REVISTA GESTÃO & SUSTENTABILIDADE AMBIENTAL ISNN 2238-8753 unisul ecossistema ânima

EVIDÊNCIA DE BENEFÍCIOS DE UMA ÁREA NATURAL PROMOVENDO A REDUÇÃO DE INJÚRIAS CAUSADAS PELA LAGARTA DO CARTUCHO EM PLANTAS DE MILHO

EVIDENCE OF BENEFITS OF A NATURAL AREA PROMOTING REDUCTION OF INJURIES CAUSED BY FALL ARMYWORM ON CORN PLANTS

EVIDENCIA DE LOS BENEFICIOS DE UN ÁREA NATURAL QUE PROMUEVE LA REDUCCIÓN DE LAS LESIONES CAUSADAS POR LA ORUGA MILITAR TARDÍA EN LAS PLANTAS DE MAÍZ

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RESUMO

Áreas naturais podem aumentar a quantidade de inimigos naturais (IN) de pragas agrícolas em áreas de cultivo. O nível de danos (ND) causado pela lagarta do cartucho em um cultivo de milho foi estudado em Sete Lagoas, MG. Testamos se o ND aumenta com a distância à área natural e se no período reprodutivo o efeito da distância sobre os novos danos se anularia. Avaliado o ND (450 plantas, cinco distâncias da área natural e cinco momentos), verificamos que o ND foi menor em plantas próximas à área natural e que foi homogêneo no período reprodutivo do milho. Isto sugere que os IN estão mais próximos da área natural, com mais recursos alimentares e que os IN têm distribuição homogeneizada devido a sua atração pelos recursos do período reprodutivo das plantas cultivadas. Sugere-se que a conservação da paisagem é essencial para reduzir danos de pragas em áreas de cultivo.

Palavras-Chave

Serviços ecossistêmicos; Milho; Agroecossistemas; Ecologia da paisagem; Inimigos naturais.

RESUMEN

Las áreas naturales pueden aumentar la cantidad de enemigos naturales (EN) de las plagas agrícolas. Se estudió en Sete Lagoas, MG, el nivel de daño (ND) causado por la oruga de cartucho en un cultivo de maíz. Probamos si el ND aumenta con la distancia al área natural y si en el período reproductivo el efecto de la distancia sería anulado. Después de evaluar los ND (450 plantas, cinco distancias y cinco momentos) encontramos que el ND era menor en plantas cercanas al área natural

y homogéneo en el período reproductivo del maíz. Esto sugiere que los EN están más cerca del área natural, con más recursos alimenticios y que tienen una distribución homogeneizada debido a su atracción por los recursos del período reproductivo de las plantas cultivadas. Se sugiere que la conservación del paisaje es esencial para reducir el daño de las plagas en las áreas de cultivo.

Palabras clave
Servicios ecosistémicos; Maíz; Agroecosistema; Ecología del paisaje; Enemigos naturales.

ABSTRACT
Natural areas can increase the number of natural enemies (NE) of agricultural pests in cultivation areas. The level of damage (LD) caused by the fall armyworm in a corn crop was studied in Sete Lagoas, MG. We tested whether the LD increases with the distance to the natural area and that the effect of the distance is null on the new damage in the reproductive period of corn. Rated the LD (450 plants, five distances and five moments), we found that the it was lower in plants close to the natural area and that it was homogeneous in the reproductive period. This suggests that the NE are closer to the natural area, with more food resources and that the NE have homogenized distribution due to their attraction to the resources of the reproductive period of plants. It is suggested that landscape conservation may reduce pest damage in cultivation areas.

Key Words
Ecosystem services; Maize; Agroecosystem; Landscape ecology; Natural enemies.

1 INTRODUÇÃO

Commonly human activities cause harsh alterations in the landscape and constitute a significant cause of biodiversity decline and consequent ecosystem services loss (Costanza et al., 1997; Rey Benayas and Bullock, 2012; Sutton et al., 2016). Alterations in the landscape result in a mosaic of forest remnants, urban areas, and misused agricultural lands (Laurance and Bierregaard, 1997) which reduces the total benefits from nature to human activities, including agriculture (Eastwood et al., 2016; Letourneau et al., 2012).

