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Article

Weed Interference on the Accumulation of Dry Mass and Macronutrients of Eggplant 'Nápoli'

Interferência de Plantas Daninhas no Acúmulo de Massa Seca e Macronutrientes de Berinjela 'Nápoli'

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ABSTRACT - The presence of weeds may affect both growth and nutrition of agricultural crops due to interference. The objective was to evaluate the interference of weeds in the dry mass distribution and in the accumulation of dry mass and macronutrients in eggplant. The treatments consisted of increasing weed-free and weedy periods (0-14, 0-28, 0-42, 0-56, 0-70, 0-84, 0-98, 0-112, 0-126, 0-140 and 0-154 days after transplanting) in eggplant 'Nápoli'. The experiment was arranged in a randomized block design with three replicates. Weeds affected the distribution of dry mass between vegetative and reproductive organs of eggplant. There was a significant reduction in the accumulation of dry mass and macronutrients when weeds grew with eggplant crop beyond 42 days after transplanting, reaching the maximum reduction of 79%, 75%, 80%, 82%, 83%, 83% and 80% in the accumulation of dry mass, K, N, Ca, Mg, P and S, respectively. Therefore, the weed community significantly affects the growth and mineral nutrition of eggplant 'Napoli', and there should be no weed-crop coexistence beyond 28 days after seedling transplanting.

Keywords: *Solanum melogena*, weed competition, plant growth, mineral nutrition.

RESUMO - A convivência com plantas daninhas pode afetar o crescimento e a nutrição de culturas agrícolas devido à interferência. O objetivo deste estudo foi avaliar a interferência das plantas daninhas na distribuição de massa seca e no acúmulo de massa seca e de macronutrientes em plantas de berinjela. Os tratamentos consistiram de períodos crescentes de convivência e de controle de plantas daninhas (0-14, 0-28, 0-42, 0-56, 0-70, 0-84, 0-98, 0-112, 0-126, 0-140 e 0-154 dias após o transplantio) na cultura da berinjela cultivar Nápoli. O experimento foi disposto em delineamento em blocos casualizados com três repetições. As plantas daninhas afetaram a distribuição de massa seca entre os órgãos vegetativos e reprodutivos das plantas de berinjela. Houve redução expressiva no acúmulo de massa seca e macronutrientes quando as plantas daninhas conviveram com a cultura de berinjela além de 42 dias após o transplante, atingindo a máxima redução de 79%, 75%, 80%, 82%, 83%, 83% e 80% no acúmulo de massa seca, K, N, Ca, Mg, P e S, respectivamente. Portanto, a comunidade infestante afeta significativamente o crescimento e a nutrição mineral de berinjela Nápoli, não devendo haver convivência além de 28 dias após o transplante das mudas.

Palavras-chave: *Solanum melogena*, competição de plantas daninhas, crescimento de plantas, nutrição mineral.

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INTRODUCTION

Eggplant (*Solanum melongena* L.) is a vegetable of the family Solanaceae (Weber et al., 2010), showing high economic importance for the State of São Paulo (Marques et al., 2016, 2017), in Brazil. The cultivation of eggplant has increased due to the medicinal properties of its fruits, mainly in the reduction of cholesterol levels and blood pressure, and also to peculiar characteristics used in herbal diets with relevant medicinal substances (Montemor and Souza, 2009; Oliveira et al., 2014). Eggplant is also recognized for its nutraceutical benefits, being rich in nutrients with higher content of potassium, magnesium, calcium and iron (Michalojc and Buczkowska, 2008; Flores et al., 2015). Potassium is the nutrient found in the highest concentration in eggplant (Raigón et al., 2008), and the sequence of the most required nutrients, under nutrient solution studies, are: potassium, nitrogen, calcium, magnesium, phosphorus and sulfur (Haag and Minami, 1998).

