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Nicandra physalodes growth at different concentrations of N, P and K

Crescimento de *Nicandra physalodes* em resposta à adubação com N, P e K

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Abstract

Nicandra physalodes (L.) Gaertn. is a weed that frequently infests Brazilian agricultural areas. Knowledge of the plant's response to competition, in the form of nutrient availability in soil, is fundamental to management of agroecosystems. This study aimed to evaluate the effect of concentrations of N, P and K on the growth of *N. physalodes*. The experiment was carried out in greenhouse conditions, using a randomized complete block design with split-plot arrangement (4 x 10), with three replications. The main plots were four combinations of N, P and K: (L1) 0, 0.3 and 17.2 mg dm^{-3}; (L2) 30, 450.3 and 75.4 mg dm^{-3}; (L3) 60, 900.3 and 133.4 mg dm^{-3}; and (L4) 120, 1800.3 and 249.68 mg dm^{-3}. Subplots were used for 10 different harvest times: 26, 33, 40, 47, 54, 61, 76, 91, 106 and 121 days after emergence (DAE). The dry matter, dry matter partitioning, leaf area, relative growth rate, height and photochemical efficiency of photosystem II were measured in *N. physalodes* plants at each harvest time. Overall, the leaves showed higher total dry matter accumulation up to 61 DAE. After that, the reproductive organs showed higher accumulation. Increasing concentrations of N, P and K resulted in higher plant height and dry matter of *N. physalodes*. Moreover, doubling the nutrient levels resulted in a proportional increase in dry matter accumulation. However, *N. physalodes* showed lower growth under natural soil fertility conditions (L1 treatment). Thus, increasing concentrations of N, P, and K promoted higher growth of *N. physalodes*. Biomass distribution was not changed by fertilization. There is evidence that *N. physalodes* could adapt easily in fertile soil. Thus, this species has greater competitive potential in high fertility soils.

Key words: Apple of Peru, weed, plant nutrition

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Resumo

A *Nicandra physalodes* (L.) Gaertn. é uma planta daninha que infesta com frequência áreas agrícolas brasileiras. O conhecimento do comportamento das plantas frente aos fatores de competição, como a disponibilidade de nutrientes no solo, é fundamental para direcionar o manejo dos agroecossistemas. Nesse contexto, objetivou-se avaliar o efeito de doses de N, P e K no crescimento de *N. physalodes*. O experimento foi conduzido em casa de vegetação, em delineamento de blocos casualizados arranjado em parcelas subdivididas, com três repetições. Nas parcelas foram aplicadas as doses de N, P e K: 0, 0,3 e 17,2 (D1); 30, 450,3 e 75,4 (D2); 60, 900,3 e 133,4 (D3); 120, 1800,3 e 249,68 mg dm^{-3} (D4) e nas subparcelas as épocas de colheita (26, 33, 40, 47, 54, 61, 76, 91, 106 e 121 dias após emergência (DAE)). Avaliou-se a matéria seca, área foliar, distribuição da matéria seca, taxa de crescimento relativo, altura e a eficiência fotoquímica do fotossistema II das plantas de *N. physalodes*. De maneira geral, as folhas apresentaram maior participação no acúmulo de matéria seca total até os 61 DAE; posteriormente, órgãos reprodutivos apresentaram maior participação. O aumento das doses de N, P e K proporcionou maior altura e produção de matéria seca da planta daninha, sendo que quando se dobrou as doses dos nutrientes aplicados observou-se aumento proporcional em acúmulo da matéria seca. Porém, ao ser cultivada nas condições de fertilidade natural do solo (tratamento D1), *N. physalodes* apresentou baixas taxas de crescimento. Conclui-se que o aumento das doses de N, P e K promove aumento do crescimento de *N. physalodes*, no entanto, o padrão de distribuição de biomassa não é alterado pela adubação. Essa espécie adapta-se bem a solos férteis, assim, pode-se considerar que a mesma tem maior potencial competitivo em solos de alta fertilidade.