The forest remnants can maintain several benefits to human well-being and for agriculture, for example, increasing pollination (Werling et al., 2014), improving nutrients recycling (Sandhu et al., 2010), enhancing water storage (Richards et al., 2015), presenting more landscape aesthetics (Junge et al., 2011) and higher levels of pest control (Blubaugh and Kaplan, 2015; Davis et al., 2013). Notably, the natural enemies of crop pests benefit from forest remnants since they provide nesting sites and food resources to their populations (Ricketts, 2004; Seidl et al., 2020; Tianhong et al., 2010; Werling et al., 2014).

The contact of crop plants with natural ones (Farwig et al., 2009) or the distance between a cultivated plant and a natural area (Sousa et al., 2011) and the presence of flowering in the cultivated area (Carrié et al., 2012), all of them may affect the abundance of natural enemies and its beneficial action in crops. For example, the richness of parasitoids and their action preying on lepidopteran pests in California crops is negatively related to agricultural intensification, suggesting that semi-wild and perennial habitat maintenance can provide ecosystem services to short-cycle crop fields (Letourneau et al., 2012). In Germany, the presence of the semi-natural habitat may increase by 8-33% of the biological control done by predators and parasitoids of aphids in an intensively cultivated region (Redlich et al., 2018). On the Swiss plateau, insect pollination, and pest predation also are increased when crop diversification, protection of permanent grassland, and semi-natural habitats are increased (Sutter et al., 2017). Including in the cities, farmers from urban gardens have used several on-farm practices to improve diversification and to reduce insect pest populations by beneficial insect populations increase (Arnold et al., 2019). All these studies illustrate a just well-known positive correlation between landscape and biodiversity attributes with ecosystem services available for natural, urban, and crop areas (Harrison et al., 2014).

In Brazil, corn (*Zea mays* L.) is a crop of high economic and high social importance, being produced by the conventional and organic system and having insect pests causing massive losses (CABI, 2019; Cruz et al., 2002; Sousa et al., 2011; Zancanaro et al., 2012). The fall armyworm (*Spodoptera frugiperda* Smith – Lepidoptera: Noctuidae) is one of the significant corn pests in Brazil. Its larvae eat the corn leaves and when they are young, they skeletonize all the leaf lamina, but after, when at later instars, they make larger holes in leaves (CABI, 2019) and the damages caused may be estimated by a visual scale of injuries (Davis et al., 1992).

The principal used methods to control fall armyworms are chemicals and transgenic seeds in the conventional crop systems (Yang et al., 2016). In the organic crop systems, the use of methods for natural control of pests and diseases is more frequent (Tooker et al., 2020) since there is a growing interest in the use of more sustainable practices. One example of more sustainable practice is the maintenance of natural areas near the crop fields aiming for natural benefits as pest control did by beneficial organisms (Power, 2010; Sousa et al., 2011; Thierfelder et al., 2018; Thiéry et al., 2018).

Here, we evaluated fall armyworm injuries in corn plants considering a possible interference of a neighbor's natural area as a source of natural enemies to corn crop and considering the

flowering in corn plants as an essential and attractive resource to natural enemies which live in the adjacent natural area. So, we tested the two hypotheses: i) as farther is a corn plant to the natural area as more significant is its injury level and, ii) after the flowering season, the effect of the distance on the injury level is lost since the natural enemies attractivity in all corn crop is near the same.

2 MATERIAL AND METHODS

The study was carried out at Sete Lagoas, MG, Brazil, where the climate is tropical typical Savanna with hot and rainy summers with 1.340 mm annual precipitation and a mean annual temperature of 21ºC. We experimented with a corn crop with 2.4 ha located at 19°22'21"S and 44°06'57"W. The soil was worked with a heavy grid and leveler and was mechanically seeded using BRS 451 corn seed. Six seeds were used per linear meter of the row, and each row was spaced 0.70 cm. The chemical fertilizer N:P:K (4-14-8) in the 500 kg⁄ha concentration was used. Insecticides were not used in the area. This corn crop was located at the side of a Savanna remnant or about 2.0 ha.

