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MAIZE CULTIVATION UNDER DIFFERENT MANUAL WEEDING PERIODS

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ABSTRACT: Maize crop development is directly related to the rapid emergence and uniform growth of plants, which can significantly assist in the competitive ability for resources such as water, light and nutrients, and competition with invasive plants can limit the physiological stages of plants, preventing their development. Given the above, this work aimed to evaluate maize cultivation under different manual weeding periods. The experiment was carried out in April 2019, at the "Sebastiana Augusta de Moraes" Technical School, using maize hybrid AG1051. The experimental design was in randomized blocks with five treatments, that is, weeding was carreied out at 0, 15, 30, 60 and 75 days after sowing and four replicates , totaling twenty plots. Weeds reduce maize development, and the ideal control time is up to 45 days after sowing. For parameters average height of insertion of the first cob, average number of leaves and average stem diameter, it was observed that the accumulation of invasive plants affects maize development up to 45 days after sowing, and from that moment on, there is competition between maize plants themselves.

KEY WORDS: *Zea mays* L., weed competition, development.

CULTIVO DE MILHO EM DIFERENTES PERÍODOS DE CAPINA MANUAL

RESUMO: O desenvolvimento da cultura do milho está diretamente relacionado à rápida emergência e crescimento uniforme das plantas, o que pode auxiliar significativamente na habilidade competitiva por recursos como água, luz e nutrientes, a competição com plantas invasoras pode limitar os estágios fisiológicos da planta impedindo o seu desenvolvimento. Diante do exposto, este trabalho teve como objetivo avaliar o cultivo do milho em diferentes períodos de capina manual. O experimento foi realizado em abril de 2019, na Escola Técnica Sebastiana Augusta de Moraes, onde foi semeado o híbrido AG1051, o delineamento experimental foi em blocos casualizados com cinco tratamentos, ou seja, capina no período de 0, 15, 30, 60 e 75 dias após a semeadura e quatro repetições totalizando vinte parcelas. As ervas daninhas reduzem o desenvolvimento do milho, o tempo ideal de controle é até 45 dias após a semeadura. Para os parâmetros altura média de inserção da primeira espiga, número médio de folhas e diâmetro médio do caule, observou-se que o acúmulo de planta invasora afeta o desenvolvimento do milho até 45 dias após a semeadura, a partir desse momento há competição entre as próprias plantas de milho.

PALAVRAS CHAVE: *Zea mays* L.; mato competição; desenvolvimento.

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INTRODUCTION

Maize (*Zea mays* L.) has short life cycle and requires warm weather and adequate conditions for adequate development, and loss of production is due to the competitive effect provided by weeds, which also host insects, pests and diseases (Gharde et al., 2018). In total, weeds have the potential to cause losses of 32%, while insects cause losses around 18% and diseases around 18% (Evert et al., 2017). Maize and all other cultivated plants are subject to intra and interspecific weed competition, which may progressively increase over the course of the crop cycle (Swanton et al., 2015; Alcântara et al., 2018).

Weeds are invasive plants unwanted in production environments as they cause damage to the crop, as maize is sensitive to interferences, which can negatively impact productivity (Manabe et al. 2015) due to reduction in stem diameter, number of branches, leaf area and height (Rastegar et al., 2018). The increase in the number of weed species in conventional cultivation fields occurs mainly due to the use of quick-release nitrogenous fertilizers and herbicides at doses lower than those recommended (Storkey and Neve, 2018).

In Brazil, weed species in certain areas are dependent on the seed bank contained in the soil (Braz et al., 2016), where the main weeds present are "picão-preto" (*Bidens* ssp.), "corda-de-viola" (*Ipomoea* ssp.), "trapoeraba" (*Commelina benghalensis*). In addition to competition for space, nutrients and water, weeds can also harm crops through allelopathy, which causes poor development of plant tissues, especially in the plant establishment phase and even reduce germination (Dass et al., 2017). The interaction of weeds with crops of economic interest involves competition for light, considered the main limiting factor for crop growth, where shading overlaps one over the other (Zhang and Niu, 2016).

This negative response to weed competition may be a reflection of morphophysiological changes in the cultivated plant, which makes it necessary to understand these changes, which leads to greater leaf transpiration or even to reduction in the photosynthetic rate, consequently leading to less dry mass accumulation (Swanton et al., 2015; Alcântara et al., 2018).

The period before interference (PAI) occurs from sowing or emergence, when weeds can coexist with the crop without significant reduction in productivity and economic losses, which coexistence up to 21 days after emergence (DAE) has no effect on crop yield (Bianco et al., 2017). After this period, development problems in relation to high competition start to be detected, and the coexistence of the crop with weeds for 42 days after crop emergence provides losses of 21.65% in productivity (Santos et al., 2016).

Some important controls must carried out more quickly and others need a long period to be carried out, such as manual weeding, which is common in small areas and family farming (Barbosa et al., 2018), and postponing the removal of weeds in advanced stages usually requires more time and work, causing small farmers to spend 50 to 70% of their total time on the control ofweeds (Monteiro et al., 2016).

Therefore, this manual control method is very important, as it offers cheaper resources and ensures better weed control (Kumar et al., 2017). The use of herbicides is more constant and frequent in larger agricultural areas. However, the continued use of herbicides can change the weed flowering due to poor control, also causing resistance to herbicides. In this way, it is necessary to know the period that weeds cause greater damage to maize plants, becoming a strategy to control these plants before the critical point at which they start causing economic losses.

Given the above, this work aimed to evaluate maize cultivation under different manual weeding periods.

MATERIAL AND METHODS

The experiment was carried out in October 2019 at the "Sebastiana Augusta de Moraes" Technical School, located in the Municipality of Andradina, State of São Paulo, located at geographical coordinates 20°58'26.367"S and 51°19'15.565"W and altitude of 396 meters a.s.l. A randomized block design was used, with five treatments and four replicates, totaling 20 plots. Treatments consisted of the following manual weeding periods: T1: no weeding (zero); T2: weeding up to 15 days after sowing; T3: weeding up to 30 days after sowing; T4: weeding up to 60 days after sowing and T5: weeding up to 75 days after sowing. Soil was corrected and fertilized according to Raij et al. (1996) based on the soil chemical attributes as described in Table 1.