Palavras-chave: Joá-de-capote, planta daninha, nutrição de plantas

Nicandra physalodes (L.) Gaertn. is a South American weed known popularly as apple of Peru or shoo-fly plant that frequently infests Brazilian agricultural areas. It is an annual shrub, 1.0 to 2.0 m high (KISSMANN; GROTH, 2000). The plant is able to produce large amounts of seed, which increases its dispersal and makes it difficult to control. It commonly infests crops such as soybean (NEPOMUCENO et al., 2007), cotton (BRAZ et al., 2011) and okra (BACHEGA et al., 2013), and also pastures (KISSMANN; GROTH, 2000). However, there is little information available on the biology and management of *N. physalodes*.

The survivability and reproduction of a biotype in a population determines its ecological adaptability, which depends on biological characteristics such as germination rate, growth and seed production (CHRISTOFFOLETI, 2001). The growth potential of each individual is determined mainly by the availability of resources and the adaptability of the plant in the environment (OBARA; BEZUTTE; ALVES, 1994). The analysis of plant growth is still the simplest and most accurate way to quantify the contribution of different physiological processes to plant growth, since it is applicable in the study of variations between genetically different plants or plants subjected to different environmental conditions (CAMPOS et al., 2012).

Weeds are known to be efficient in the extraction, use and accumulation of soil nutrients but vary by species and local environmental conditions (CURY et al., 2012). Plant development is subject to availability of resources in the environment and the ability of plants to extract and use resources; competition for nutrients is one of the main ecological factors that reduce crop yields. Thus, knowledge of plant behavior in response to growth factors such as the availability of nutrients in the soil is essential to management of plants in agroecosystems. Therefore, this work aimed to evaluate the effect of different concentrations of N, P and K on growth of *N. physalodes*.

The experiment was carried out in a greenhouse of the Department of Agronomy of the Universidade Federal dos Vales do Jequitinhonha e Mucuri (UFVJM), Diamantina-MG, in May and September 2012.

Seeds of *N. physalodes* were collected from the experimental field of UFVJM Diamantina-MG. Dormancy was broken by pulverising fruit briefly in a blender to separate the seeds from the fruit, Seeds were subsequently immersed in water at room temperature. The water was exchanged at two-hour intervals. This process was repeated six times then the seeds were placed to dry in a ventilated and shaded environment.

Dry seeds were germinated on a plastic platter containing soil (red-yellow latosol). At 25 days after sowing, each seedling was transplanted to a 8 dm^3 plastic plot containing soil with the following physical and chemical characteristics: pH (water) of 6.1; organic matter content of 1000 mg dm^{-3}; clay content of 110 000 mg dm^{-3}; P and K, 0.3 and 17.2 mg dm^{-3}, respectively; and Ca, Mg, Al, Al and cation-exchange capacity of 13, 3, 0.2, 19 and 16.6 mmol dm^{-3}, respectively.

The treatments were arranged in a randomized block design with three replications in a split-plot arrangement (4 x 10). NPK treatments were applied in each experimental plot in four levels: 0, 0.5, 1 and 2 times the dose recommended by Cantarutti et al. (2007), corresponding to NPK of: (L1) 0, 0.3, 17.2 mg dm^{-3}; (L2) 30, 450.3, 75.4 mg dm^{-3}; (L3) 60, 900.3, 133.4 mg dm^{-3}; and (L4) 120, 1800.3, 249.68 mg dm^{-3}. The subplots were for 10 harvest times (26, 33, 40, 47, 54, 61, 76, 91, 106 and 121 days after emergence (DAE)). We used ammonium sulfate (N), simple superphosphate (P) and potassium chloride (K) applied one day before transplanting the weeds.

At each harvest, height and leaf area of plants were measured and the plants were separated into root, stem, leaves and reproductive organs. Leaves were digitally photographed and the images processed in the software Image-Pro Plus™ to obtain the leaf area. All plant material was placed in paper bags, keeping different parts of the plant separate, and put in a fan-forced oven at 65°C where they remained until hey reached constant weight. They were then weighed on a digital scale with a precision of 0.0001 g.

Relative growth rate (RGR) was determined for each time of assessment based on the results of leaf area and dry matter accumulation according to the method proposed by Benincasa (2003).