The development of the corn plants has very well delimited stages (Table 1), and the fall armyworm injury was measured in five of these stages: V3, V7, V10, VT, and R1. For each of the selected stages, a visual rating injury scale (Davis et al., 1992) was used on corn plants (Zancanaro et al., 2012) applying values from 0 (zero) to 9 (nine), correlated to injuries on the plant (Table 2).

Table 1

Corn growth vegetative (V) and reproductive (R) stages with a summarized description.

Stage	Name and description
VE	Emergence. Shoot breaks through the topsoil surface.
V1	First leaf. Plant with one leaf collar visible.
V2	Second leaf. Two leaves with a visible collar.
V3	Third leaf. Three leaves with a visible collar.
Vn	Fourth to nth leaf. Plant with n leaf collar visible.
Vt	Tassel. The tassel has emerged; occurs transition to reproductive stages.
R1	Silk. Occurs emergence of silks.
R2	Blister. Kernels are like white blisters with a clear liquid inside.
R3	Milk. Yellow kernels with a milky inner fluid.
R4	Dough. Due to starch accumulation, the inner fluid becomes doughy.
R5	Dent. Kernels become dented and a milk line develops toward the kernel tip.
R6	Physiological maturity. Maximum dry matter development. There is a black layer at the kernel base.

Note: Adapted from Ritchie et al., 1986.

Three transects were determined parallel and separated by 50 m each of the other. For each transect were marked 30 fixed corn plants with six plants in each different five distances (0, 25, 50, 75, and 100 m) from the Savanna remnant. The six plants at each distance interval have attributed a value based on the injury scale level measured at five development stages (V3, V7, V10, VT, and R1). So, were took 450 injury level values with six plants for every five different distances, five different development stages, and three distinct transects.

Table 2

Injury scale level, from zero (0) to nine (9), used to evaluate fall armyworm damage on corn plants.

Level	Description
0	Plant without injuries.
1	Plant with injuries (points-form injuries).
2	Plant with injuries (points-form injuries) and from 1 to 3 small (until 1.5 cm) circle injuries.
3	Plant with 1 to 5 small (until 1.5 cm) circle injuries and with from 1 to 3 elongated injuries (until 1.5 cm).
4	Plant with 1 to 5 small (until 1.5 cm) circle injuries and with from 1 to 3 elongated injuries (larger than 1.5 cm and smaller than 3 cm).
5	Plant with 1 to 3 substantial elongated injuries (larger than 3 cm) in one or two leaves and with 1 to 5 elongated holes until 1.5 cm.
6	Plant with 1 to 3 substantial elongated injuries (larger than 3 cm) in two or more leaves and with 1 to 3 large holes with more than 1.5 cm in 2 or more leaves.

7	Plant with 3 to 5 substantial elongated injuries (larger than 3.5 cm) in two or more leaves and with between 3 and 5 large holes (larger than 1.5 cm) in 2 or more leaves.
8	Plant with more than 5 elongated injuries (with various sizes) in most of the leaves and with more than 5 large and intermediate holes with more than 3 cm in many leaves.
9	Plant with practically all the leaves destroyed.

Note: Adapted from Davis et al., 1992.

The dependent variable (rate from 0 to 9 of the visual rating injury scale) presents no homogeneity of variance and normal residues, so, the nonparametric procedure of Kruskal-Wallis (Zar, 2009) was used to test the first hypothesis that considers a distance effect between Savanna area and corn plants on the injuries' level. The same analysis was used to test the second hypothesis, which considers a nullity of distance effect on injuries' level when occurs flowering. The injuries' level measured at the VT stage was subtracted from that measured at the R1 stage, permitting to compare of added injuries' level at the time between VT and R1 stages, testing the second hypothesis. We used a Z-test for posteriori effects and for all tests a significance level of 5% was considered. All analyses were performed using Statistica 13.3 software (JPZ804I376009FA-9).

