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Population fluctuation of sucking insects in irrigated and non-irrigated cotton crops

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ABSTRACT

In the cotton crop (*Gossypium hirsutum L.*), there is a complexity of pests that appear systematically, thus significantly reducing crop yield; and their population fluctuation is strongly influenced by meteorological conditions that result in a greater or lesser density of these insects. Thus, this work aimed to evaluate the population fluctuation of insect pests with sucking feeding behavior in an area with and without irrigation in the cotton plant under second-harvest conditions. The experiment was developed at the State University of Maringá - Campus of Umuarama. In the experimental area, grid meshes of 10 × 10 m were demarcated, forming plots of 100 m², resulting in a total of 64 points in the irrigated area and 42 points in the non-irrigated area. The sampling points were demarcated in the center of each grid where three randomly selected plants were sampled. Samplings were carried out weekly, from 37 to 122 days after the emergence (DAE) of cotton, examining the aerial part of the plant, to observe the presence of aphids (*Aphis gossypii*), thrips (*Frankliniella schultzei*), and whitefly (*Bemisia tabaci*). The non-irrigated area provided the highest population peaks of whiteflies and thrips. On the other hand, the irrigated area had a higher incidence of aphids. However, with the increase in the population of ladybugs, the incidence of pests reduced significantly, showing the efficiency and importance of the control carried out by natural predators.

Keywords: *Gossypium hirsutum* L, *Aphis gossypii*, *Bemisia*, Irrigation.

Flutuação populacional de insetos sugadores em algodão irrigado e não irrigado

RESUMO

Na cultura do algodão (*Gossypium hirsutum* L.) há um complexo de pragas que ocorrem sistematicamente e reduzem significativamente a produtividade, e sua flutuação populacional é fortemente influenciada pelas condições meteorológicas, resultando em maior ou menor densidade desses insetos. Dessa forma, o objetivo do trabalho foi avaliar a flutuação populacional de insetos-praga com comportamento alimentar sugador em área com e sem irrigação no algodoeiro, nas condições de segunda-safra. O experimento foi desenvolvido na Universidade Estadual de Maringá - Campus de Umuarama. Na área experimental foram demarcadas malhas em grid de 10 × 10 m, formando parcelas de 100 m², resultando em um total de 64 pontos na área irrigada e 42 pontos na área não irrigada. Os pontos amostrais foram demarcados no centro de cada grid onde foi realizada a amostragem de três plantas, selecionadas aleatoriamente. As amostragens foram realizadas semanalmente, dos 37 aos 122 dias após emergência (DAE) do algodão, examinando-se a parte aérea da planta, com intuito de observar a presença de pulgões (*Aphis gossypii*), tripes (*Frankliniella schultzei*) e mosca-branca (*Bemisia tabaci*). A área não irrigada proporcionou os maiores picos populacionais de mosca-branca e tripes. Por outro lado, a área irrigada apresentou maior incidência de pulgão. Porém, com o aumento populacional de joaninhas, a incidência da praga reduziu significativamente, mostrando a eficiência e importância do controle realizado por predadores naturais.

Palavras-chave: *Gossypium hirsutum* L, *Aphis gossypii*, *Bemisia*, Irrigação.

1. Introduction

Cotton (*Gossypium hirsutum* L.) is one of the main economically exploited crops worldwide (Stopar et al., 2021; Yuan; Sun, 2021). Currently, Brazil is the 4th largest cotton producer in the world, surpassed only by India, China, and the United States (ABRAPA, 2021). The versatility of products and by-products obtained from the cotton plant is one of the main attractions of this culture, as its fiber is the main product meant for the textile industry. The cotton seed, rich in oil, is used in some human food products, in the manufacture of margarine and soap, in addition to by-products such as cake from cottonseed, which is used in animal feed (Neves et al., 2017; Alves et al., 2021).

Conducting the second-crop cotton crop appears as an option for planting in the state of Paraná, and its implementation in irrigated systems can guarantee production stability with important increases in productivity and quality of fiber produced (EMBAPA, 2014). However, like any other crop, cotton can be susceptible to damage caused by a complexity of pests that occur systematically, and that can drastically reduce production if the management of these pests is not carried out correctly and at the right time Nadeem et al. (2022). In this case, it is a great challenge to keep the infestation level under control (Chi et al., 2021).