Macronutrients are important for plants because they are part of their structure and of their key metabolites for the production process. In the eggplant crop, the highest yields of fruits, number of fruits per plant, fruit length and height of the plant were observed with the addition of nitrogen (Moraditochaee et al., 2011). The nutrient accumulation in plants reflects the nutritional requirement, which represents the amounts of macro and micronutrients that plants uptake from the soil during the cropping season to attend all stages of development, further expressing adequate harvests (Prado, 2008). The unavailability of nutrients interferes with the concentration of various elements in plant tissues, and, as a consequence, it limits plant growth, reduces dry mass and leads to the development of symptoms of deficiency (Prado et al., 2007; Puga et al., 2010; Flores et al., 2015)

Weeds interfere with the accumulation of these nutrients in agricultural crops. Some weed species, e.g. *Solanum americanum* Mill. and *Euphorbia heterophylla* L., accumulate mainly potassium and nitrogen, competing with agricultural crops (Bianco et al., 2010; Carvalho et al., 2010). In cultivation of eucalyptus clones, the weeds *Urochloa decumbens* (Stapf) R.D. Webster, *Ipomoea nil* (L.) Roth., *Commelina diffusa* Brum.f., *Spermacoce latifolia* Aubl. and *Panicum maximum* Jacq. interfere with the nutrient accumulation of this crop, and the level of interference depends on the weed species found in the weed community (Medeiros et al., 2016).

In order to assess the level of nutritional losses due to weed interference in eggplant cultivation, researches are needed to evaluate the nutrient accumulation curves in the presence and the absence of weeds, aiming to define the level of interference with the crop, or, in other words, to define the amount of nutrients that the crop stops accumulating due to the presence of weeds. Similar studies determined the nutritional losses in the soybean crop in the absence of and in the presence of increasing densities of the weed *E. heterophylla* (Carvalho et al., 2010) and in common bean cultivars and different weeds (Cury et al., 2013).

The interference of weeds in the accumulation of nutrients in agricultural crops is well known. However, each crop shows its peculiarities during the competition with weeds for nutrients in relation to the ecological factors. Added to this are the different levels of weed interference (Cury et al., 2013). Therefore, the objective of this research was to evaluate the weed interference with the distribution of dry mass and the accumulation of dry mass and macronutrients in eggplant 'Nápoli'.

MATERIAL AND METHODS

The experimental field was carried out in Jaboticabal, SP (latitude 21°5'22"S, longitude 48°18'58"WGr. and altitude of 575 m), in 2013. The climate of the region is the Cwa type (classification of Köppen), with predominant summer rains and relatively dry winter. The soil of the experimental area is classified as a typical kaolinite-oxidic Eutroferric Red Latosol of clayey texture, with a moderate A. The soil was prepared in conventional tillage system using disk plow and leveling harrow.

Soil samples were collected before soil preparation and then sent to the laboratory for analysis. Both planting and cover fertilization were carried out according to recommendations of Raij et al. (1997), based on the following results of soil analysis: pH ($CaCl_2$) = 2.6; 26 g dm^{-3} of organic matter; 83 mg dm^{-3} of P_{resin}; 2.6, 28, 10, 22, 63 and 41 mmol$_c$ dm^{-3} of K, Ca, Mg, H+Al, cation-exchange capacity and sum of bases, respectively; and 70% of base saturation. The planting fertilization was performed in the furrows, just before transplanting, using the 4-14-8 fertilizer at 150 g m^{-1}, and the cover fertilization was performed 5 cm next to the planting line, at 15 days after transplanting of seedlings (DAT), using ammonium sulfate at 7 g m^{-1} plus potassium chloride at 3.5 g m^{-1}.

Four-leaf stage seedlings of eggplant 'Nápoli' was obtained from a specialized producer and then transplanted in the 1.50 x 1.00 m spacing (plants/lines), in February 2013. The experimental plots consisted of three planting lines (15 plants per line) with 15 m long and 3 m wide (total of 45 m^2). The two lateral lines of each plot, as well as the first and the last plant of the middle line, were not considered for evaluations. Thus, the useful area of each plot (19.5 m^2) consisted of the 13 plants of the center of the middle line.

The plants grew during 154 DAT. Plant protection treatments for pest and disease control, as well as sprinkler irrigation, were performed whenever necessary, according to technical recommendations for the eggplant crop.

Treatments were divided into two groups: weedy periods and weed-free periods, both starting from the seedling transplanting and ending at 14, 28, 42, 56, 70, 84, 98, 112, 126, 140 and 154 DAT. Treatments were arranged in a randomized block design with three replicates. Weed community was evaluated by phytosociological studies (data not shown), and the most important weeds were *Nicandra physaloides* (L.) Pers., *Alternanthera tenella* Colla. and *Eleusine indica* (L.) Gaertn. For the establishment of weedy periods, weeds were allowed to grow in coexistence with eggplant until the periods cited above, and then removed by hand weeding afterwards. For the establishment of weed-free periods, weeds were removed by hand weeding from seedling transplanting until the periods cited above, and then allowed to grow in coexistence with the eggplant afterwards.