The distribution of dry matter in each plant part was calculated using percentage of dry matter of each part related to the total during the evaluation period, which allowed the interpretation of organic translocation (BENINCASA, 2003).

At 46 and 86 DAE, we measured the photochemical efficiency of photosystem II from leaves using a fluorometer (Junior-Pam Teaching Chlorophyll Fluorometer – Walz, Effeltrich, Germany). Chlorophyll *a* fluorescence was measured in the middle third of the first fully expanded leaves of plants after 60 minutes of dark adaptation. Assessments were done at night, with emission of a pulse of saturating light for 0.3 s, at a frequency of 0.6 kHz to determine initial fluorescence (Fo), maximal fluorescence (Fm) and the ratio between fluorescence and maximal fluorescence (Fv/Fm) (GENTY; BRIANTAIS; BAKER, 1989).

Fv/Fm data subjected to analysis of variance and expressed as mean and standard deviation for each treatment at different sampling times. The remaining data were subjected to regression analysis and the model was chosen taking into account the statistical significance (F test), the coefficient of determination (R^2) and the biological significance of the model (PIMENTEL-GOMES, 2009).

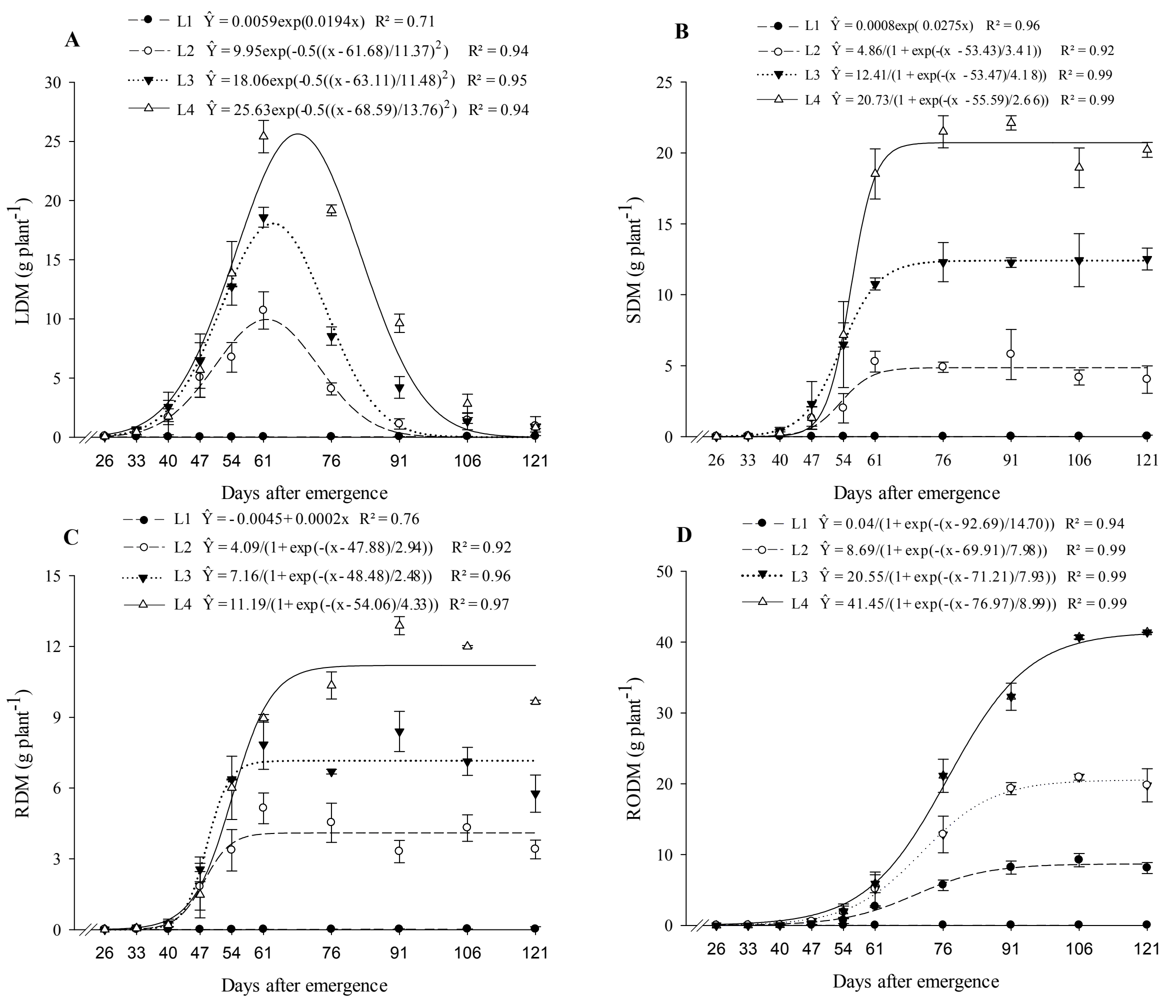
Inflorescence of *N. physalodes* began before the first harvest (between 21 and 25 DAE), with 20%, 47% and 57% of plants flowering in L2, L3 and L4 treatments, respectively. Inflorescence in the treatment without fertilization (L1) began between 33 and 45 DAE. Kissmann and Groth (2000) suggest that early flowering in this plant is influenced by photoperiod.