Monitoring is the first foundation of integrated pest management programs, as it provides a precise diagnosis of the situation regarding the occurrence of pests, subsidizes decision-making on the most appropriate strategies for controlling insects, and above all aims at the rational use of resources like insecticides (Borém and Freire, 2014). The monitoring of insects present in the cultivation area must be carried out throughout the crop's development cycle, taking into account the climatic variation that occurs in this period, due to its direct influence on the occurrence and population peaks of insects (Silva, 2022). The main abiotic factors that influence the distribution and abundance of insects are time, radiation, temperature, humidity, light, wind, and their interactions (Held, 2020).

According to Alves et al. (2020), among the main pests that occur in the cotton crop, it is possible to observe the presence of some that have a sucking feeding behavior, such as the aphid *Aphis gossypii* Glover (Hemiptera Aphididae), thrips *Frankliniella schultzei* (Trybom) (Thysanoptera: Thripidae), whitefly *Bemisia tabaci* (Gennadius) (Heteroptera: Aleyrodidae). These insects, in addition to causing direct damage by sucking the sap, can also act as transmitters of disease agents for plants (Miranda, 2010).

According to Gibb (2015), with monitoring, it is possible to collect and identify the insects present in the crop and monitor their behavior when exposed to climate variations in a given period. Thus, population surveys are carried out, which are used in studies of pest dynamics to determine the density, fluctuation, and migration of insect populations. By carrying out the survey and studying the population fluctuation of crop pests, it is possible to make evident the dependence of the distribution and abundance of insect species on all environmental factors (Nadeem et al., 2022). Thus, this work aimed to evaluate the population fluctuation of insect pests with a sucking feeding behavior in an area with and without irrigation in the cotton plant under second-harvest conditions.

2. Material and Methods

The experiment was carried out at the State University of Maringá, at the Regional Campus of Umuarama – Fazenda. The experimental area is located at 23°47' south latitude, 53°15' west longitude, and at an altitude of 401 meters. According to the Köeppen classification, the climate of the region is of the type (Cfa) Peel et al. (2007), mesothermal humid subtropical, and according to IAPAR (2014), the region presents an annual average temperature of 24°C and precipitation of 1600 mm. In addition, the soil in the experimental area is classified as a typical dystrophic red oxisol, with a sandy texture (EMBRAPA, 2018).

Cotton sowing was carried out adopting a row spacing of 0.90 m with a seeder adjusted to 11 seeds per meter, resulting in an estimated population of 122,000 plants·ha^{-1}. The cotton variety used was characterized by an early cycle with GLTP technology (association of GlyTol®, LiberrtyLink®, and TwinLinkPlus® technologies), which provides high performance in controlling caterpillars. It is noteworthy that the TwinLink® technology has genes from *Bacilis thurungiensis* (Bt), allowing the control of the main caterpillars found in cotton. The plant population was carried out in an area irrigated by conventional sprinklers and in a non-irrigated area. The soil has chemical characteristics that are shown in Table 1.

Based on the values of the elements in Table 1, fertilization was carried out with 100 kg·ha-1 of the 10-15-15 formula, following the soil analysis and recommendation of the technical bulletin on fertilization and liming of the Instituto Agronômico de Campinas (IAC) (Raij et al., 1997). The experimental area was demarcated with meshes that had a dimension of 10 × 10 m, resulting in grids with 100 m². The plots were identified, totaling 106 points, 64 points in the irrigated area and 42 points in the non-irrigated area, where three plants were randomly selected for insect population evaluation.

Table 1. Chemical characterization of the soil found in the experimental area.

pH	P	M.O.	Ca	K	Mg	Al	CTC	V
$CaCl_2$	mg dm^{-3}	g dm^{-3}	-------------------$cmol_c$ dm^{-3}--------------------					%
4.50	14.89	14.87	1.25	0.16	0.37	0.30	4.97	35.99

P and K extracted with HCl 0.05 mol L^{-1} + H_2SO_4 0.025 mol L^{-1}; organic matter extracted by the Walkley-Black (1934) method; Ca, Mg and Al extracted with KCl 1 mol L^{-1}

