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Study the Application of Insecticide Program and its Impact on the Relationship between Leaf Miner *Liriomyza huidobrensis* Populations and the Early Blight Disease in Potato Fields

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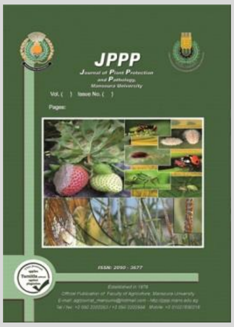

ABSTRACT

The early blight caused by *Alternaria solani* is a serious disease that threats potato plants during the growing seasons. This study investigated the relationship between leaf miner infestation and the incidence and severity of early blight in potato fields in El-Minya governorate, Egypt. An insecticide program included three different insecticides i.e., Abamectin 1.8 % EC, Fipronil 20% SC, and Imidacloprid 35%SC was applied to study its impact on leaf miner population as well as early blight incidence and severity. The leaf miner population was monitored during 2020 and 2021 growing seasons. Early blight incidence (DI), disease severity (DS), and area under the early blight progress curve (AUDPC) were estimated along with leaf miner infestation. The results showed high significant correlation between leaf miner infestation which represented by (the number of leaf miner adults, larvae, mines/leaflet and the minded leaf area) and the infection by *A. solani* which represented by (DI and DS of early blight) during the two growing seasons. The application of the insecticide program significantly decreased the number of leaf miner adults, mines, larvae, and minded area% as well as DI and DS of early blight. Also, it affected the correlation between the number of leaf miner adults as well as DI and DS. This study expands our knowledge about the relationship between leaf miner infestation and *A. solani* infection in the open potato fields and how that could be useful in setting up an effective integrated pest management program to control both leaf miner and early blight.

Keywords: Early blight, *Alternaria solani*, insecticides, Potato, *Liriomyza. huidobrensis*

INTRODUCTION

In Egypt, potato is one of the strategic vegetable crops that occupying an advanced rank among the local growing crops (Baddour and Sakara, 2020). Potato is considered one of the most important vegetable crops in quantities of production and consumption worldwide as well (FAO, 2005). In the volume of production, it ranks fourth in the world after wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), and maize (*Zea mays* L.) (Bowen, 2003).

Numerous pathogens and insect pests attack potato plants and cause considerable quantitative and qualitative losses in yield. The early blight, caused by the necrotrophic fungus Alternaria solani, is an important disease of potatoes that can cause major yield losses. Infection by this polycyclic disease led to production losses of 35–78% in tomatoes and 5–40% in potatoes, respectively (Christ and Maczuga,1989; Shtienberg *et al*., 1990 and Grigolli *et al*., 2011). Pathogen-induced foliar damage at the early bulking stages of potatoes and this results in more significant yield loss than during potato tuber maturation and late bulking (Jindo *et al*., 2021).

The disease affects leaves, stems and tubers of potato and reduces the yield, tuber size, storability of tubers, quality of fresh-market and processing tubers and market ability of the crop (Van der Waals *et al*., 2001). The symptoms appear on leaves as small, circular, or irregular, dark brown concentric ring spots alternating with bands of light-tan tissue, giving them a distinctive target spot appearance. The spots enlarge gradually in diameter and sporulate (Van der Waals *et al*., 2001). Early blight development depends on plant age and environmental conditions such as temperature, high humidity and abiotic stress (Holley *et al*., 1985; Bussey and Stevenson, 1991; Duarte *et al*., 2014 and Christ, 1991). No resistant potato cultivars are available now and the disease is mainly controlled by the application of fungicides and agriculture practices (Abuley and Nielsen, 2017).

On the other hand, leaf miner *Liriomyza huidobrensis* Becker (Diptera: Agromyzidae) is another crucial pest that attacks potatoes during the growing season (Picanço *et al*., 2011). The adult female makes punctures during feeding and oviposition, which gives the attacked leaves a spotted appearance at the tips and along the edges of infested leaves (Alves *et al*., 2014). Unlike *Liriomyza trifolii* (Burgess) and *L. sativae* Blanchard, the larvae of *L. huidobrensis* feed within the lower mesophyll layer, which has a more significant impact on leaf photosynthesis that makes low population densities of *L. huidobrensis* cause more harm to the host plant than any other Liriomyza species (Heinz and Chaney, 1995 and Parrella *et al*., 1985). Reducing the photosynthesis activity of the mined leaf area directly impacts the growth and yield of infested crop (Mujica and Kroschel, 2013). A significant loss of potato yield (up to 100%) has been reported in Cordoba, Argentina; Coquimbo, Chile, and Indonesia by this leaf miner species (Lopez *et al*., 2003; Larrain, 2004 and Shepard *et al*., 1998). Mujica and Cisneros (1997) found that *L. huidobrensis*

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reduced the yield of potato varieties (Cica, Revolution, Tomasa, Perricholi and Yungay) by 46, 53, 54, 50 and 62%, respectively. Further, Mujica and Kroschel (2013) found that each 1% increase in the percentage of foliar injury of the Canchan variety lead to a reduction in yield by 1.21, 0.46 and 0.93% in 2005, 2007, and 2008, respectively.