Table 1: Soil chemical attributes in the experimental area at the time of sowing.

pH	OM	P	K	Ca	Mg	H+Al	Al	SB	CEC	V%	m%
$CaCl_2$	g dm^{-3}	mg dm^{-3}	----------------------------- $mmol_c$ dm^{-3} -----------------------------								
5.4	13.0	10.0	2.8	13.0	10.0	18.0	0.0	25.8	43.8	59.0	0.0

OM: Organic matter; SB: Sum of bases; CEC: Cation exchange capacity; V%: Base saturation; m%: Saturation by aluminum.

Maize hybrid AG1051 was sown at population density of 60 thousand plants per hectare. Plots were composed by four rows of five meters in length with spacing between rows of 0.7 m, with three border rows that were not part of the useful area of the experiment. All phytosanitary treatments for the crop were carried out as required and recommended.

At stage R4, five plants were randomly sampled to determine the following parameters: height of insertion of the corn cob (HICC) determined through the use of a ruler graduated in millimeters; stem diamiter (SD) determined at 20 cm above ground level; number of leaves (NL) through direct counting and leaf area (LA), where leaf width and length were measured and then the crop correction factor was applied according to Abel et al. (2010). Leaves were also removed for nutritional diagnosis according to methodology described by Embrapa (2009), for the determination of the following nutrients: Nitrogen (N g kg^{-1}); Phosphorus (P g kg^{-1}); Potassium (K g kg^{-1}); Magnesium (Mg g kg^{-1}) and Calcium (Ca g kg^{-1}).

All variables were submitted to the F test ($p<0.05$) and regression analysis was performed, in which linear, quadratic and cubic models were tested, where the chosen model was based on the p value and R^2 value (Banzatto and Kronka, 2013). Pearson correlation was also performed and the R statistical software was used (R CORE TEAM, 2015).

RESULTS AND DISCUSSION

Quadratic response was observed for height of insertion of the corn cob (HICC) after the different manual weeding periods, as shown in Table 2. There was no significant effect on the number of leaves, which presented average of 13.62±0.42.

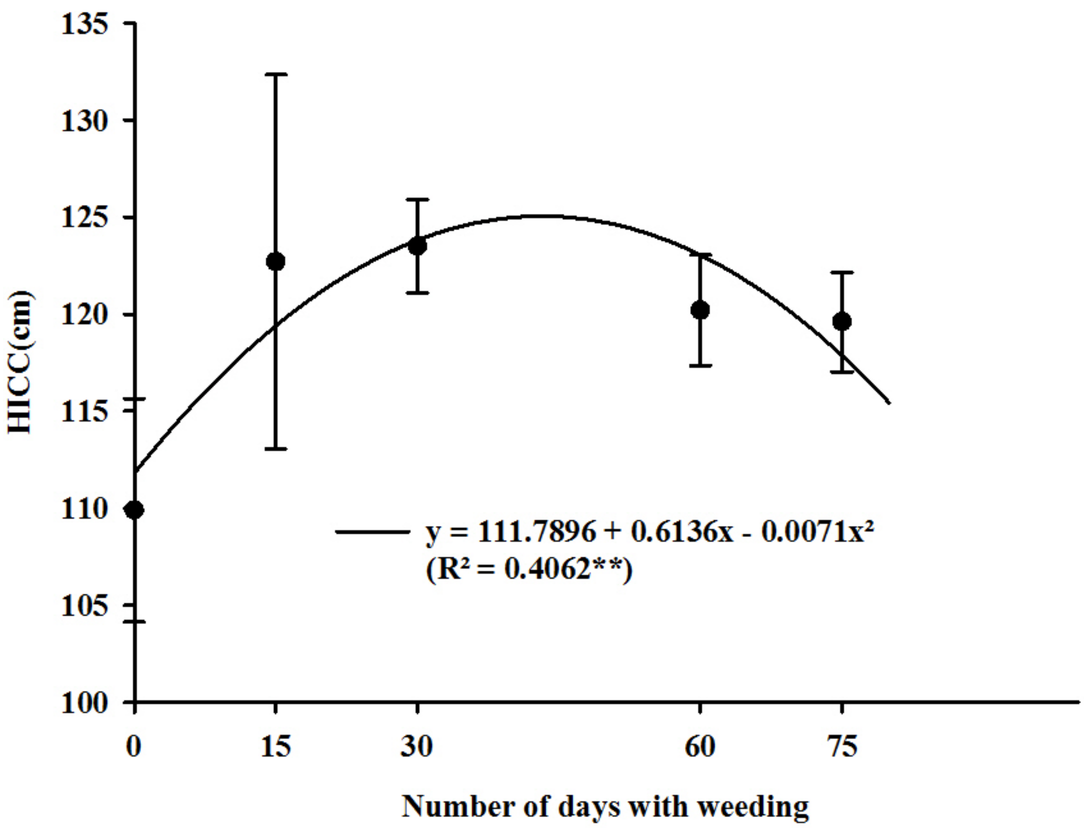
Table 2: P values of regressions of maize development parameters under different manual weeding periods , where the following models were tested: linear, quadratic and cubic. Andradina, 2019.

	HICC	CD	NF	LA
p value	292.6739	0.0048	0.0059	44964.3277
Regression	Q**	Q**	Ns	Q**

height of insertion of the corn cob (HICC); stem diamiter (SD); number of leaves (NL) and leaf area (LA). Ns p= 0.05; * 0.01=<p<0.05; ** p<0.01. Regression models : linear (L); quadratic (Q) and cubic (C).