The evaluations were carried out visually, consisting of the identification and counting of whiteflies, aphids, thrips, and coccinellids in the aerial segments of the evaluated plants, and on each sampling date a general sampling of all the vegetative and reproductive structures of the plants was carried out, to arrive at the number of insects present, with fortnightly samplings between 37 and 122 days after emergence (DAE), totaling seven evaluations. Irrigation management was carried out via climate, with reference to evapotranspiration (ETo), calculated by the method proposed in the FAO Bulletin 56 (Allen et al., 1998), with methodology adapted from the Penman-Monteith method, as shown in Equation (1):

$$ETo = \frac{0.408 \cdot S \cdot (Rn - G) + \gamma \cdot \frac{900}{Ta+273} \cdot u_2 \cdot (es - ea)}{S + \gamma \cdot (1 + 0.34 \cdot u_2)} \quad (1)$$

where: (S) is the tangent to the saturation vapor pressure curve in air; (Rn) is the net radiation, in MJ m-2 d-1; (G) is the heat flux in the soil, in MJ m-2 d-1; (Ta) is the average air temperature, in °C; (u2) is the wind speed at 2 m, in m s-1; (es-ea) is the vapor pressure deficit, in kPa e; (γ) is the psychrometric constant.

The meteorological data were obtained using an automatic meteorological station installed next to the experimental area, and with the reference of evapotranspiration data, it was possible to obtain the crop evapotranspiration (ETc) through the product of the ETo with the crop coefficient (Kc) for the cotton crop according to Doorenbos and Kassam (1979). Thus, the applied irrigation depth was found through the ratio between the ETc and the application efficiency (Ea), considering an Ea of 0.80.

The station performed readings of maximum, average, and minimum temperature, maximum, average, and minimum relative humidity, global solar radiation, atmospheric pressure, wind speed, and direction with data storage every 15 and 60 minutes and 24 hours. With the meteorological data, the station was programed to calculate and store vapor pressure deficit (DPV) and reference evapotranspiration (ETo) data. Crop evapotranspiration (ETc) was obtained through the product of ETo with the crop coefficient (kc) of cotton provided by Doorenbos and Kassam (1994). With the ETc data, rainfall, and irrigation carried out over the period of development of the experiment, it was possible to calculate the water balance of cotton cultivation.

To carry out the data analysis, we initially verified whether the statistical assumptions of the main effects being additive, the independent and normally distributed errors, and the homogenous variances were satisfied. The evaluated parameters were submitted to a normality test, using the Shapiro-Wilk test, and a homogeneity test using the Levene test. With the data collected during the evaluations, the average number of insects per plant was obtained and diagrams were created that represent the population fluctuation of insects during the course of the experiment, using spreadsheet and graphic editing software. With the meteorological data and the average number of insects per plant, the Pearson correlation coefficients between these variables were estimated. The hypothesis that the Pearson correlation coefficient is equal to zero (H0: 0) was evaluated using the t-test, with the analyses being performed using the statistical software R (R, 2021).

3. Results and Discussion

As temperature is one of the main abiotic factors that interfere with the population fluctuation of insects, Figure 1 presents the decendial data of minimum, average, and maximum temperatures for the microclimate of the experimental area. The maximum and minimum values of temperatures observed during the development of the cotton plant were 36.06 and 1.13ºC, respectively. Despite some days with maximum temperatures above the critical temperature superior to the development of the cotton crop (35ºC) according to Rosolem et al. (2014), the cotton plant was developed in meteorological conditions with temperatures below this limit in most of the crops. On the other hand, from 90 DAE of the plant, the minimum temperatures constantly observed remained below 21ºC considered the lower minimum temperature limiting the development of the crop (Rosolem et al., 2014). Temperatures below the minimum critical point slow down the plant's metabolism, and the main implication is the loss of young flowers in formation, which ends up directly interfering with production (Snider and Kawakami, 2014). Cotton water balance data over the 172 days of cultivation in the irrigated (Figure 2A) and non-irrigated areas (Figure 2B), provided information on the deficit and surplus of water stored in the soil, as well as the volume of precipitation during the development of culture.