3 RESULTS AND DISCUSSION

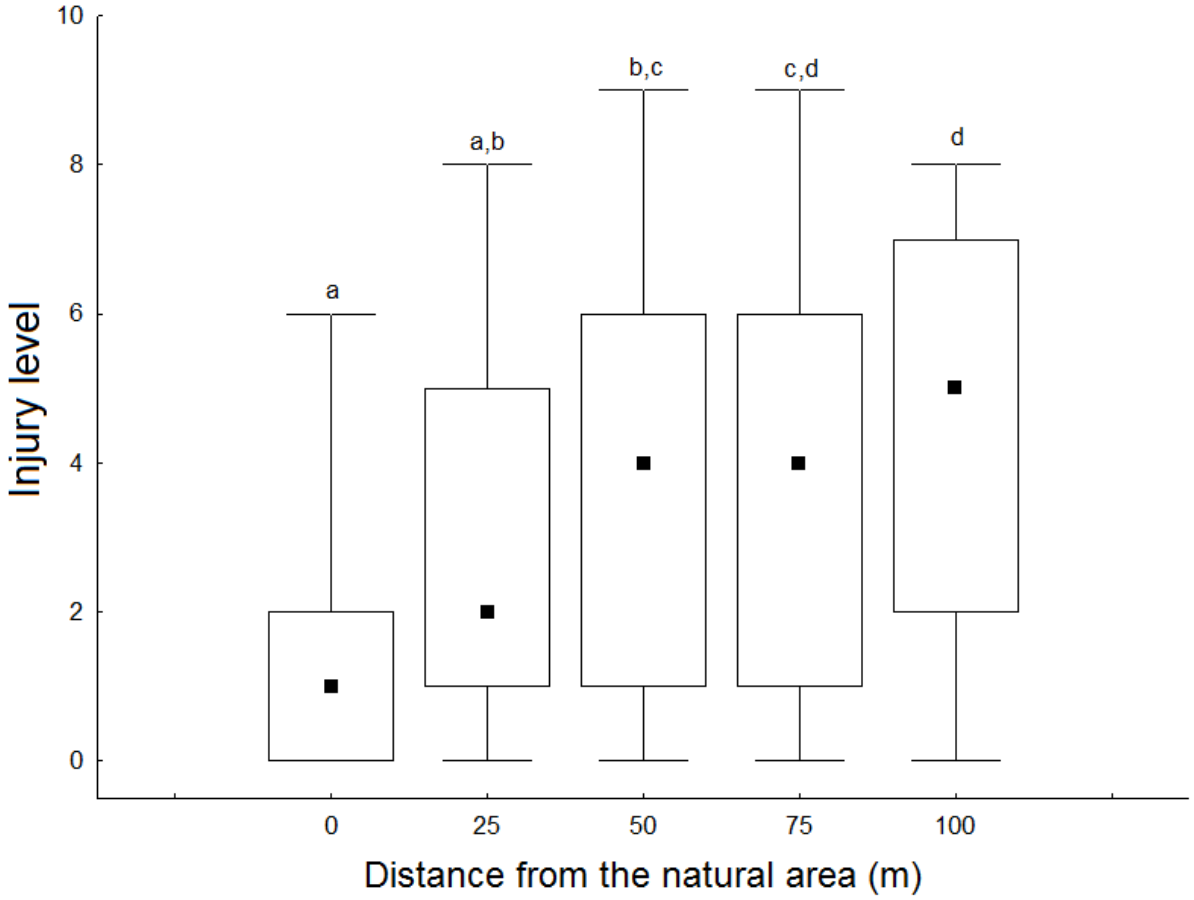
As predicted, how smaller the distance between corn plants and the natural area, the lower the injury level on corn leaves ($H_{(4,448)}$=59.431; p<0.001; Figure 1). When were isolated each one of the development stages there was no distance effect on injuries' level on stage V3 ($H_{(4,144)}$=7.499; p=0.111) but, this effect was present on stages V7 ($H_{(4,143)}$=46.712; p<0.001; Figure 2a), V10 ($H_{(4,143)}$=44.074; p<0.001; Figure 2b), VT ($H_{(4,141)}$=54.156; p<0.001; Figure 2c) and, R1 ($H_{(4,143)}$=53.267; p<0.001; Figure 2d), with injuries' level increasing with the distance of natural area. As also supposed, there was no effect of the distance of natural area on corn plant injuries' level when only injuries between VT and R1 stages were considered ($H_{(4,89)}$=2.787; p=0.594).