The dry mass and macronutrient accumulation were evaluated in all periods of both treatment groups. Therefore, plants were collected to determine the accumulation of dry mass and macronutrients in the crop at the end of each weedy and weed-free period. Three plants per plot were collected in the first sampling (14 DAT) because of the reduced size of the plants. In the further samplings, only one eggplant per plot was collected.

The collected plants were separated into leaves, stems and reproductive structures plus fruits. The plant material was washed in the sequence proposed by Sarruge and Haag (1974). After washing, the plant materials were dried at room temperature, packed in properly identified and perforated paper bags, and then dried in a forced air convection oven at 65 ^oC during 72 hours. After drying, the dry mass of the different parts of the plants was determined using a semi-analytical balance (precision 0.01 g).

After weighing, the dried material was milled (60 mesh) using a Willey mill grinder and then stored in properly closed plastic bags to avoid changing the humidity with the environment. After milling, the material was submitted to sulfuric acid digestion for nitrogen determination and nitric-perchloric acid digestion for determination of the other macronutrients. The analysis of macronutrient contents in the different parts of the plant was carried out by specific methodologies. The total nitrogen (N) content and the phosphorus (P) content was determined by the methods semi-micro Kjedahl and phosphovanadato-molybdic acid colorimetry, respectively (Sarruge and Haag, 1974). The potassium (K), calcium (Ca) and magnesium (Mg) contents were determined by atomic absorption spectrophotometry (Jorgensen, 1977) and the sulfur (S) content was determined by turbidimetric method (Vitti, 1989).

The macronutrient accumulation data for each part of the plant was calculated multiplying the macronutrient content by the corresponding dry mass. The total accumulation in shoot of eggplant was obtained by the sum of the accumulations of the different aboveground parts of the plant, while the total content of each nutrient absorbed by the plant was calculated by the relation between the total accumulation of the nutrient by the plant and the total dry mass accumulated by the plant.

The trend of accumulation of dry mass and macronutrients in shoot of eggplant, in each treatment group, was estimated using the exponential regression model:

$$Y = \exp(a + bx + cx^2)$$

where Y indicates the accumulation of dry mass or macronutrients and x indicates the days after seedlings transplanting.

In this way, the dry mass and macronutrient accumulation curves were adjusted according to the plant life cycle, in order to reflect the behavior of eggplant in the presence and absence of weeds. Graphical elements and the determination of both inflection and maximum points for dry mass and macronutrients accumulation in shoot of eggplant were performed by using the Origin® software.

RESULTS AND DISCUSSION

The present research allowed to establish the march of accumulation of dry mass and macronutrients by eggplant 'Nápoli' in the presence and the absence of weeds. Thus, it was possible to observe changes in the cycle and in the potential of dry mass and macronutrient accumulation by the crop, as well as to evaluate the potential of weed interference on the growth and mineral nutrition of the eggplant maintained in coexistence with the weed community.

Dry mass

The accumulation of dry mass by eggplant was reduced in the presence of weeds, mainly after 28 DAT (Figure 1). There was increasing accumulation (inflection point) of dry mass up to 98 DAT (5.84 g per plant day^{-1}) and 139 DAT (1.01 g per plant day^{-1}), respectively for eggplant crop maintained in the absence and in the presence of weeds (Table 1), representing a reduction of 83%. The weed-free crop accumulated the maximum dry mass (521.24 g per plant) at 152 DAT (maximum point), while in the presence of weeds the accumulation was 79% lower (111.26 g per plant) during the same period (Table 2). The maximum accumulation of dry mass by eggplant maintained in the presence of weeds was found at 154 DAT (113.19 g per plant) (Table 2), and it was not possible to determine the maximum point, by the adjusted equation, during the crop cycle.