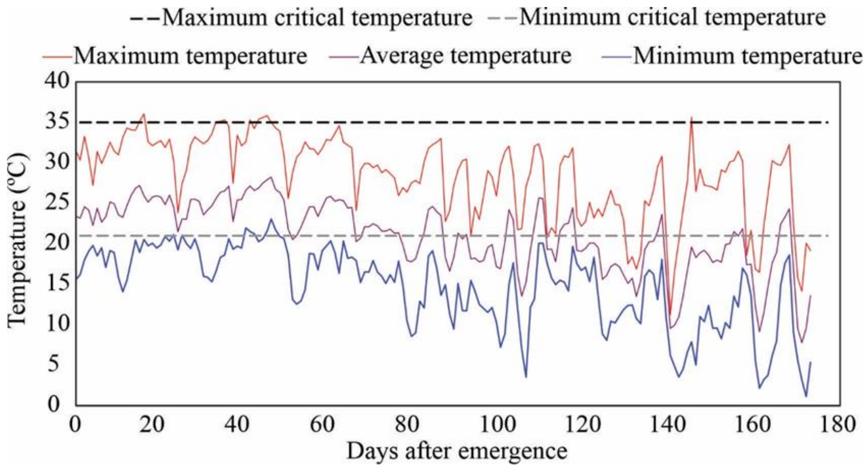

Figure 1. Upper and lower critical temperatures and maximum, average, and minimum temperatures were observed during the development of cultivated cotton in the northwest of the State of Paraná. * Decendial values.

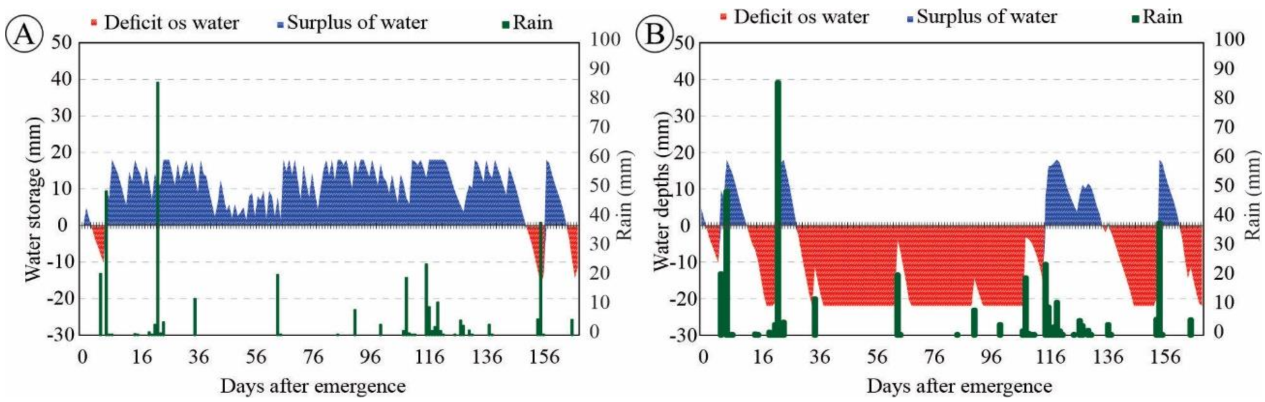

Figure 2. Water balance and precipitation throughout the development cycle of cotton cultivated in Umuarama/PR.

It can be seen that throughout a large part of the cultivation cycle, the water balance of the irrigated area (Figure 2A) presented a water surplus, indicating that the soil moisture was at moisture levels that allowed the plant to maintain its maximum evapotranspiration. In the period between two and seven DAE, irrigation was not carried out because the plants were in the emergence and germination phase, which justifies the occurrence of a water deficit in the soil. After 150 DAE, irrigation was stopped and for this reason, water deficit values are observed in the soil. Regarding the non-irrigated area (Figure 2B), the long period of water deficiency, verified between the period from 30 DAE to 110 DAE, stands out.

Monitoring the water deficit in the soil can indicate whether the plant is in a possible induction of water stress, and within this condition, Miranda (2010) proposes that sucking insects such as aphids, mealybugs, and whiteflies could benefit in terms of food, especially due to the higher concentration of nitrogen and soluble sugars present in the sap of plants induced by stress. This assertion can be confirmed by Oliveira et al. (2014), who found greater population growth of the mealy cochineal *Ferrisia dasylirii* (Cockerell) (Hemiptera: Pseudococcidae) in cotton plants subjected to water deficiency.

The main pest of the crop, the cotton weevil (*A. grandis*) was observed in the adult phase in only two evaluations, first in the non-irrigated area, occurring in the 3rd evaluation (64 DAE), while in the irrigated area it was present only in the sixth evaluation (106 DAE) with the observation of four insects. It is noteworthy that due to the installation of the experiment with the cotton crop taking place in new planting areas, the occurrence of the cotton boll weevil was considered incipient.

