, due to its physicochemical properties, it can also be used to feed ruminants and non-ruminants and in industrial processes, such as biodiesel.

The inappropriate use of synthetic or organic fertilizers can result in environmental pollution, nutritional imbalance, reduced production and increased costs. For example, nitrogen is an essential plant nutrient, and all protein-based metabolic processes that lead to increased vegetative and reproductive growth depend on adequate N supplementation (LAWLOR 2002). In the sunflower crop, its deficit results in low production rates and low oil quality; in excess, causes excessive growth, causing sensitive leaves, favorable to the incidence of pests and diseases, affecting grain yield, as well as lodging problems and a decrease in the percentage of oil (SANTOS et al. 2013), as well as to N_2O emission and eutrophication of aquatic ecosystems (HENRYSON et al. 2020).

Brazil is the 4th largest consumer of nitrogen in the World. However, considering the low national production, it imported, in 2020, 88% of the total volume consumed, corresponding to 10.9 million tons, with Russia (21%) and China (20%) the largest suppliers (GLOBALFERT 2021). With the international crisis and barriers to imports, it is necessary to promote greater efficiency in using this important input.

A better understanding of the relationship between production components and N dosage can help to estimate the most suitable dosage of fertilizer for plants, considering that the influence of nitrogen fertilizers on plants varies with species and cultivar, the dose applied, the climate and the place of growth (GUL & KARA 2015). For example, VIANA et al. (2018), in Campina Grande/PB, did not observe an effect of up to 140 kg N ha^{-1} on the yield of the BRS-323 cultivar; on the other hand, SILVA et al. (2016), in Crato/CE, observed that the dose of 115.5 kg N ha^{-1} promoted maximum yields on the Embrapa 122-V2000 cultivar. For this reason, this research aimed to evaluate N dosage in sunflowers in the Agreste Meridional Region of Pernambuco, Brazil.

MATERIAL AND METHODS

The research was carried out in the experimental area of the Federal University of the Agreste of Pernambuco, Garanhuns Academic Unit (UFAPE/UAG) under coordinates 8º 54' 13" S and 36º 29' 38" W, 847 m a.s.l. The region has an 'AS' climate, which represents a tropical climate with a dry season, according to the Köppen classification (CLIMATE-DATA 2022), with total rainfall of 870.4 mm (equivalent to 70% of the annual total precipitation), a rainy season concentrated between May/July (autumn-winter). The minimum average temperature is 16.9 ºC and the maximum is 25.5 ºC, with a relative humidity of 75% (INMET 2022). The soil was classified as dystrophic Yellow Argisol.

The experiment was installed in a randomized block design, with five treatments (0, 40, 80, 120, 160 kg N ha^{-1}, using ammonium sulfate) and four blocks. Each plot consisted of six rows of 5.0 m, with the four central rows being considered a useful area. The sunflower cv. Embrapa 122-V2000 was used, early cycle of 100 days, introduced in the region without records of research on nitrogen fertilization.

The chemical attributes of the soil in the depth of 0 - 20 cm, sampled before the installation of the experiment were: pH (H_2O): 6.24; organic matter: 3.5 mg dm^{-3}; P (Mehlich): 8.45 mg dm^{-3}; H^+ (calcium acetate, pH 7.0) + Al^{3+} (1N KCl), K^+ (Mehlich), Ca^+ + Mg^{2+} (1N KCl) showed, respectively, 3.6; 0.11 and 3.0 cmol$_c$ dm^{-3}. The sand, silt, and clay fractions were 58, 15 and 27%, respectively, and the texture was classified as sandy clay loam.

The experiment was carried out in a conventional tillage system, with two harrowing harrows and one leveling harrow (0.20 m). Then, mechanized planting was carried out, using a fertilizer seeder of three-row pantographic manufactured by Baldan® Company (SP light H-2500), one seed per hole at 5 cm depth. The spacing adopted was 0.80 x 0.20 m, in which the plant population was 62,500 plants ha^{-1}.