There were significant interactions between nutrient doses and harvesting times in dry matter of leaf, stem, root and reproductive organs, leaf area, height and relative growth rate of plants. Unpacking these interactions allowed regression equations for harvesting time to be adjusted at each level of N, P and K (Figures 1, 2 and 3).

Low dry matter accumulation of leaves, stem, root and reproductive organs was observed according to harvesting time for plants of *N. physalodes* in the treatment L1 (Figure 1). This treatment resulted in total dry matter around 168 times greater than plants grown in fertilized soil.

N. physalodes plants grown in fertilizer treatments L2, L3 and L4 showed rapid initial growth up to near 61 DAE (Figure 1). From that point, there was a pronounced decrease in dry matter of leaves due to leaf senescence (Figure 1A). In the same period, the accumulation of stem and root dry matter tended to stabilize (Figures 1B and 1C).

Figure 1. Measures of dry matter in *Nicandra physalodes* plants over the life cycle in four treatments of N, P and K. (A) Leaf dry matter – LDM, (B) stem dry matter – SDM, (C) roots dry matter, (D) reproductive organs dry matter – RODM. Treatments are: (L1) 0, 0.3, 17.2 mg dm^{-3} N, P, K; (L2) 30, 450.3, 75.4 mg dm^{-3} N, P, K; (L3) 60, 900.3, 133.4 mg dm^{-3} N, P, K; and (L4) 120, 1800.3, 249.68 mg dm^{-3} N, P, K. Data are the mean of three replications ± standard deviation.