These results indicate a smaller and slower growth of eggplant growing in the presence of weeds. The reduction almost of 80% in the accumulation of dry mass also evidences the high potential of weed interference on the eggplant crop and, as well as the low crop competitive capacity. Reductions close to 70% were observed in okra (Santos et al., 2010), a very susceptible crop, and to 40% in corn (Ghanizade et al., 2014), a crop more competitive with weeds.

The presence of the weed community also affected the distribution of dry mass between the vegetative and reproductive organs of eggplant (Figure 2). The eggplant leaves were the organs

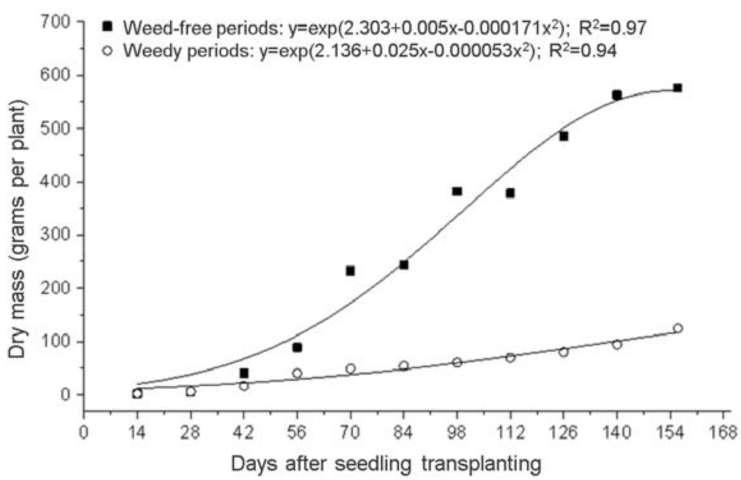

Figure 1 - Accumulation of dry mass in shoot of eggplant 'Nápoli' growing in increasing weed-free and weedy periods.

Table 1 - Inflection point and the respective accumulation of dry mass and macronutrients in shoot of eggplant 'Nápoli' growing in increasing weed-free and weedy periods

Variable	Weed-free		Weedy		Loss
	Point	Accumulation	Point	Accumulation	
	(DAT)	(mg kg^{-1})	(DAT)	(mg kg^{-1})	(%)
Dry mass	98	15.84	139	1.01	94
K	88	137.61	135	24.74	82
N	89	128.47	141	19.60	85
Ca	101	168.00	148	19.19	89
Mg	102	18.70	132	2.27	88
P	85	10.14	135	1.25	88
S	89	7.47	133	1.06	86

Table 2 - Maximum point and the respective accumulation of dry mass and macronutrients in shoot of eggplant 'Nápoli' growing in increasing weed-free and weedy periods

Variable	Weed-free		Weedy		Loss
	Point	Accumulation	Point	Accumulation	
	(DAT)	(mg kg^{-1})	(DAT)	(mg kg^{-1})	(%)
Dry mass	152	521.24	154	113.19	79
K	150	14,072.81	154	3,524.07	75
N	144	11,708.11	154	2,394.50	80
Ca	141	11,291.78	154	2,074.83	82
Mg	158	1,752.12	154	291.34	83
P	137	882.88	154	153.86	83
S	145	699.33	154	138.47	80