In general, distance from the Savanna environment affected measured injury level caused by the fall armyworm to corn plants. The absence of effect on stage V3 may be due to small-time since plants emerged from seeds (about 14 days). Studies have suggested that biodiversity conservation nearby the agroecosystems has a critical function in maintaining natural enemies of crop pests (Carrié et al., 2012; Seidl et al., 2020) due to, for example, the activity of Hymenoptera

and Diptera using nectar and pollen as food resources (Jervis et al., 1992; Menalled et al., 2000) and the action of parasitoid adults feeding on flowers (Carrié et al., 2012).

Figure 1

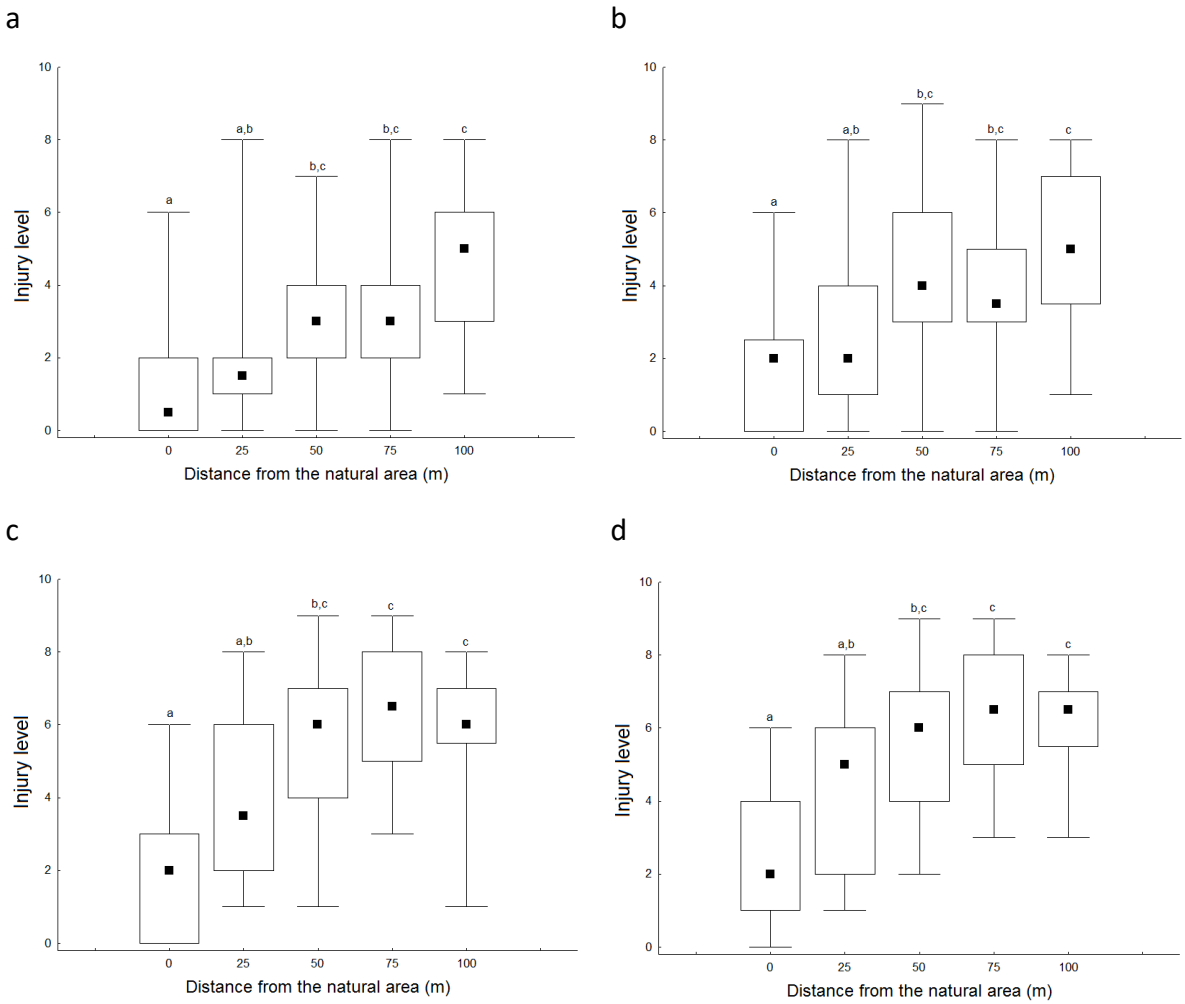
Injury level of corn plants in the function of the different distances from a natural area at Sete Lagoas, MG, Brazil.