In Figure 1 shows the height of insertion of the corn cob (HICC), in which the maximum point of manual weeding was up to 45 days after sowing.

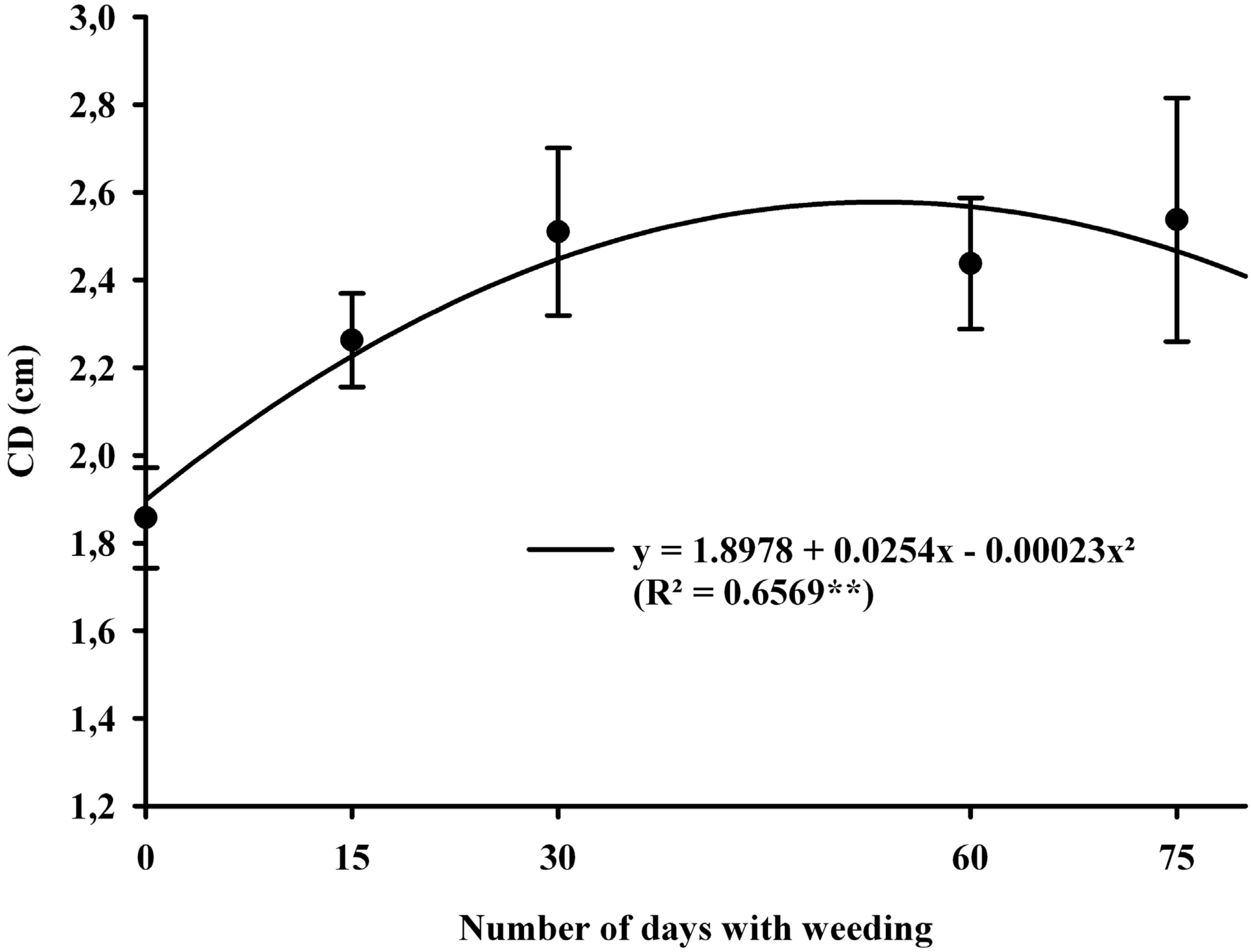
Figure 1: Average values of height of insertion of the corn cob (HICC) of maize grown under different manual weeding periods . Andradina, 2019.



This shows that weeds only interfere until 45 days after sowing; after that period, maize plants started to compete with each other for space and nutrients. In this way, the reduction in the average height of the insertion of the first cob is prpobabçy due to the fact that plant reallocates energy for growth in the initial stages to compete with weeds. This behavior occurs in situations of high weed populations, where plants respond with faster initial growth to overcome competition, with less crop development, weeds interfere throughout the crop cycle and can reduce plant development and characteristics (GALON et al. 2018).

Figure 2 shows the culm diamiter (CD), in which the results obtained with manual weeding with the intervention of weeds show an increase until the established day. Revealing that competition for growth factors available in the environment from the maximum point obtained, weeds no longer demonstrate competitiveness in the results, as corn has already overlapped with weeds and with that competition occurs around the crop itself. Figure 2 shows the stem diameter (SD), in which the results obtained with manual weeding with the intervention of weeds show increase until day 53 in the weeding period, revealing that regarding the competition for growth factors available in the environment from the maximum point obtained, weeds no longer demonstrate competitiveness in results, as the corn has already overlapped weeds and competition occurs around the crop itself.