The most important type of injury of leaf miner is produced by its larvae, which feed on leaves lower mesophyll, building cavities called mines and consequently easing bacteria and fungi entrance (Bueno *et al.,* 2007; Palumbo, 2012 and Soares *et al*., 2019).

A few information is available about the impact of leaf miner on the occurrence and development of plant diseases. Also, the potential damage it may cause to the growing crops by transmitting and dispersing plant disease pathogens, i.e., bacteria, fungi, and viruses. Venkateswarlu and Ramapandu, (1992) studied the relationship between leaf miner infestation and the severity of canker in acid lime and sathgudi sweet orange, and the study revealed that the disease severity was highly correlated with leaf miner infestation. The injuries caused by citrus leaf miner increased the incidence of citrus canker and impacted the area under disease progress curve (AUDPC) (Waldir, 2006; Gottwald *et al*., 1997 and Chagas *et al*., 2001). Durairaj *et al*. (2010) reported that *L. trifolii* females predisposing *Solanum lycopersicum* L. to infection by Alternaria by perforating the leaves of the plants. They found that releasing *L. trifolii* prior to pathogen inoculation significantly increased the severity of the disease. Also, leaf perforation during *L. trifolii* oviposition enhanced leaf necrosis caused by *Alternaria alternata* in *S. tuberosum* L. (Deadman *et al*., 2002). A high correlation was detected between number of mines by *L. huidobrensis* and the severity of early blight caused by *Alternaria solani* (Soares *et al*., 2019). High number of leaf miner adults, larvae and mines was observed in potato fields with high early blight incidence in middle Egypt (personal observation).

This study aims to investigate the relationship between the population of the leaf miner, L. huidobrensis (numbers of adult insects, larvae, mines and the minded area) and incidence (DI), severity (DS), and area under disease progress curve (AUDPC) of the early blight disease in potato fields during 2020 and 2021 growing seasons. In addition, to examine the impact of an insecticide program consisted of abamectin (member of the Avermectin family),fipronil (phenylpyrazole chemical family), and imidacloprid (neonicotinoids) on the leaf miner populations as well as incidence, severity and development of the early blight disease.

MATERIALS AND METHODS

Field experiment design

To study the impact of leaf miner, *L huidobrensis*, infestation on the severity and development of potato early blight. An experiment was conducted during 2020/2021 and 2021/2022 growing seasons in about 1.5 ha (3.5 feddans) potato field located at Bourjaya village, El-Minia province. The experiment was conducted as split plots with insecticide application as main plots.

Impact of insecticide applications on the leaf miner, *Liriomyza huidobrensis*, populations

As mentioned in the experimental design, the experiment was split into two main plots, treated and non-treated with insecticides. The program included three insecticides, abamectin 1.8% EC, fipronil 20% SC and imidacloprid 35%SC. The insecticides were applied alternately as follows; The program started one month after the planting date, and spraying was displayed every two weeks starting with abamectin 1.8 EC followed by fipronil 20% SC and imidacloprid 35%SC at 40, 25 and 40 ml 100L^{-1} water, respectively. Each insecticide was applied only once during the season except abamectin 1.8 EC, which was applied again two weeks after imidacloprid 35%SC application. The field was split into two main plots, treated and non- treated plots with insecticides. Five plots (3×4 m^2) were chosen randomly in each main plot (each plot represents one replicate). Potato cv. Spunta is considered one of the most cultivated potato cultivars in Egypt, and thus it was used in this experiment. Two samples' methods were used to estimate the larval and adult populations of the leaf miner in both treated and non-treated plots

Sticky traps

The sticky traps were used to monitor leaf miner adults on potato plants during both growing seasons. Four sticky traps were positioned at 50 cm height on each subplot (3×4 m^2) representing the four cardinal field directions, north, south, east, and west. The traps were made of yellow plastic panels measuring 25 × 25 cm and covered with Delvac oil as an adhesive for collecting flying insects. Traps were attached horizontally on the poles in a parallel arrangement and oriented in each plot to face the cardinal field direction. The average number of the leaf miner adults from the four traps around the plots was recorded weekly .