Due to the flowering, available resources ate the R1 stage was homogenous in the corn crop, and this factor probably affected the action of natural enemies in the corn crop that was homogeneous at this time. Currently, benefits from natural enemies to the corn plants are independent of the distance of plants to the natural area. So, the regular distribution of floral resources across the corn crop permitted homogenization of the benefits from the natural enemies in the corn crop.

Figure 2

Injury level in corn plants due to the different distances from the natural area at Sete Lagoas, MG, Brazil, considering the V7 (a), V10 (b), VT (c), and R1 (d) stages.



Indeed, since the invasion time of the pests on the field occurs between V1 and V3 stages, the natural enemies do not prevent crop losses at more considerable distances. However, if farm owners can place inside or around the crop other perennials or annuals plants, able to produce a large mass of flowers (Carrié et al., 2012) before and during the invasion of pests in the corn crop, it is probable that natural enemies increase their population abundance and optimize their distribution on the field, preventing crop losses caused by pests like the fall armyworm.

The more complex agroecosystems may increase benefits to the corn crop due to the more diverse content of natural enemies (Castro et al., 2020; Seidl et al., 2020; Vandermeer et al., 2010; Veres et al., 2013). The use of secondary crops and the maintenance of the natural areas are an

example of good practices to help farm owners to obtain benefits from the environment, maximizing their profits (Redlich et al., 2018; Sutter et al., 2017). In fact, for more than one decade, the conservation agriculture practices are preconized by the Food and Agriculture Organization of the United Nations aiming to improve diversification and save natural resources which may increase farmers and crop resilience to external factors including better pest populations control did by beneficial insects (FAO, 2011).

4 CONCLUSION

Here we find a natural and beneficial process from a natural area to a crop: the decrease of the injury level in cultivated plants (Figure 1, Figure 2). The influence of the natural area reduces injury level and certainly improves the economic value of the crop, but also, the perceived economic and social value of the natural areas to adjacent crops by farmers. However, we measured only effects on injury level. It is important to understand and to sum to the decrease of injury level, the probable beneficial actions of beneficial soil microorganisms, seed predators, or pollinators all of them observed in natural areas and in crops (Castro et al., 2020; Cheatham et al., 2009; Zhang and Swinton, 2009; Latini et al., 2020; Suárez et al., 2022). So, to invest efforts in the study of other processes may improve understanding and comprehensive using of natural areas to adjacent crops, as so its conservation.

Acknowledgments

The first author was supported by a scholarship from Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) and Pró-Reitoria de Pesquisa e Pós Graduação da Universidade Federal de São João del-Rei (UFSJ).

Authorship contribution statement

The two authors contributed to conceptualization, methodology, supervision, data acquisition, analysis, and validation. They also equally contributed to writing the first and final versions of the manuscript.

Declaration of competing interest

The authors declare no conflicting economic interests or personal connections that could have emerged to influence the work described in this paper.

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