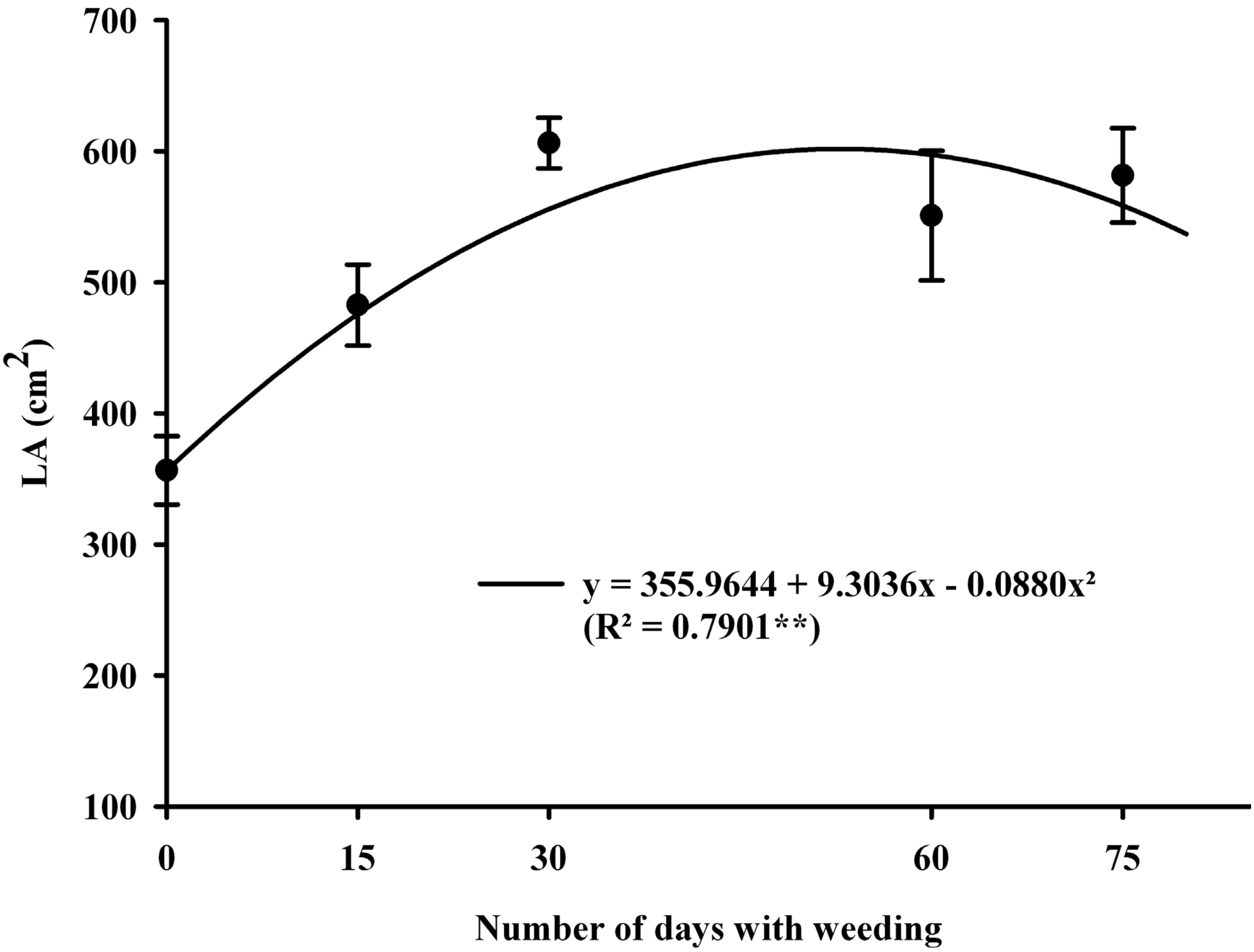
Figure 2: Average stem diamiter (SD) values of maize cultivated under different manual weeding periods . Andradina, 2019.



Studies relating the interference of weeds in the development of grasses in different spacing contributed to research, relating the decrease in stem diameter and plant height by the intraspecific competition behavior of the crop with undesirable plants (OLIVEIRA et al. 2016). Studies relating the interference of weeds in the development of grasses at different spacings demonstrated a decrease in stem diameter and plant height due to the intraspecific competition behavior with undesirable plants.As the population increases, the decrease in stem diameter may have been caused by interspecific factors, competition for light, water, space and nutrients, resulting in plants with smaller vegetative size, thus reducing the straw diameter , which consequently led to lower production gain (KRENCHINSKI et al. 2016).

Figure 3 shows the average leaf area of maize during its cycle with different manual weeding periods, where there was quadratic response and maximum point up to 55 days. Only two correlations were observed among variables analyzed in maize when submitted to different manual weeding periods as shown in Figure 6. When comparing the agronomic and productive characteristics of the maize culture in a sandy texture quartz neossol, it was observed that as the plant population increases, the stem diameter decreases (ALMEIDA JUNIOR et al. 2018), which phenomenon may be related to competition for light in denser plantings, resulting in larger plants with smaller stem diameter, and less dry mass gain (KAPPES et al. 2013).

Figure 3: Average leaf area (LA) values of maize cultivated under different manual weeding periods . Andradina, 2019.



Significant positive correlation between leaf area (LA) and stem diamiter (SD) was observed, while the expansion in the leaf area provides increase in stem diameter, which result was already expected, because larger leaf area leads to greater dry mass accumulation due to the increase in the photosynthetic rate of plants; however, negative correlation between K and Ca was observed (Figure 4), showing that with the increase in K concentration reduction of Ca concentration on leaves, as shown in Table 3.

Figure 4: Pearson's correlations among analyzed variables of maize submitted to different manual weeding periods . Andradina, 2019.