During the experiment, weed control was performed by hand weeding. There was no need for irrigation or pest and disease control due to the rains. According to the recommendations of QUAGGIO & UNGARO (1997), 50 kg P_2O_5 ha^{-1} (triple superphosphate), 50 kg K_2O ha^{-1} (potassium chloride) and 1.0 kg B ha^{-1} (boric acid) were applied at planting. Nitrogen treatments were applied twice: 1/3 at 20 days and 2/3 at 40 days after emergence.

At 70 days after planting, when the plants reached the R5 phenological stage (WENNECK et al. 2019), the variables were evaluated: plant height (m, measured with a tape measure) and stem diameter (mm, measured with a caliper) in 10 plants of the useful area of the plot; leaf area (LA; cm^2), following the equation proposed by MALDANER et al. (2009): LA = 1.7582 x $W^{1.7069}$, where W is the width of all leaves of five plants in the usable area.

At the time of harvest, 100 days after planting, the capitulum diameter was calculated, measuring the entire extension of the floral bud diametrically, with the aid of a tape measure. After, the dry biomass of the aerial part (DB, kg ha^{-1}), in which the plants of four linear meters were cut close to the ground, weighed (with the aid of a digital scale), sub-sampled (500 g), packed in paper bags of the kraft type and dried in a forced circulation oven at 65 ºC until constant mass. Grain yield (GY, kg ha^{-1}) was estimated manually after threshing, with grains at 14% moisture. Nitrogen use efficiency (NUE, kg kg^{-1}) was evaluated, according to MOLL et al. (1982), following two criteria: NUE_{DB} = [dry biomass (kg ha^{-1})/N applied (kg ha^{-1})]; NUE_{GY} = [grain yield (kg ha^{-1})/N applied (kg ha^{-1})].

In data analysis, homoscedasticity (Bartlett test), normality of residuals (Shapiro-Wilk test), independence of residuals (Durbin Watson test), and model additivity (Tukey test) were tested, all of which were non-significant ($p>0.05$). Then, analysis of variance (ANOVA) and linear regression was performed to calculate the regression coefficients using the *ExpDes* package (FERREIRA et al. 2014) of the R software (R CORE TEAM 2022).

RESULTS AND DISCUSSION

A significant effect ($p<0.05$) was observed for all variables, indicating that the biometric characters of sunflower plants were influenced by N doses (Table 1). The coefficient of variation ranged from 5.11% for height plants, indicating great experimental precision, up to 16.40%, acceptable in field-level experiments (FERREIRA 2018). Similar results were obtained by AMORIM et al. (2008), in Campinas/SP.

Table 1. Summary of ANOVA (F test), considering sunflower biometric characters as a function of nitrogen doses.

SV	HP	SD	LA	CD	Y_{DB}	Y_G	NUE_{YDB}	NUE_{GY}
N-doses	27.86**	7.32**	54.18**	21.07**	56.16**	21.25**	736.57**	93.16**
Blocks	0.11	1.05	0.35	1.21	1.08	0.64	0.13	1.33
CV (%)	5.11	12.24	8.26	5.97	7.88	16.40	5.12	15.5

SV: Sources of variation; HP: height plant; SD: stem diamete:; LA: leaf area; CD: capitulum diameter; Y_{DB}: yield dry biomass; Y_G: yield grain; NUE_{DB}: nitrogen use efficiency of dry biomass; $NUE_{GY:}$ nitrogen use efficiency of grain. CV (%): coefficient of variation.

The height plant was fitted to a quadratic model, with a maximum value of 1.68 m at a dose of 67.0 kg N ha^{-1} (Figure 1). With the same cultivar, AMORIM et al. (2008) observed an average height of 1.20 m, applying 50 kg N ha^{-1} recommended by QUAGGIO & UNGARO (1997). SOARES et al. (2016), in João Câmara/RN, did not observe an influence of 100 kg N ha^{-1}, with a maximum height of 1.20 m. ÖZER et al. (2004), in Erzurum/Turkey, did not observe an effect of up to 160 kg N ha^{-1} on the height of AS-508 and Super 25 cultivars, with an average of 1.37 m. On the other hand, VALERIANO et al. (2020), in Uberaba/MG, observed a linear effect of N on the 'Hélio 358' cultivar at the maximum dose (1.28 m; 120 kg ha^{-1}). According to GUL & KARA (2015), these observed differences vary with the environment, justifying the research carried out in the different agroecosystems.