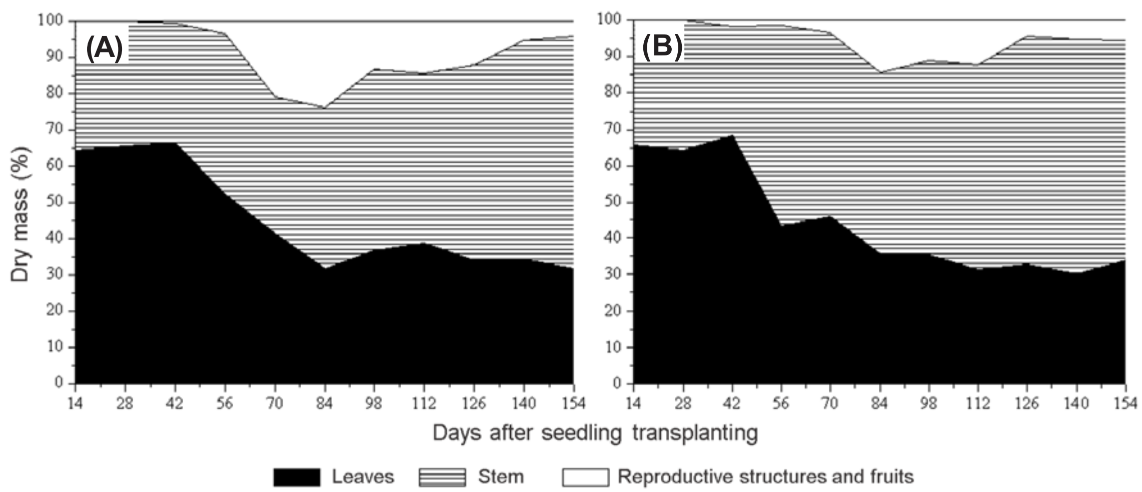

Figure 2 - Distribution of dry mass in leaves, stems and reproductive structures plus fruits of eggplant 'Nápoli' growing in increasing weed-free (A) and weedy (B) periods.

accumulating more dry mass at the beginning of the cycle, independently of the coexistence with weeds. However, leaves were the main organs accumulating dry mass (accumulation by >50%) in the weed-free crop up to 60 DAT and in the crop maintained in coexistence with weeds up to 52 DAT. After that, the stem began to accumulate more dry mass, becoming the most important organ (accumulation by >38%) after 75 DAT, in the weed-free crop, and after 56 DAT, in the crop maintained in coexistence with weeds. The reproductive structures plus fruits accumulated less dry mass, reaching a maximum accumulation of 24% in the weed-free crop and of 15% in the crop maintained in coexistence with weeds at 84 DAT.

The dry mass allocation in the stem to detriment of leaves, as observed in the eggplant crop maintained in coexistence with weeds, may be related to the attempt of the crop to overlap the canopy of the weed community, becoming taller the higher the weed competition (Carvalho et al., 2010; Cury et al., 2013).

The damage caused by weeds in agricultural crops is also observed in several other studies, such as, for example, in eggplant 'Criollo Lila', where it was found that weeds reduced stem diameter (Aramendiz-Tatis et al., 2010); and, in corn crop, where the weed interference reduced leaf area index and, consequently, the growth rate of the crop (Ghanizadeh et al., 2014).

Macronutrients

The decreasing order of macronutrient accumulation by eggplant was K>N>Ca> Mg>S>P in both crops maintained in the presence and the absence of weeds, being K the most required macronutrient (Figure 3). In experiments with omission of nutrients in eggplant, it was found that K is the element of greatest demand for the crop, followed by N and Ca (Flores et al., 2015). However, the accumulation of all macronutrients by eggplant was reduced in the presence of weeds, mainly after 42 DAT (K, N, P and S) and 56 DAT (Ca and Mg) (Figure 3).