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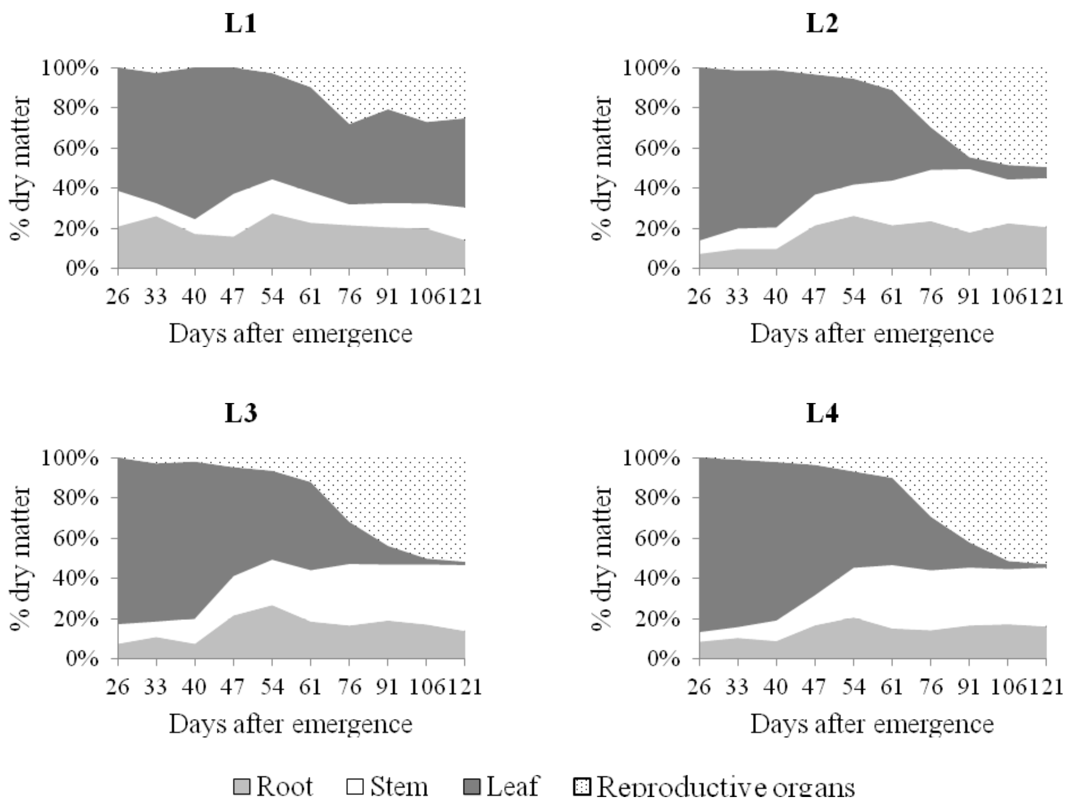
The initial growth of reproductive organs of *N. physalodes* in fertilizer treatments was slow up to 61 DAE, independent of levels of N, P and K (Figure 1D). After this period, reproductive dry matter rapidly increased up to 91 DAE on plants subjected to the L2 and L3 treatments, and up to 106 DAE in plants grown in conditions of greater fertility (L4 treatment), then there was pronounced reduction in the rate of dry matter accumulation in reproductive organs. Thus, there was almost no increase in the accumulation and allocation of assimilates between 91 and 106 DAE, at which time accumulation of dry matter in stem and roots was stabilizing. Therefore, after 91-106 DAE, the plant drastically reduced growth and enhanced the process of fruit ripening.

Rapid growth and high dry matter production of shoots are important biological characteristics of species that compete with crops and can rapidly cover the ground in areas of crop rotation (CAMPOS et al., 2012). Therefore, as a result of high growth rates and dry matter production of shoots of *N. physalodes*, mainly when grown on fertile soils, it can be inferred that this weed has high competitive potential and ability to cover the ground.

N. physalodes grown without fertilization produced a higher proportion of leaf dry matter at all harvest times in this experiment. However, there was an increase in the proportion of dry matter in reproductive organs 47 DAE, indicating that the plants invest in the continuation of the species under adverse conditions such as the L1 treatment (Figure 2). The percentage of dry matter in stem and roots varied little during the experiment with values of 6-17% and 16-27%, respectively.

Figure 2. Dry matter partitioning (%) in different organs of *Nicandra physalodes* plants over the life cycle at four different levels of fertilizer: (L1) 0, 0.3, 17.2 mg dm^{-3} N, P, K; (L2) 30, 450.3, 75.4 mg dm^{-3} N, P, K; (L3) 60, 900.3, 133.4 mg dm^{-3} N, P, K; and (L4) 120, 1800.3, 249.68 mg dm^{-3} N, P, K.



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In plants grown in soil with fertilizers (L2, L3 and L4), similar dry matter partitioning was observed regardless of treatment (Figure 2). Overall, the leaves had higher dry matter content in relation to other parts of the plant in the first 61 DAE, with values varying between 44% and 85% of the total. In the same period, the stem showed accumulation between 6% and 26% and reproductive organs between 0% and 11%. After the initial period of 61 days the reverse occurred: the proportion of dry matter in leaves became lower, representing between 3% and 23% of the total, the stems represented between 27% and 31%, and reproductive organs 30-51% of total dry matter. The proportion of dry matter in roots was less variable during plant growth, representing between 8% and 11% up to 40 DAE and 15-25% in the remaining period of plant growth, probably due to the limiting effect of the capacity of the plot.