The stem diameter is an important component, because it is associated with the plant support, mainly from the R5 stage, when achenes are being formed, which can cause the plant to fall off due to the increase in flower weight, where diameter is correlated with yield (AMORIM et al. 2008). In this research, the response of the Embrapa 122-V2000 cultivar was fitted to a quadratic model, with a maximum value of 22.71 mm at a dose of 90.73 kg N ha^{-1} (Figure 2). From this value, there is a significant reduction ($p<0.05$) in the stem diameter, that is, the dose of 160 kg N ha^{-1} reduced the diameter by 17.43 mm. Similar results were observed by VALERIANO et al. (2020), in which the 'Hélio 253' reached a maximum of 25.7 mm at a dose of 120 kg N ha^{-1}. The differential response to N among the cultivated genotypes may be related to the genetic variability observed in their germplasm, which is of high magnitude (DUDHE et al. 2020).

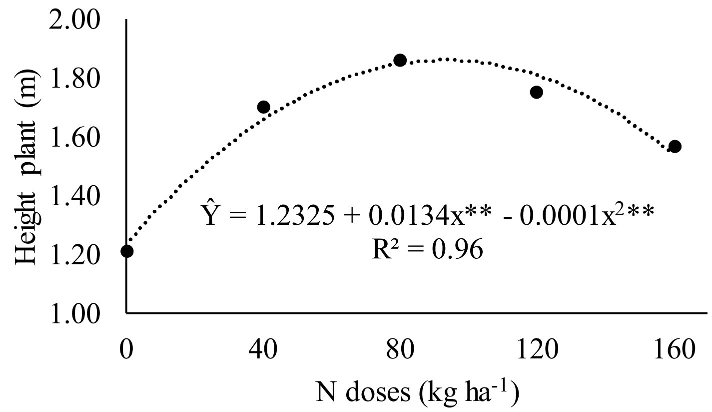

Figure 1. Sunflower height plant (m) as a function of N doses.

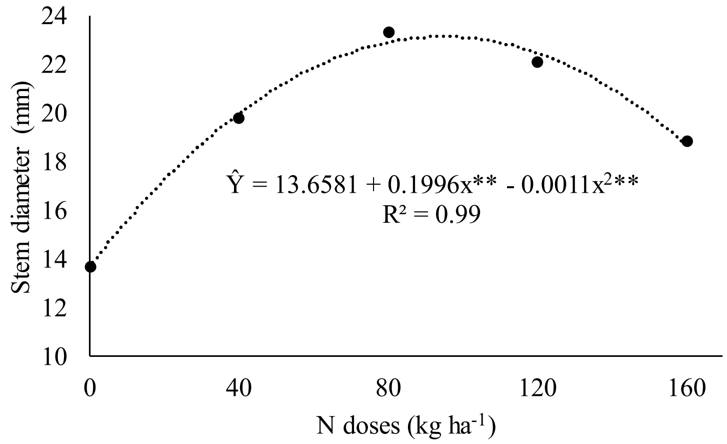

Figure 2. Sunflower stem diameter (mm) as a function of N doses.

Leaf area is related to photosynthetic capacity, its positively correlated with achene yield (IQBAL et al. 2013). In this research, the leaf area was fitted to a quadratic model, with a maximum value of 423.41 cm^2 at a dose of 90.7 kg N ha^{-1} (Figure 3). The addition of 10 kg N ha^{-1} above the maximum level promotes a reduction of 3.19 cm^2, probably due to the phytotoxic effect of N, such as reduced activity of the enzymes glutamine and glutamate synthetase, superoxide dismutase, and peroxidase. In addition, it promotes the accumulation of reactive oxygen species, causing photorespiration (ATP consumption) and accumulation of NH_4^+, which stimulates ethylene synthesis, triggering leaves senescence (KONG et al. 2017, JIAN et al. 2018), as observed in this research.