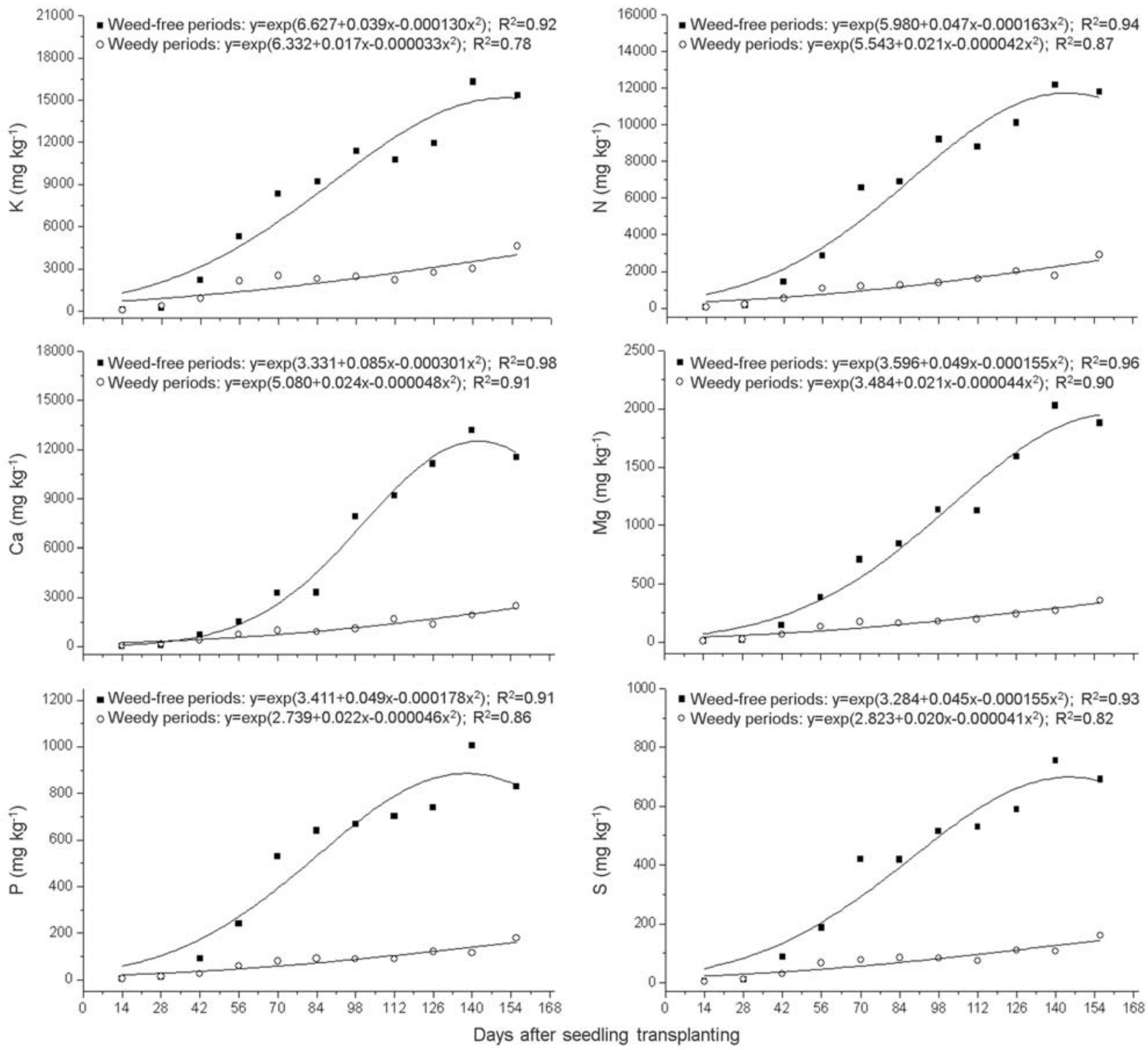

Figure 3 - Accumulation of macronutrients in shoot of eggplant 'Nápoli' growing in increasing weed-free and weedy periods.

In both crops maintained in the absence and the presence of weeds, respectively, there was increasing daily accumulation (inflection point) of K up to 88 DAT (137.61 mg kg^{-1} day^{-1}) and up to 135 DAT (24.74 mg kg^{-1} day^{-1}), of N up to 89 DAT (128.47 mg kg^{-1} day^{-1}) and up to 141 DAT (19.60 mg kg^{-1} day^{-1}), of Ca up to 101 DAT (168.00 mg kg^{-1} day^{-1}) and up to 148 DAT (19.19 mg kg^{-1} day^{-1}), of Mg up to 102 DAT (18.70 mg kg^{-1} day^{-1}) and up to 132 DAT (2.27 mg kg^{-1} day^{-1}), of P up to 85 DAT (10.14 mg kg^{-1} day^{-1}) and up to 135 DAT (1.25 mg kg^{-1} day^{-1}) and of S up to 89 DAT (7.47 mg kg^{-1} day^{-1}) and up to 133 DAT (1.06 mg kg^{-1} day^{-1}) (Table 1). These results indicate a smaller and slower accumulation of macronutrients by the crop maintained in coexistence with weeds, representing a reduction in nutrient accumulation by 82%, 85%, 89%, 88%, 88% and 86% for K, N, Ca, Mg, P and S, respectively (Table 1).