A pronounced decrease in the percentage of dry matter accumulated in leaves of *N. physalodes* from early fruiting is due to changes in the main drain from leaves to reproductive structures (TAIZ; ZEIGER, 2009).

At the beginning of growth, regardless of the treatment, a higher proportion of dry matter is found in leaves in *N. physalodes*, because this plant quickly develops its photosynthetic system (Figure 2). The rapid development of leaf structure with subsequent formation of the root system favors domination of the space in which the plant is developing, mainly due to higher interception of incident radiation.

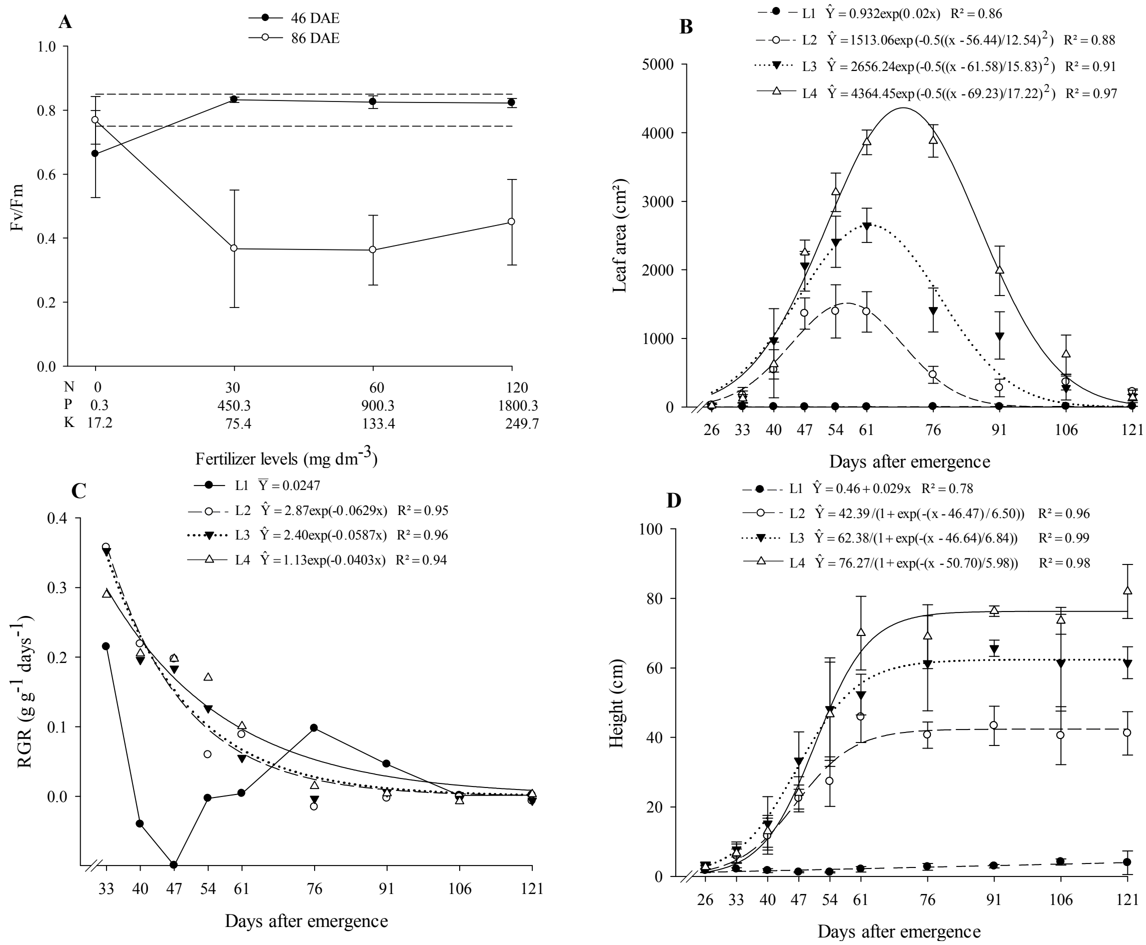
Dry matter accumulation in reproductive organs of *N. physalodes* grown in fertilized soil intensified after 61 DAE, representing around 50% of the total dry matter at the end of the growth assessment. A key feature for the success of a weed in agricultural areas is related to the ability of these plants to produce and disperse seeds throughout its development cycle (BAKER, 1974). Domesticated plants such as soybeans, corn, beans, and others, during the process of selection and breeding have lost the ability to disperse seeds and the seed production is in a time and no during a long time (BIANCO et al., 2012). Although *N. physalodes* accumulates dry matter in fruit in a similar way to that commonly observed in some crops, the maturation of fruit in this species is not uniform, which contributes to the production of seeds over the full life cycle, although seed dispersal must occur in a shorter period of time for most non-crop species.