Figure 3 shows the population fluctuation of the main insects identified in irrigated and non-irrigated cotton cultivation in the experimental area, such as whitefly (*B. tabaci*), aphid (*A. gossypii*), and thrips (*F. schultzei*). From Figure 3A, it was possible to observe that the whitefly had its occurrence recorded in the culture shortly after the emergence of the seedlings, until the end of the cycle, confirming the statements by Barros et al. (2019), that this insect occurs throughout the period of crop development. However, the population peak of occurrence of this pest in the irrigated area was reached in the first evaluation (37

DAE), with an average of seven adults of *B. tabaci* per plant. From then on, its population remained below the level of economic damage, considered to be three or more adults per leaf (Edde, 2021).

At 41 DAE, chemical control was carried out using a systemic insecticide of the neonicotinoid chemical group. From then on, a reduction in the pest population was observed in the following evaluations, which was decisive for maintaining population levels below the level of economic damage in all areas following evaluations in the irrigated area. In turn, in the non-irrigated area (Figure 3A), the insect population had a population peak of approximately 7.4 whitefly adults per plant, verified in the sixth evaluation (106 DAE). In Figure 3A, it is possible to observe that the number of points with *B. tabaci* was higher in the area without irrigation, except in the 1st (37 DAE) and seventh assessment (122 DAE), on these dates, both areas had populations below the level of damage. This result can be explained by the decision to apply the chemical control carried out in the area without irrigation at 117 DAE.

According to Edde (2021), the conditions that favor the whitefly population increase are high temperatures and dry seasons. Non-irrigated areas suffered for a long period without rainfall (Figure 2B). In the non-irrigated area, there was a higher average of individuals in five evaluations, respectively, in the second evaluation with 54% more *B. tabaci*, third evaluation with 27%, fourth evaluation with 29%, fifth evaluation with 12%, and sixth evaluation with 80% compared to the irrigated area. Thus, in the irrigated area, higher insect averages were obtained only in the first evaluation with a higher average of 15% of whiteflies and in the seventh evaluation with 38% more occurrence of *B. tabaci*.

Figure 3B shows the population fluctuation per plant of thrips (*F. schultzei*), observed on each assessment date in irrigated and non-irrigated areas. The presence of *F. schultzei* was observed from the first evaluation (37 DAE) to the sixth evaluation (106 DAE), with a population peak verified in the fourth evaluation (78 DAE) and sixth evaluation (106 DAE), in areas without and with irrigation, respectively. In both areas, the peak population approached 10 thrips per plant. These higher population peaks occurred after the formation and opening of flower buds, confirming the statements by Barros et al. (2019), that in this period, the population of *F. schultzei* increased because the insect feeds on the grain of cotton pollen. In addition, the higher incidence of the insect in the area without irrigation (Figure 3B) occurred due to the low humidity favoring the development and population growth of this species (Borém and Freire, 2014).

From the previous information, it is evident why the level of economic damage was overcome in the irrigated area only in the fourth (78 DAE) and fifth evaluation (92 DAE), with an average greater than six thrips per leaf (Abdelraheem et al., 2021). On the other hand, in the non-irrigated area, the average occurrence of thrips was higher in the third, fourth, and fifth evaluations, with a population of 11, 23, and 48% higher when compared to the population in the irrigated area.

Aphids (*A. gossypii*) were observed throughout the evaluation period (Figure 3C), confirming the statements by Barros et al. (2019), that the insect can occur throughout the cotton crop cycle. The population peak was verified in the fourth evaluation (78 DAE) with the record of the presence of approximately 70 aphids per plant in the irrigated area. In this same evaluation, the population peak of the insect in the non-irrigated area was also verified, corresponding to 54 aphids per plant, certifying the statements by Barros et al. (2019), that the insect has a preference for the initial-intermediate phase (70 days) of the crop, which is the moment when its highest population peaks occurred.

In addition, the reason why the highest population peak was observed in the irrigated area can be explained by the insect's preference for humid and warm environments (Miranda, 2010; Edde, 2021). From the evaluations carried out, it was observed that in the irrigated area, aphid populations were higher in evaluations 3, 4, and 5, when compared to the non-irrigated area. In percentage terms, the superiority was 72.9, 29.7, and 0.43%, respectively, for evaluations 3, 4, and 5. In the other evaluations, the non-irrigated area exceeded the irrigated area by 51.7; 27; 68.7, and 75.6% for evaluations 1, 2, 6, and 7, respectively.