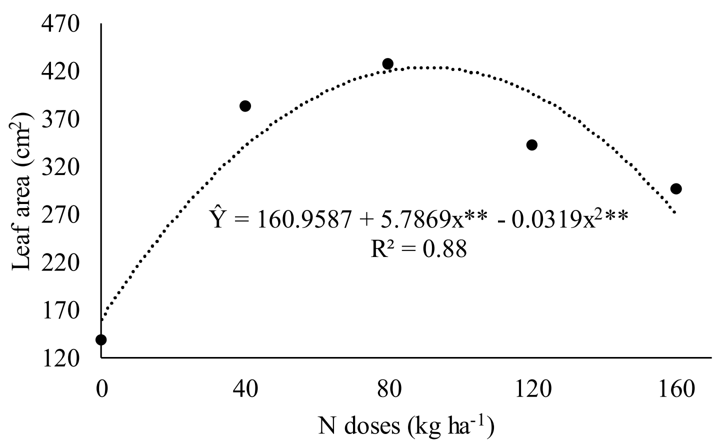

Figure 3. Sunflower leaf area (cm^2) as a function of N doses.

The capitulum diameter is a production component that is directly linked to yield (SOARES et al. 2016), that is, more productive genotypes tend to have a larger diameter, as observed by AMORIM et al. (2008), in which the Embrapa 122-V2000 cultivar, with 11.0 cm, had a grain yield of 1,411.8 kg ha^{-1}, while the V20044 cultivar, with 13.0 cm, had a yield of 1,642.2 kg ha^{-1}. In this research, the maximum diameter (15.22 cm) was obtained with a dose of 93.5 kg N ha^{-1}, decreasing with the increase of N (Figure 4). On the other hand, SANTOS et al. (2016), in Remígio/PB, observed a linear effect of N doses, with a capitulum diameter of 17.51 cm at a dose of 120 kg N ha^{-1}.

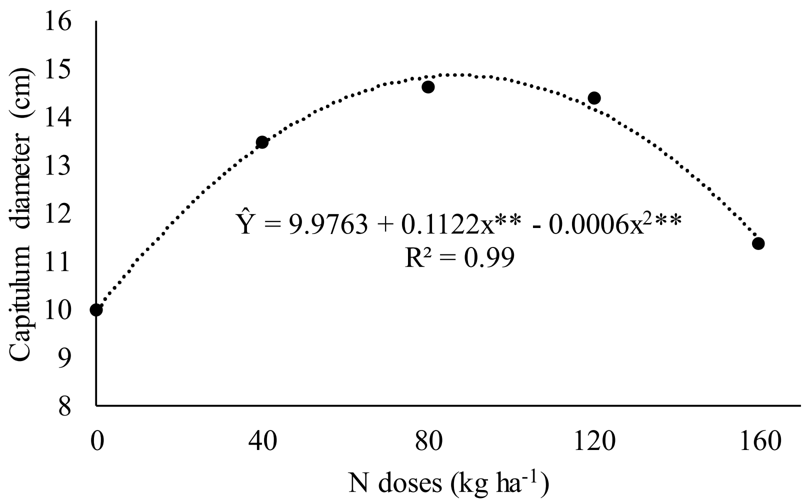

Figure 4. Sunflower capitulum diameter (cm) as a function of N doses.

The dry sunflower biomass was fitted to a quadratic model, with a maximum value (6,075.13 kg DM ha^{-1}) at the dose of 91.1 kg N ha^{-1} (Figure 5). Sunflower is known to be an oilseed species. However, considering the yield of shoot biomass and its nutritional value, it has potential for use in animal feed, especially in the semiarid region, where production is seasonal due to water deficit. When used in silage production, TOMICH et al. (2004) observed variation in the protein level (7.2 to 9.8%), ether extract (10.5 to 19.2%) and digestibility (46.9 to 56.7%), depending on the cultivar, indicating it in the inclusion of the bovine diet. By Garanhuns/PE it is inserted in the Agreste region of the State; with a strong livestock link, the sunflower can increase animal production.