Studies have shown differential uptake and utilization of N, P and K between species or among cultivars of the same species (FAGERIA, 1998). According to Weiss (1983) plant growth and yield respond differently when subjected to different levels of nutrition, so that plants selected to grow at a particular fertility level can be adjusted to produce maximally at this level. Despite the use of high doses of N, P and K in the soil, *N physalodes* showed similar behavior in relation to dry matter partitioning; there were no differences among treatments in the proportion of dry matter allocated to vegetative growth relative to reproductive organs.

The maximum photochemical quantum yield of photosystem II of *N. physalodes* was estimated by the ratio Fv/Fm, which has an optimal range of 0.75-0.85 (Figure 3A). Data within this range indicate that the photosynthetic apparatus of the plant is intact (BOLHÀR-NORDENKAMPF et al., 1989), whereas smaller values of this ratio reflect the presence of some stress on the photosynthetic apparatus (BJÖRKMAN; DEMMING, 1987). We found that plants of *N. physalodes* when grown in soil that received no fertilizer (L1) presented an average Fv/Fm of 0.66 at 46 DAE, indicating that the photosystem was compromised. By 86 DAE, there is evidence of plant adaptation to the environment, with consequent recovery of the photosystem, illustrated by the average increase in the ratio Fv/Fm to 0.77 (Figure 3A).

At 46 DAE, *N. physalodes* plants grown in soil with fertilizer had an average Fv/Fm of 0.83, regardless of the levels of N, P and K in the treatments (Figure 3A). By 86 DAE, fertilizer treatments resulted in decrease of quantum photosynthesis of plants due to leaf senescence. The photosynthetic activity of the plant per leaf area increased with leaf age, up to full expansion of leaves; after this time, leaf scenescence begins and photosynthetic capacity gradually declines (TAIZ; ZEIGER, 2009).

Figure 3. Measure of fluorescence in *Nicandra physalodes* subjected to different N, P and K levels, at 46 and 86 days after emergence (A) Maximal quantum yields (Fv/Fm), and measures of growth in *Nicandra physalodes* plants over the life cycle in four treatments of N, P and K. (B) Leaf area, (C) Relative growth rate – RGR, (D) height of *N. physalodes*. Treatments are: (L1) 0, 0.3, 17.2 mg dm^{-3} N, P, K; (L2) 30, 450.3, 75.4 mg dm^{-3} N, P, K; (L3) 60, 900.3, 133.4 mg dm^{-3} N, P, K; and (L4) 120, 1800.3, 249.68 mg dm^{-3} N, P, K. Data are the mean of three replications ± standard deviation.



Source: Elaboration of the authors.

N. physalodes grown in treatments L2, L3 and L4 showed high initial increments of leaf area, reaching maximum increment close to 61 DAE, when this variable began to decline (Figure 3B). The increase in leaf area was similar to the increase in dry matter accumulation in the leaves of *N. physalodes*, with the point of inflection occurring close to 61 DAE. However, when this weed was grown in the absence of fertilizer (L1) the leaf area increased exponentially with time, but was a low increasing during the harvesting time similar to the dry matter in the leaves (Figure 3B).