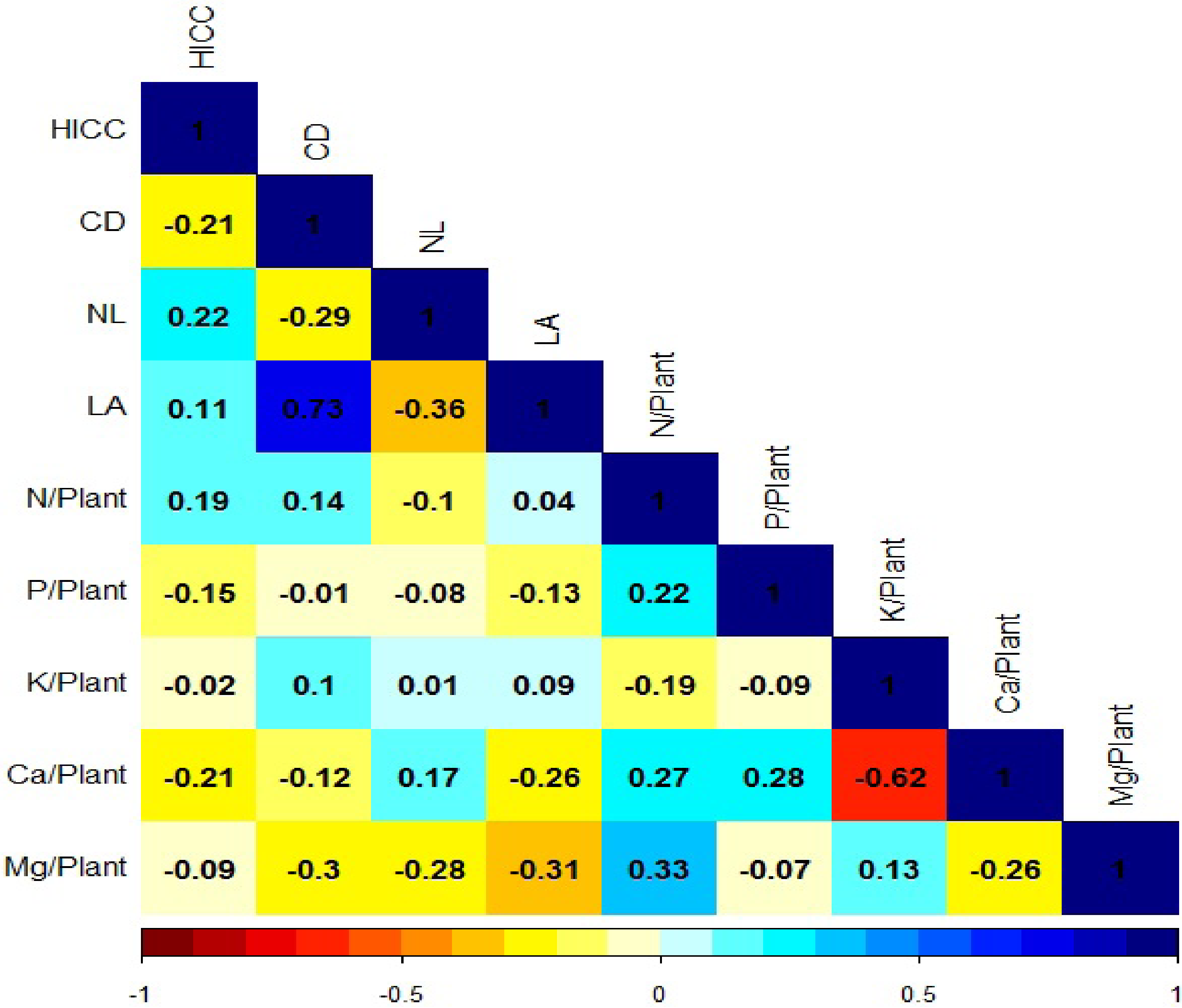


Table 3: Significant linear regressions after the Pearson correlation when maize was submitted to different manual weeding periods. Andradina, 2019.

Variable	Y = βo + βil + βjJ + ... + βnN	p value	R^2
SD (cm)	CD = 89.4082634 + 0.27595452 LA	0.0003**	0.5358
Ca (g kg-1)	Ca = 8.15137243 - 0.17229132 K	0.0021**	0.3796

There was reduction in leaf area due to weed competition in the maize crop, characterizing the dominance effect that consequently favored lower leaf area density, so that the photosynthetic rate was reduced, causing reduction in plant development (AGUIAR et al. 2019).

Thus, the presence of weeds during the crop cycle leads to greater demand for nutrients in the soil, which started to compromise its contents in plant shoots, as a positive linear response was observed for the nitrogen content in maize leaves submitted to different manual weeding periods as demonstrated in Table 4.

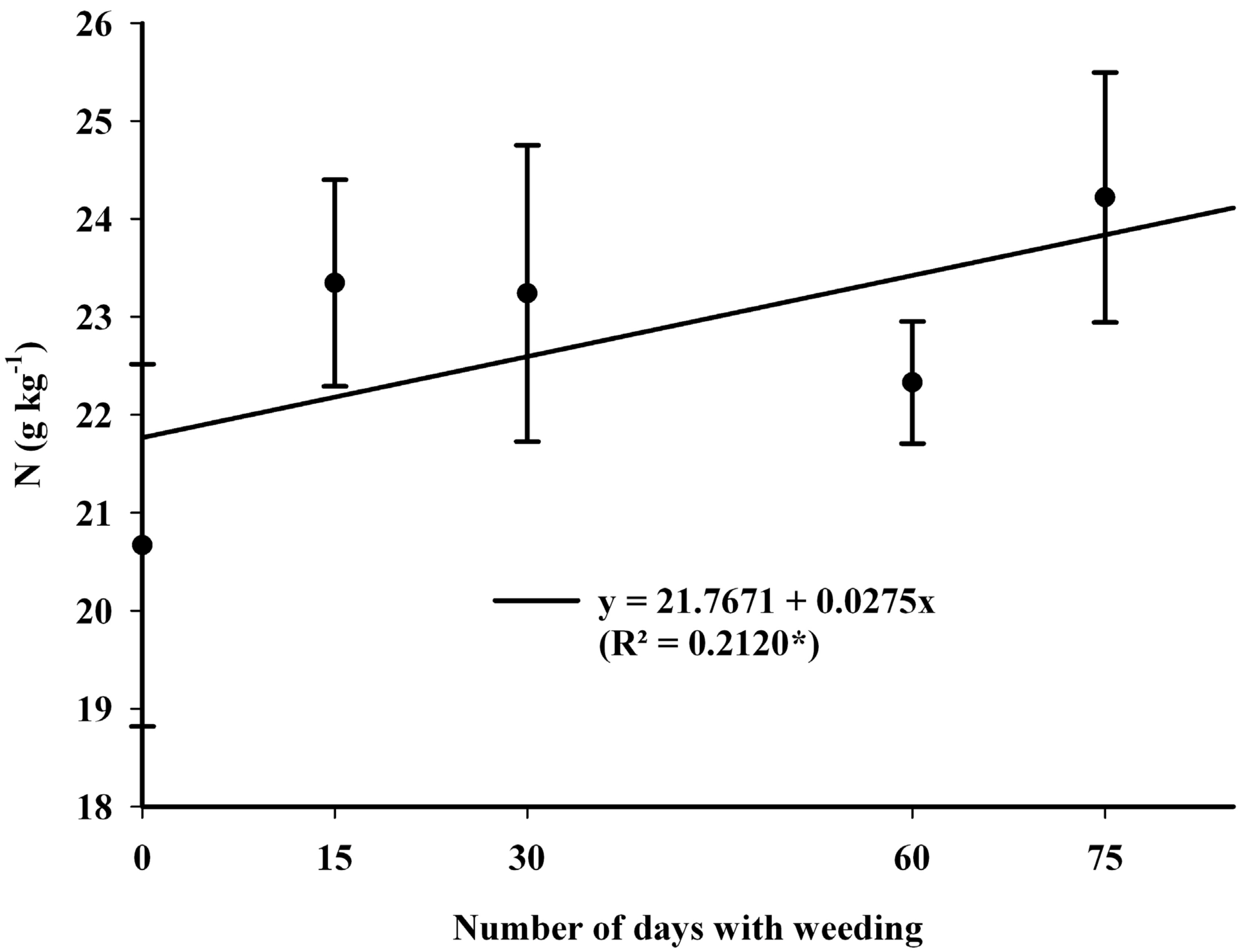
Table 4: P values of regressions of foliar nutritional contents of maize submitted to different manual weeding periods, where the following models were tested: linear, quadratic and cubic. Andradina, 2019.