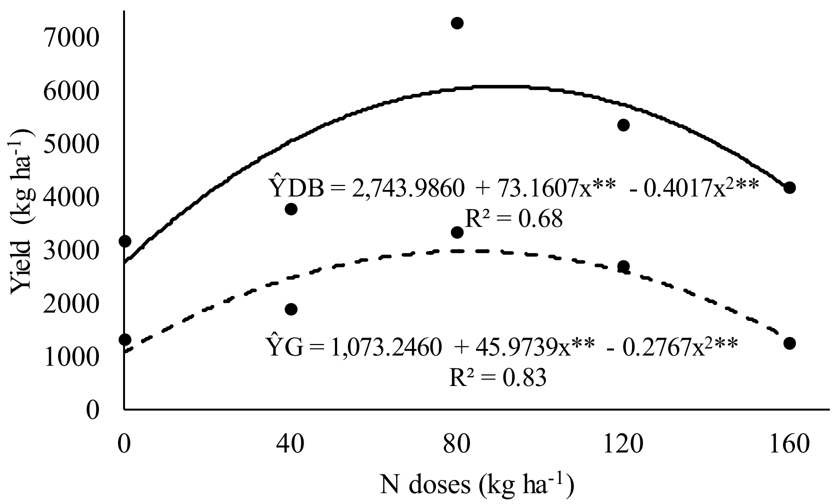

Figure 5. Sunflower dry biomass yield ($\hat{Y}_{DB}$, solid line) and grain yield ($\hat{Y}_{G}$, dashed line) as a function of N doses.

The sunflower grain yield was fitted to a quadratic model, with a maximum value (2,982.89 kg ha^{-1}) at the dose of 83.1 kg N ha^{-1}, a value higher than the National yield, of 1,646.0 kg ha^{-1} (CONAB 2022). GJORGJIEVA et al. (2015), in Ovche Pole/Macedonia, observed yields ranging from 2,244.0 to 3,549.0 kg ha^{-1} for the 'NLK12S126' and 'NLN12N011 DMR' hybrids, respectively. In Caruaru/PE, yield under non-irrigation ranged from 1,059.0 to 1,960.4 kg ha^{-1} for the Embrapa 122-T and Multissol cultivars, respectively (SILVA et al. 2019).

These researches followed the recommendations of local fertilization. However, when tested doses of N, VALERIANO et al. (2020) observed higher yield with 120 kg N ha^{-1} (7,024.9 kg ha^{-1}). Likewise, SANTOS et al. (2016) observed a linear effect of N on grain yield (2,037.0 kg ha^{-1} at a dose of 120 kg N ha^{-1}). With a dose of 160 kg N ha^{-1}, ÖZER et al. (2004) obtained a maximum yield of 2,704.2 kg ha^{-1}.

The differences observed in yield, even within the same cultivar, show the influence of the environment on the plants. Although tolerant to semiarid regions (AKPOJOTOR et al. 2019), sunflower is C_3 metabolism (HAWORTH et al. 2016), adapted to temperate regions, characteristic of the Garanhuns/PE, which may explain the higher yield found in this research. It is possible that linoleic acid is predominant under the experimental conditions due to the low temperatures (CORREIA et al. 2014). According to FERNANDES et al. (2009), cattle that received sunflower seeds in the diet had higher concentrations of linoleic acid in the meat, increasing the ratio of unsaturated/saturated and polyunsaturated/saturated fatty acids, improving its quality.