Leaf area is one of the most important indices of plant growth because it represents the size of its assimilatory apparatus, which is directly related to plant physiological processes (TAIZ; ZEIGER, 2009). Fast-growing species are possibly more competitive than slow-growing species due to their rapid production of greater leaf area which shades the soil. This study shows that increasing soil fertility favors growth of *N. physalodes*, since the species is more competitive when grown in fertile soil.

Plants of *N. physalodes* grown in soil with fertilizer, regardless of soil fertility level, showed decreasing RGR, with an average of 0.184 g g^{-1} day^{-1}, 0.153 g g^{-1} day^{-1} and 0.123 g g^{-1} day^{-1} for L2, L3 and L4 treatments, respectively, considering only positive growth rate (Figure 3C).

When the plant is growing there must be sufficient photoassimilates for the metabolic demands of the plant, and also to store nutrients or build new structural organs. Thus, increasing accumulation of dry matter results in smaller amounts of photoassimilates available for growth, and consequently, the RGR decreases (BENINCASA, 2003).

RGR is considered an index of efficiency of the plant, because it represents the daily yield capacity of dry matter produced per gram of plant dry matter (CHRISTOFFOLETI, 2001). Species with higher RGR have an ecological advantage due to rapid space occupation and rapid growth, which are essential to ruderal species (VIDAL; TREZZI, 2000). Thus, comparing *N. physalodes* in treatments L2, L3 and L4, increasing N, P and K levels in the soil did not affect growth efficiency, since growth behavior was similar in all treatments, with reduced RGR during the growth cycle, although the total dry matter accumulation was limited by the levels of these macronutrients in soil (Figure 3C).

Grown in low fertility soil (L1), *N. physalodes* showed reduction in RGR until 47 DAE, when negative values of RGR were observed. After 47 DAE, there was a tendency to increase RGR, which again decreased close to 76 DAE (Figure 3C). The initial decrease of RGR at the beginning of plant development is probably due to the stress of transplantation of seedlings, since the seed-raising substrate was more fertile than the experimental substrate. This stress is evidenced in Figure 3A, showing evidence that the photosynthetic apparatus was compromised due to the lower Fv/Fm. However, at 86 DAE, the plants adapted to the environment, promoting physiological recovery and, consequently, RGR increased, corroborated by the higher Fv/Fm.

As observed for dry matter accumulation, increasing N, P and K levels in the soil promoted the height of *N. physalodes* (Figure 3D). When in L1 soil conditions, the plants showed the same low increment in height over time. With the addition of macronutrients to the soil the plants reached maximum size of 42.39 cm, 62.38 cm and 76.27 cm in L2, L3 and L4, respectively, close to 76 DAE with subsequent stabilization of growth. *N. physalodes* decreased the rate of growth in height at 61 DAE, after which dry matter accumulation in reproductive organs intensified (Figure 1D). At the beginning of the reproductive period, assimilates are diverted to productive organs with fruits becoming a drain on assimilates, thus reducing the vegetative growth rate (TAIZ; ZEIGER, 2009). Growth analysis is used to detect functional and structural differences among individuals estimating their ecological adaptation (HOLT; RADOSEVICH, 1983). Even though *N. physalodes* grown in different soil fertility regimes responds to increased N, P and K levels, reproductive behavior and photoassimilate distribution were not altered by the availability of these macronutrients.

Weeds that have rapid initial growth require that management measures be applied to young plants for best results, since the development of the plant is difficult to control and to avoid competition between weeds and crops (Campos et al., 2012). Thus, control measures should be adopted in the early development of *N. physalodes*.

In general, greater effects of added N, P and K in soil on the growth of *N. physalodes* were observed after 54 DAE, since up to that time the rates of growth and dry matter accumulation were similar across the four treatments. After 54 DAE growth of this weed was limited by the amount of nutrients available in the soil, since higher concentrations promoted dry matter, leaf area and accumulation of plant height. Dry matter distribution and the RGR of *N. physalodes* grown in fertilized soil, regardless of concentration, were similar throughout the period of the experiment.

This study showed that under our experimental conditions *N. physalodes* was well adapted to fertilized soils, and had fast initial growth. Thus, this species has greater competitive potential in high fertility soils, which could be a problem in culture of highly fertilized crops.

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