	N	P	K	Mg	Ca
p value	0.0170	0.5698	0.8016	0.0003	0.9542
Regression	L*	Ns	Ns	L**	Ns

Ns p= 0.05; * 0.01=<p<0.05; ** p<0.01. Regression models : linear (L); quadratic (Q) and cubic (C).

This upward linear response can be well illustrated in Figure 5, with the presence of weeds competing against maize plants, starting to consume all nitrogen present in the soil and, thus, reducing the availability of this element to maize plants, showing that with the absence of weeding (day zero), maize had the lowest concentration of this nutrient.

Figure 5: Average leaf nitrogen content values of maize submitted to different manual weeding periods .



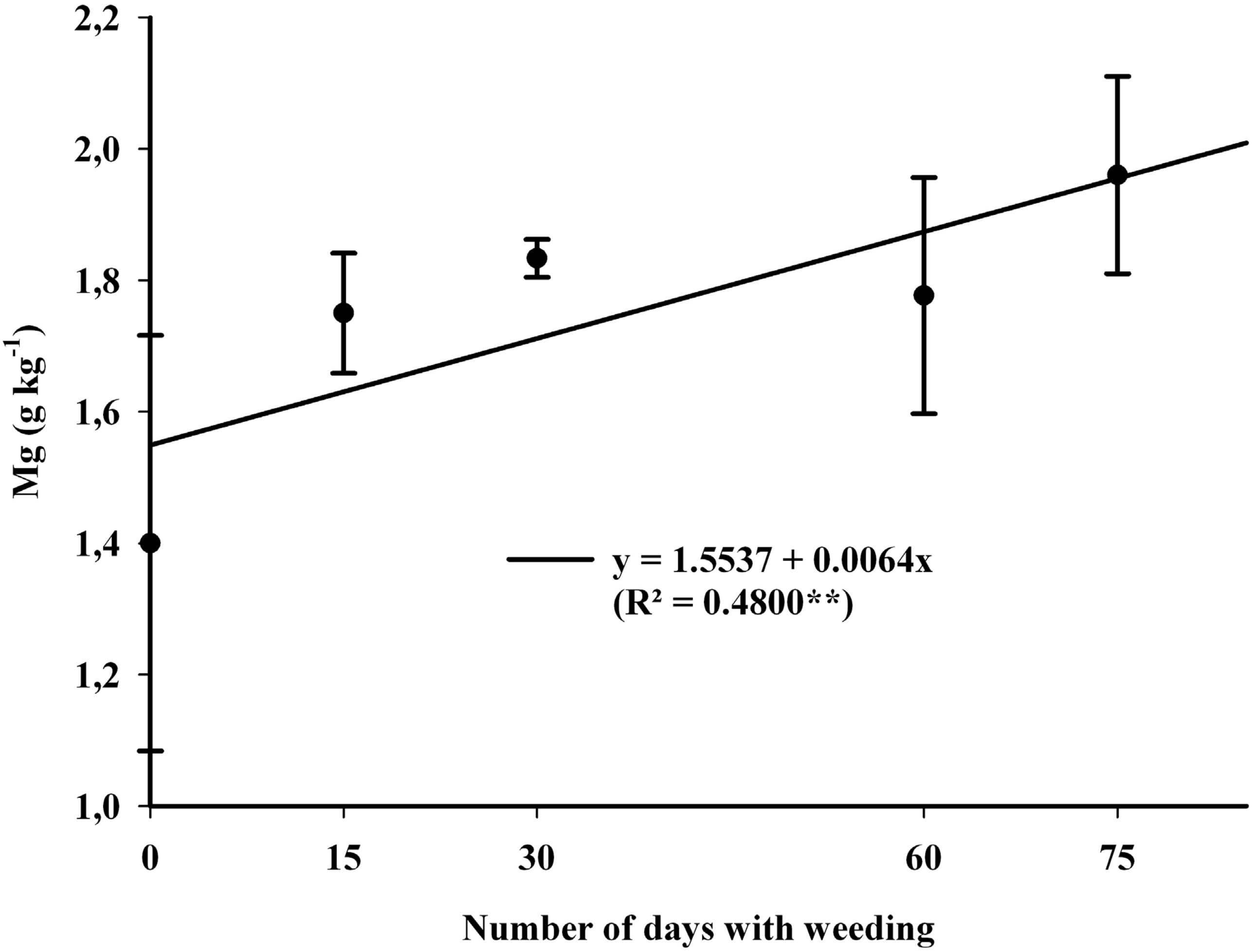
No significant differences were found in the phosphorus concentration, which presented overall average of 1.92±0.22 g kg^{-1}, potassium of 14.41±1.97 g kg^{-1} and calcium of 5.70±0.53 g kg^{-1} on maize leaves when grown under different weeding periods (Table 4).