In the weed-free crop, there was maximum accumulation of K at 150 DAT (14,072.81 mg kg^{-1}), of N at 144 DAT (11,708.11 mg kg^{-1}), of Ca at 141 DAT (11,291.78 mg kg^{-1}), of Mg at 158 DAT (1,752.12 mg kg^{-1}), of P at 137 DAT (882.88 mg kg^{-1}) and of S at 145 DAT (699.33 mg kg^{-1}) (Table 2). On the other hand, similar to occurred for dry mass, it was not possible to estimate the maximum point, by the adjusted equation, during the crop cycle maintained in the presence of weeds. When the it was maintained in coexistence with weeds, the crop accumulated the maximum of K (3,524.07 mg kg^{-1}), N (2,394.50 mg kg^{-1}), Ca (2,074.83 mg kg^{-1}), Mg (291.34 mg kg^{-1}), P (153.86 mg kg^{-1}) and S (138.47 mg kg^{-1}) at 154 DAT (Table 2). These results confirm a smaller and slower accumulation of macronutrients by the crop maintained in coexistence with weeds, representing a reduction in nutrient accumulation by 75%, 80%, 82%, 83%, 83% and 80% for K, N, Ca, Mg, P and S, respectively (Table 2).

The crop maintained in the presence of weeds accumulated macronutrients more slowly and at smaller amount due to the weed interference. Reduction in the accumulation of N, P and K due to weed interference was also found in the vegetative components of beans, depending on the cultivar cropped (Cury et al., 2013). For soybean crop, Carvalho et al. (2010) found an average reduction in the accumulation of macronutrients next to 85% due to the weed interference. In a study comparing the accumulation of dry mass and macronutrients between weeds and crops, Carvalho et al. (2014) conclude that some weeds have a higher macronutrient content in relation to crops due probably to the facility for nutrient competition and the ruderal characteristics.

In studies carried out in the same field, *E. indica*, *N. physaloides* (Marques et al., 2016, 2017) and *A. tenella* (Marques et al., 2017) were also the most important weeds of the weed community that occurred in the eggplant crop. These authors observed that *E. indica* was more important at the beginning of the crop cycle due mainly to the plant density, while *N. physaloides*, a species with slower initial growth and longer cycle, was more important at the end of the cycle due to the accumulation of biomass. Both species *E. indica* and *N. physaloides* are common in fields of vegetables (Marques et al., 2016), as observed in other crops, such as okra, tomato, beet etc. Therefore, at the beginning of the cycle, the C4 weeds, e.g. *E. indica*, stand out for using more efficiently high temperatures and luminosity (Christin et al., 2014; Venâncio et al., 2014), conferring higher photosynthetic rates due to the wide spacing between the planting lines and the long period of time for shading the interrows by eggplant crop. However, large and longer-cycle plants, such as *N. physaloides*, tend to dominate the field in more advanced stages of the cycle, as observed by Marques et al. (2016, 2017) and other authors.

Weeds can reduce eggplant yield by more than 95% (Aramendiz-Tatis et al., 2010; Marques et al., 2016) due to direct interference. Reduction in the quality of fruits may also be found (Aramendiz-Tatis et al., 2010). In general, yield reductions by more than 90% were observed in vegetables, such as beets, carrots and tomatoes, as discussed by Marques et al. (2016). Although yield data were not presented in the present study, there was a reduction by more than 70% in the accumulation of dry mass and macronutrients in eggplant due to the presence of weeds. Therefore, a very significant reduction in crop yield is expected, as observed by Marques et al. (2016, 2017). There is a need for weed control so that yield reduction is not significant. As the accumulation of dry mass and macronutrients was significantly reduced when weeds coexisted with eggplant beyond 42 DAT, it is suggested the weed interference starts before this period. Aramendiz-Tatis et al. (2010) found the interference started soon after transplanting and lasted up to 40 DAT, while Marques et al. (2017) observed that weed interference started at 29 DAT and lasted up to 48 DAT. It is emphasized that the duration of the period of interference depends on several factors, including factors related to weeds and crops, as well as environmental and management aspects.

In conclusion, weeds affected the distribution of dry mass between the vegetative and reproductive organs of eggplant, changing the pattern of dry mass allocation in vegetative and reproductive organs, with greater accumulation in the stem to the detriment of leaves and fruits. As a consequence, the accumulation of dry mass and macronutrients was significantly reduced when weeds coexisted with eggplant beyond 42 DAT, reaching the maximum reduction of 79%, 75%, 80%, 82%, 83%, 83% and 80% in the accumulation of dry mass, K, N, Ca, Mg, P and S, respectively, when the coexistence persists throughout the crop cycle. Therefore, the weed community significantly affects the growth and mineral nutrition of eggplant 'Nápoli', so that no coexistence should persist beyond 28 DAT.

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