Borém and Freire (2014) consider that the level of aphid control occurs when values greater than 50% of plants with the presence of aphid populations are verified, having been verified in both areas in the fourth, fifth, and sixth evaluations, and only in the irrigated area in the third and seventh evaluations. Thus, the economic damage level was not reached only in the first and second evaluations in both areas and the seventh evaluation of the non-irrigated area.

Regarding the natural control of these insects, ladybugs are efficient natural predators of aphids, so Figure 5 shows the total number of aphids (Figure 4A) and ladybugs found in the experimental area throughout the evaluations. According to Barros et al. (2006), it is expected that the population of predators related to the aphid presents a high population proportional to that of the aphids. This statement can be verified in Figure 4.

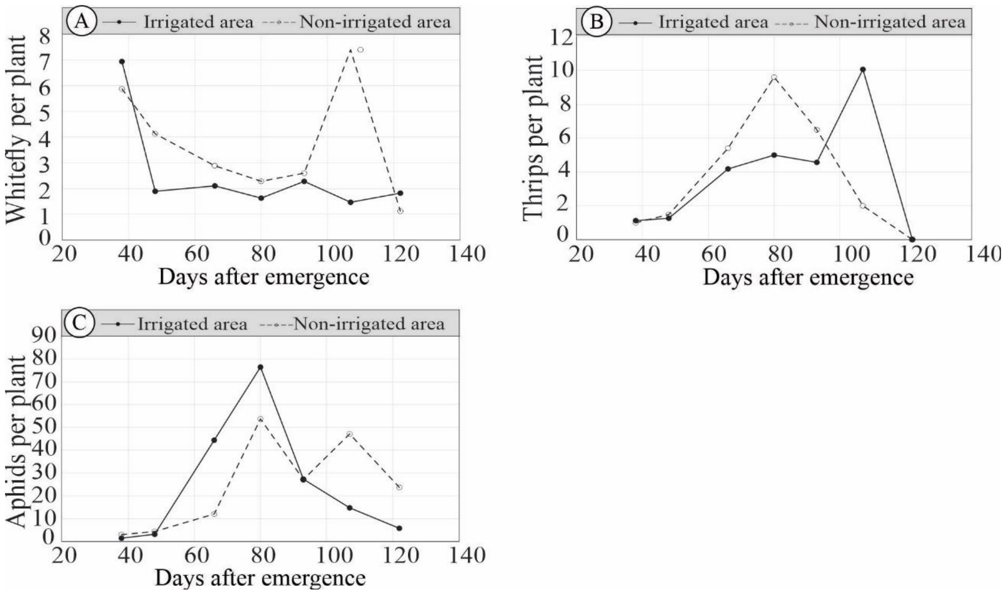

Figure 3. Population fluctuation of whitefly (A), thrips (B), and aphids per plant (C) in irrigated and non-irrigated areas over the seven evaluations carried out in the experimental area.

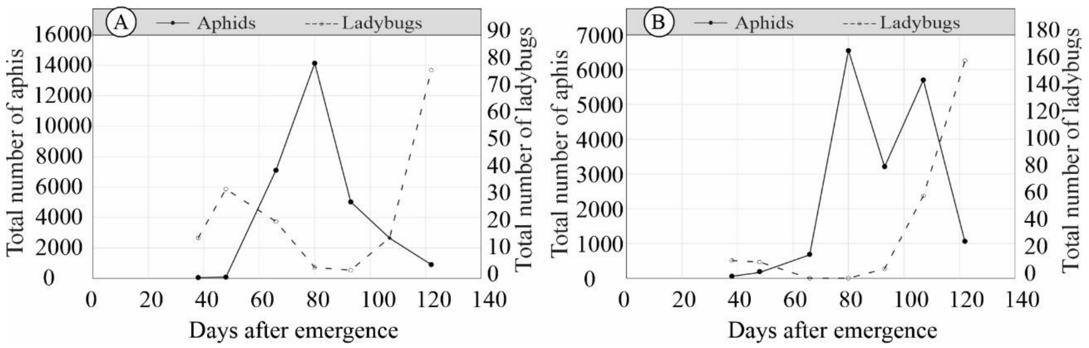

Figure 4. Population fluctuation of ladybug predators and aphids was observed in irrigated (A) and non-irrigated (B) areas during the evaluations carried out.