When N deficiency occurs in plants, protein synthesis is compromised mainly by the action of enzymes that transport other nutrients and water, which further compromises plant development (Almeida et al. 2006). It is worth mentioning that this nutrient is present in the chlorophyll composition and when defficient, leaves become yellowish-green, which compromises the plant photosynthetic rate (TAIZ and ZEIGER, 2013).

Similar to nitrogen, magnesium also showed positive linear response with weeding periods, as shown in Figure 6.

This shows that with the absence of weeds competing with the maize culture, the nutrient concentration increased. Mg deficiency causes chlorotic changes in the leaves, which starts to compromise the photosynthetic rate of the plant, since the oxygen reaction center present in the chlorophyll molecule, thus leads to a lesser accumulation of dry mass which, consequently, less development mainly at the time of plant, which may explain the negative influence of the weed presence on the height of the ear insertion (Figure 1). Mg deficiency causes chlorotic changes in leaves, which compromises the plant's photosynthetic rate, an atom that is at the center of the oxygen reaction present in the chlorophyll molecule, which thus leads to lower dry mass accumulation, consequently reducing plant development, which may explain the negative influence of the presence of weeds on the ear insertion height (Figure 1).This nutrient also acts in the enzyme mainly as an activation cofactor, as it is the element that provides electrons to occur in the reaction and also acts in the homeostatic control of cells (KOCH et al. 2018).

Figure 6: Average leaf magnesium content values of maize submitted to different manual weeding periods .



Therefore, weeds reduce the maize plant development, and the ideal control time is up to 45 days after sowing. And, for parameters average height of insertion of the first cob, average number of leaves and average stem diameter , it was observed that the accumulation of invasive plant affects plant development up to 45 days after sowing, and from this moment on, there is competition between maize plants themselves.

REFERENCES

Abel, P.; Vieira Junior, P.A.; Dourado-Neto, D.; Bernardes, M.S. Methodology to estimate maize genotypes leaf area. *Revista Brasileira de Milho e Sorgo*, **2006**, 5, 2, 182-191. (In Portuguese) https://doi.org/10.18512/1980-6477/rbms.v5n2p182-191

Aguiar, A.C.M.; Silva, D.R.O.; Basso, C.J.; Soriani, H.H.; Novello, B.D.; Muraro, D.S. Interference of volunteer corn in growth and chlorophyll fluorescence of bean. *Revista Ceres*, **2019**, 66, 3, 210-219. https://doi.org/10.1590/0034-737x201966030007

Alcântara, L.M.S.; Lisboa, L.A.M.; Storti, S.M.M.; Lima, A.E.S.;Crispim, N.P.O; Silva, G.G.; Cardoso, A.S. Initial Development of Sunflower (*Helianthus annuus* L.) under Weed Competition with Different Species of Grasses. *Journal of Experimental Agriculture International*, **2018**, 29, 2, 1-11. http://dx.doi.org/10.9734/jeai/2019/45613

Almeida, E.V.; Natale, W.; Prado, R.M.; Barbosa, J.C. Nitrogen and potassic fertilization on development of passion fruit seedlings. *Ciência Rural*, **2006**, 36, 4, 1138-1142. In Portuguese http://dx.doi.org/10.1590/S0103-84782006000400015

Almeida Júnior, J.J.; Smiljanic, K.B.A.; Matos, F.S.A.; Miranda, B.C.; Oliveira, D.M.; Camargo, H.A. Agronomic characteristics and productivity in the culture of planted corn with different populations in the reign of mineiros state of Goiás. *Nucleus*, **2018**, 15, 2, 475-483. (In Portuguese) http://dx.doi.org/10.3738/1982.2278.2881

Banzatto, D.A.; Kronka, S.N. *Experimentação Agrícola*. 4.ed. Funep. **2013**, 237p.

Barbosa, J.A.; Franke, D.E.; Ferreira, S.D.; Salvalaggio, A.C.; Costa, N.V. Management of velvet bean on the weed suppression in the curly lettuce crop. *Journal of Neotropical Agriculture*, **2018**, 5, 2, 13-18. (In Portuguese) http://dx.doi.org/10.32404/rean.v5i2.1872

Bianco, K.G.; Gaetti-Jardim, E.C.; Brighenti, F.L.; Gaetti-Jardim Júnior, E. Evaluation of antimicrobial activity of plant extracts from Brazilian savanna on cariogenic cocci. *Archives of Health Investigation*, **2017**, 6, 4, 228-286. http://dx.doi.org/10.21270/archi.v6i4.1829

Braz, G.B.P.; Oliveira Júnior, R.S.; Constantin, J.; Raimondi, R.T.; Ribeiro, L.M.; Gemelli, A.; Takano, H.K. Weeds as alternative hosts for *Pratylenchus brachyurus*. *Summa Phytopathologica*, **2016**, 42, 3, 233-238. (In Portuguese) http://dx.doi.org/10.1590/0100-5405/2129

Dass, A.; Shekhawat, K.; Choudhary, A.K.; Sepat, S.; Rathore, S.S.; Mahajan, G.; Chauhan, B.S. Weed management in rice using crop competition-a review. *Crop Protection*, **2017**, 95, 45-52. http://dx.doi.org/10.1016/j.cropro.2016.08.005

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. *Manual de análises químicas de solos, plantas e fertilizantes*. 2 ed. Revista e ampliada. Ed. Silva FC. **2009**, 627p.