Knowing the efficiency in the use of N is an important evaluation factor for estimating the appropriate dose of N that presents the best response. In this research, sunflower dry biomass was fitted to a quadratic model, with a maximum value (80.3 kg kg^{-1}) at a dose of 89.69 kg N ha^{-1} (Figure 6). Above this value, a loss of efficiency can be observed, corroborating the results of MOLL et al. (1982). In the initial growth phase, the root volume is small, reducing the utilization when excess N is applied, increasing the leaching losses (NO_3) and volatilization (NH_3, N_2O) (MAHMUD et al. 2021), reducing the efficiency. According to ALVES et al. (2017), 70.9% of the N in the plant is concentrated in the grains, 10.6% in the capitulum and 12.9% in the leaf blades. Therefore, the fractionation of nitrogen fertilization, considering the phenological phase and the correct amount, will allow greater efficiency in the use of N (KHANZADA et al. 2016).

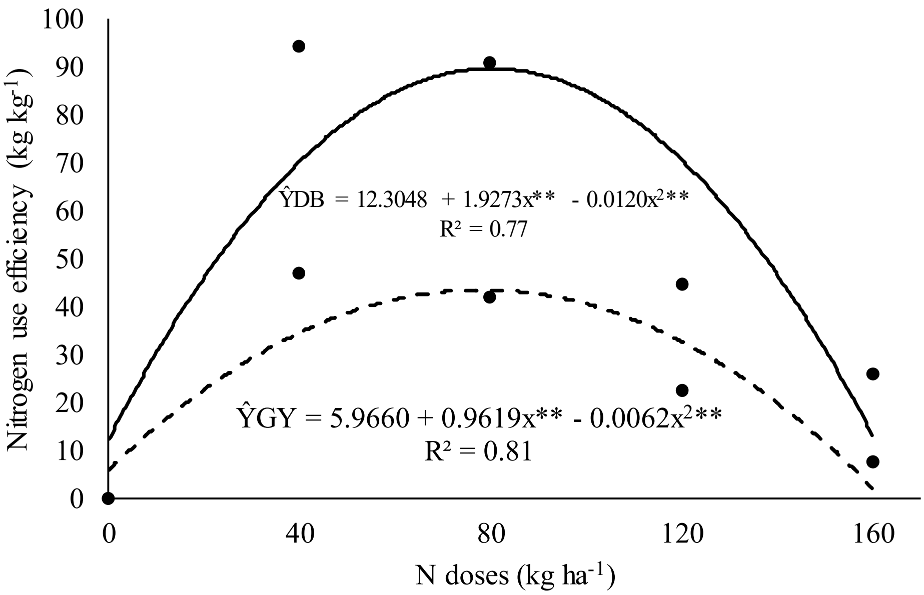

Figure 6. Sunflower nitrogen use efficiency (kg kg^{-1} N) as a function of N doses. $\hat{Y}_{DB}$: dry biomass (solid line); $\hat{Y}_{GY}$: grain yield (dashed line).

The N use efficiency, considering grain yield, was fitted to a quadratic model, with a maximum value of 43.27 kg kg^{-1} N at a dose of 77.6 kg N ha^{-1} (Figure 6). Such efficiency is lower than that calculated by dry biomass, as the first considers only grains and dry biomass, the plant as a whole. Therefore, the recommendation for nitrogen fertilization should consider the shoot dry biomass, as it will cover all fractions of the plant.

The results obtained in this research showed the sunflower cv's biometric characters. Embrapa 122-V2000 were influenced by N doses, so that the recommendation of 50 kg N ha^{-1}, proposed by QUAGGIO & UNGARO (1997), would reduce yield in the Agreste Meridional region of Pernambuco. Considering animal production, the cultivation of sunflower can reduce the demand for forage and also, from the extraction of oil in agroindustries by associations and cooperatives, it will increase the income and quality of life of rural producers.

CONCLUSION

The biometric characters of sunflower cv. Embrapa 122-V2000 are influenced by nitrogen doses, in the edaphoclimatic conditions of Agreste Meridional of Pernambuco. Considering the responses and the nitrogen use efficiency, a dose of 90 kg of N ha^{-1} is recommended, as it promotes the best agronomic indicators.

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