Aa characteristic increase in the number of aphids is observed in the fourth evaluation in the irrigated area (Figure 4A), and in the non-irrigated area (Figure 4B), a behavior that resulted in an increase in the populations of ladybugs in post-plague evaluations. One of the observed consequences of the increase in ladybugs in the evaluated periods was the concomitant decrease in the aphid population in both areas. The ladybugs found in the area were *Cycloneda sanguinea* (Linnaeus, 1763), *Eriopis connexa* (Germar, 1824), and *Hippodamia convergens* (Guerin-Meneville, 1842), all of the order Coleoptera and Family Coccinelidae. It is noteworthy that, for the conditions of this work, each species was not considered individually, as observed (Figure 4) the general context of occurrence of coccinellids was evaluated, since all species can be considered as important predators of aphids (Fiorentin et al., 2013; Moreira et al., 2022).

Pests of economic interest to the crop were also identified, such as green belly bug (*Diceraeus melacanthus*), brown bug (*Euschistus heros*) (Hemiptera: Pentatomidae), and angora beetle (*Astylus variegatus*) (Germar, 1824) (Coleoptera, Dasytidae). Due to the low presence of insects, it was not possible to create diagrams that represented their population fluctuations. Figure 5 shows Pearson's correlation considering insects (populations of aphids, ladybugs, and whiteflies), as well as meteorological elements (temperature, relative humidity, vapor pressure deficit, and solar radiation).

Figure 5 was built with data from meteorological elements obtained during the population survey evaluations carried out in areas with and without irrigation. It is noteworthy that the meteorological elements present a very strong correlation with each other, especially when considering the vapor pressure deficit (DPV), the temperature, and the average relative humidity of the air in Figure 5 (A) and (B). When observing the correlations between insects and meteorological elements, it is worth highlighting the existing correlations between aphid populations and climatic conditions. The correlation between aphids and relative humidity (RH) for the irrigated area (Figure 5A) is characterized as being a negligible correlation (-0.3).