Evert, F.K.; Fountas, S.; Jakovetic, D.; Crnojevic, V.; Travlos, I.; Kempenaar, C. Big Data for weed control and crop protection: Big Data for weed control and crop protection. *Weed Research*, **2017**, 57, 4, 218-233. http://dx.doi.org/10.1111/wre.12255

Galon, L.; Bagnara, M.A.M.; Gabiatti, R.L.; Reichert Júnior, F.W.; Basso, F.J.M.; Nonemacher, F.; Agazzi, L.R.; Radunz, L.L.; Forte, C.T. Interference Periods of Weeds Infesting Maize Crop. *Journal of Agricultural Science*, **2018**, 10, 10, 197-215. http://dx.doi.org/10.5539/jas.v10n10p197

Gharde, Y.; Singh, P.K.; Dubey, R.P.; Gupta, P.K. 2018. Assessment of yield and economic losses in agriculture due to weeds in India. *Crop Protection*, **2018**, 107, 12-18. http://dx.doi.org/10.1016/j.cropro.2018.01.007

Kappes, C.; Arf, O.; Arf, M.V.; Ferreira, J.P.; Dal Bem, E.A.; Portugal, J.R.; Vilela, R.G. Seeds inoculation with diazotrophic bacteria and nitrogen application in side-dressing and leaf in maize. *Semina: Ciências Agrárias*, **2013**, 34, 2, 527-538. (In Portuguese) http://dx.doi.org/10.5433/1679-0359.2013v34n2p527

Koch, M.; Busse, M.; Naumann, M.; Jákli, B.; Smit, I.; Cakmak, I.; Hermans, C.; Pawelzik, E. Differential effects of varied potassium and magnesium nutrition on production and partitioning of photoassimilates in potato plants. *Physiologia Plantarum,* **2019**, 166, 4, 3350-3358. https://doi.org/10.1111/ppl.12846

Krenchinski, F.H.; Albrecht, L.P.; Pereira, V.G.C.; Albrecht, A.J.P.; Cesco, V.J.S.; Rodrigues, D.M.; Bauer, F. Phytosociological and floristic survey of weeds in Western Paran. *African Journal of Agricultural Research,* **2016**, 11, 17, 1543-1551. http://dx.doi.org/10.5897/ajar2016.10860

Kumar, N.H.; Baskaran, S.; Hariraj, S.; Krishnan, V. An Autonomous Aquaponics System using 6LoWPAN based WSN. *4th International Conference on Future Internet of Things and Cloud Workshops*, **2016**, 1, 125-132. http://dx.doi.org/10.1109 / W-FiCloud.2016.37

Manabe, P.M.S.; Matos, C.C.; Ferreira, E.A.; Silva, A.F.; Silva, A.A.; Sediyama, T.; Manabe, A.; Rocha, P.R.R.; Silva, C.T. Effect of weed competition in bean. *Bioscience Journal*, **2015**, 31, 2, 333-343. (In portuguese) https://doi.org/10.14393/bj-v31n2a2015-22271

Monteiro, A.L.; Silva, P.S.L.; Tavella, L.B.; Oliveira, F.H.T.; Silva, P.I.B. Mimosa caesalpiniifolia intercropping, weeds removal and nitrogen fertilization on maize. *Horticultura Brasileira*, **2016**, 34, 2, 175-182. http://dx.doi.org/10.1590/s0102-053620160000200005

Oliveira, R.M.; Aspiazú, I.; Silva, K.M.J.; Portugal, A.F.; Silva, A.F.; Carvalho, A.J. Weed interference in sweet sorghum sowed in different spacings in minas gerais semi-arid conditions. *Revista Brasileira de Milho e Sorgo*, **2016**, 15, 3, 481-500. (In portuguese) http://dx.doi.org/10.18512/1980-6477/rbms.v15n3p481-489

R CORE TEAM. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. **2015**. https://www.R-project.org/

Raij, B.; Cantarella, H.; Quaggio, J.A.; Furlani, A.M.C. *Recomendações de adubação e calagem para o Estado de São Paulo*. 2.ed. Campinas: IAC. **1996**, 279p.

Rastegar, A.; Zare, M.; Sharafzadeh, S.; Ordookhani, K.; Alizadeh, O. The effect of planting density and weed interference on agricultural traits of different rapeseed genotypes in darab region using multivariate statistical methods. *Nativa*, **2018**, 6, 3, 276-316. http://dx.doi.org/10.31413/nativa.v6i3.5965

Santos, T.T.M.; Timossi, P.C.; Lima, S.F.; Gonçalves, D.C.; Santana, M.V. Association of the herbicides diclosulam and glyphosate on soybeans burndown aiming residual control of weeds. *Revista Brasileira de Herbicidas*, **2016**, 15, 2, 138-215. (In portuguese) http://dx.doi.org/10.7824/rbh.v15i2.460

Storkey, J.; Neve, P. What good is weed diversity?. *Weed Research*, **2018**, 58, 4, 239-243. http://dx.doi.org/10.1111/wre.12310

Swanton, C.J.; Nkoa, R.; Blackshaw, R.E. Experimental Methods for Crop–Weed Competition Studies. *Weed Science*, **2015**, 63, 2-11. https://doi.org/10.1614/WS-D-13-00062.1

Taiz, L.; Zeiger, E. *Fisiologia vegetal*. 5. ed. Porto Alegre: Artmed. **2013**, 918p.

Zhang, Y.; Niu, H. The development of the DNDC plant growth sub-model and the application of DNDC in agriculture: A review. *Agriculture, Ecosystems & Environment*, **2016**, 230, 271-282. http://dx.doi.org/10.1016/j.agee.2016.06.017