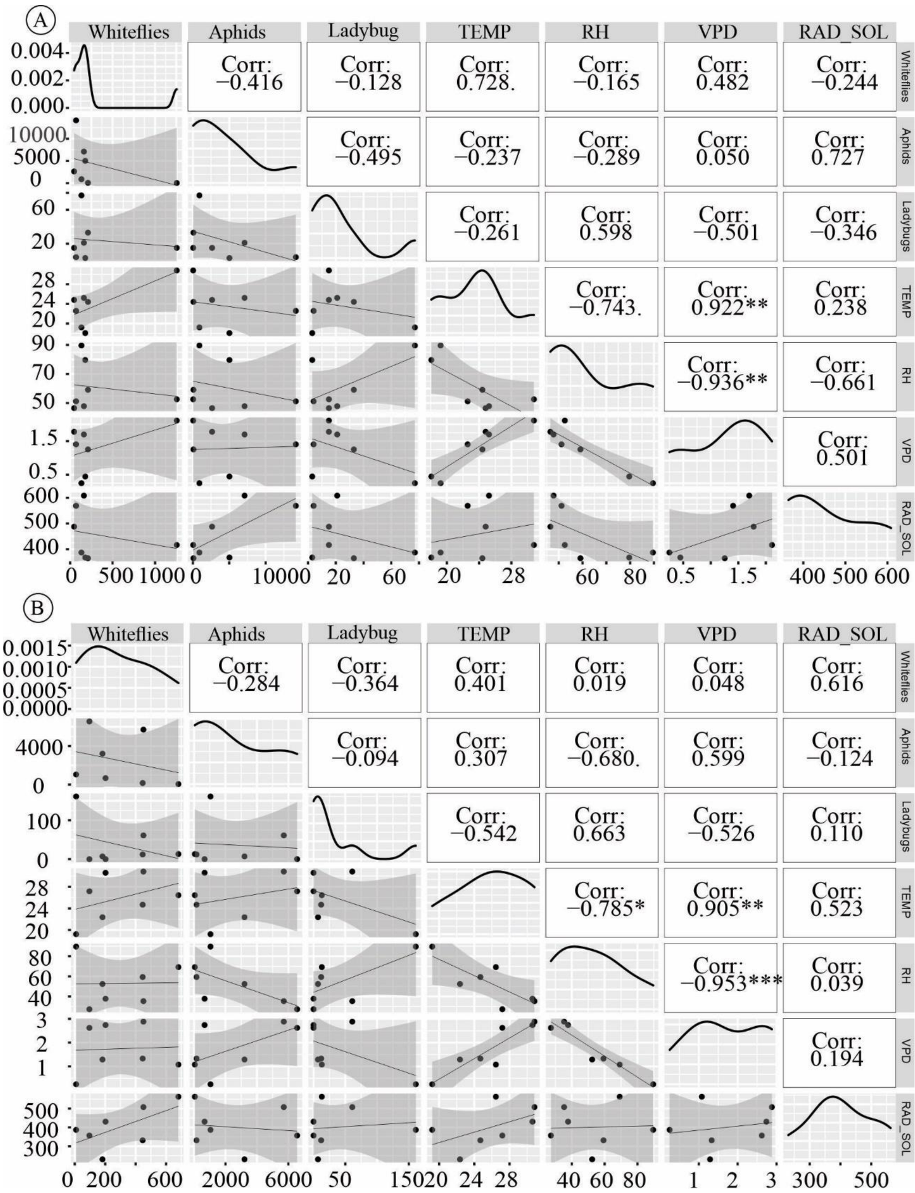

Figure 5. Correlation between aphids, ladybugs, and whiteflies found during cotton cultivation in irrigated (A) and non-irrigated areas (B) and the meteorological elements temperature (TEMP), relative humidity (RH), vapor pressure deficit (VPD) and solar radiation (RAD_SOL).

For the non-irrigated area (Figure 5B), this correlation becomes strongly negative (-0.7) and this result suggests that the higher the RH of the air, the lower the aphid populations, creates a microclimate over the leaf canopy, increasing the relative humidity of the air close to this layer. A strong negative correlation between aphid populations and relative air humidity was verified by Cividanes and Cividanes (2010) and Ramos et al. (2018) who indicate that this result may occur due to the pattern of variation in the population density of different species of aphids being linked to numerous factors that contribute to differences in their population dynamics. Honek (1985) confirms that aphid species are similarly influenced by meteorological factors and have similar characteristics in abundance and preference for favorable microclimates. However, it is not clear what the real influence of relative humidity is on the dynamics of these populations. Therefore, specific research must be developed to better understand this behavior.

The same effect is noticeable for the meteorological element DPV, where a negligible correlation is observed in the irrigated area and a strong positive correlation (0.6) in the area without irrigation, indicating that when there is an increase in this meteorological variable, aphid populations tend to increase. A possible explanation for these results is based on the soil-plant-atmosphere interaction, as low RH values and high DPV values result in increased plant transpiration. In an irrigated area (Figure 5A), with the soil presenting conditions for the plant to absorb water and keep its plant cells always turgid, plant transpiration is greater, reducing water evaporation (Marin et al., 2017), making the environment more humid due to the microclimate that arises there.

Because the soil does not have moisture that allows transpiration at its maximum rate, the plants cultivated in the non-irrigated area (Figure 5B) may have remained with their non-turgid plant tissue for a longer time, which according to Huberty and Denno (2004), concentrates nitrogen and sugars in the plant sap, favoring the attraction and population growth of these pests. Another important point to be mentioned is that, when analyzing Figure 5, it is noticed that the increase in ladybug populations resulted in a decrease in aphid populations, in both areas, which confirms that ladybugs are effective natural predators of this insect plague (Jiang et al., 2020). However, there was no correlation between them (Figure 5).

4. Conclusions

From the results, it is concluded that insects tend to move along a moisture gradient, looking for more favorable conditions for their development, avoiding excesses of humidity as well as the lack of it. Thus, the non-irrigated area provided higher population peaks of whiteflies and thrips. On the other hand, the irrigated area had a higher incidence of aphids. Ladybugs proved to be efficient in natural aphid control.

Authors' Contribution

Cleverton Timóteo de Assunção contributed to the writing of the manuscript, supervision, analysis of results, and final correction of the manuscript. Daniel Haraguchi Santos contributed by participating in the execution of the experiment, data collection, writing, and final correction of the manuscript. Greissi Tente Giraldi performed the analysis and interpretation of the results and contributed to the final correction of the manuscript.

Ana Daniela Lopes contributed to interpreting and analyzing the results, writing, and correcting the manuscript. Júlio César Guerreiro contributed to the execution of the experiment, writing, analysis, and interpretation of data, and final correction of the manuscript. João Paulo Francisco contributed to the execution of the experiment, analysis, and interpretation of results, statistics, writing, and final correction of the manuscript.

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