Leaf sampling

The number of *L huidobrensis* larvae, mines and minded area (cm^2) was estimated by randomly collecting twenty-five leaflets/plot (from the middle of the canopy of potatoes). The collected leaflets were kept in paper bags and transferred to the laboratory for subsequent counts of larvae and mines per each leaflet using a stereoscopic microscope, according to the direct count technique (Southwood, 1978; Gusmao *et al*., 2005 and Gusmao *et al*., 2006). The number of larvae, mines and minded leaf area was considered as criteria in determining leaf miner's infestation.

To measure the minded leaf area (mines area), individual leaflets samples which used to count number of larvae and mines were scanned into a digital format using a Hewlett-Packard Scan Jet 4850 desktop scanner. The leaflet was scanned by placing it on the scanner, closing the lid, and displaying the scanning option. The captured images were saved as a TIFF file. Digital images were analyzed using Adobe Photoshop CS2 to measure the damaged leaf area(cm^2).

Assessment of early blight disease incidence and severity.

The disease was assessed by counting the total number of potato plants in the middle three lines of each plot. The disease incidence was estimated according to the following equation:

$$\mathbf{DI\ (\%) = \frac{No.\ of\ infected\ plants}{total\ No.\ of\ inspected\ plants} \times 100}$$

Early blight severity was estimated using a 0–7 scale as described by Christ (1991); where 0 = no lesions; 1 = trace to 1%; 2 = 1-5%; 3 = 6-10%; 4 = 11-25%; 5 = 26-50%;

6 = 51-75%; and 7 = 76-100% and the following equation was used to calculate the final disease severity:

Disease severity (%) =

$$\frac{\sum \text{(rating No.} \times \text{No. of leaves in the rating)}}{\text{(Total No. of inspected leaves} \times \text{highest rating)}} \times 100$$

The area under disease progress curve (AUDPC) was calculated according to the following formula as adopted by Pandey *et al*., (1989).

$$\text{AUDCP} = \Sigma[(X_i + X_{i+1})/2]t_i,$$

where X_i and X_{i+1} are severity on the date *i* and date *i* + 1, respectively and t_i is the number of days between date *i* and date *i* + 1.

Statistical analysis

One-way ANOVA was used to study the effect of the insecticides application program on number of leaf miner adults, larvae, mines, and the minded area. Further, One-way ANOVA was used to study the effect of the insecticides application program on disease incidence, severity, and area under the disease progress curve in both treated and no-treated plots with insecticides. Means separated using Tukey test t 0.05 probability level. The relationship between each stage of *L huidobrensis* i.e., the number of leaf miner adults, larvae, mines and the minded area and each disease parameter i.e., early blight incidence and severity was investigated separately by correlation and regression techniques. The data were analyzed using JMP data analysis software version 14.

RESULTS AND DISCUSSION

Results

The impact of insecticides application on the leaf miner, *Liriomyza huidobrensis*, population.

Number of *L. huidobrensis* adults

The number of leaf miner *L. huidobrensis* adults was monitored weekly from the third week after the sowing date and continued for 11 weeks in insecticides-treated and untreated plots by sticky traps (Fig. 1a and b). Overall, the number of leaf miner adults fluctuated during the season in insecticides treated and untreated plots during the 2020 and 2021 growing seasons. In untreated plots, the average number of leaf miner adults was more than 10 adults trap^{-1} in the 1st week of rating and ranged between 20 and 25 adult trap^{-1} from the 2nd week until 5th week in 2020, but it was less than 10 adult trap^{-1} in the 3rd week in 2021 and went up again over 10 adult trap^{-1} in the 4th week. The highest peak in nontreated was observed in 6th week (more than 40 adult trap^{-1} in 2020 and approximately 30 adult trap^{-1} in 2021) and the second highest peak was in 9th week approximately 45 adult trap^{-1} in 2020 and 30 adults trap^{-1} in 2021. In insecticide-treated plots, the number of leaf miners was, in general, lower than the untreated plots during the 2020 and 2021 seasons. More fluctuation in the leaf miner population was observed in 2020. The number of leaf miners reached high peaks, being 20 to 25 adult trap^{-1}, through three times, being 4, 7 and 10th weeks during the season. In 2021, the insecticide-treated plots were less fluctuated compared to 2020, where the leaf miner adults were more suppressed by the insecticides application and ranged around 10 adult trap^{-1} with only one peak in the 4th week, reaching almost 20 adult trap^{-1}. Overall, the application of insecticides significantly reduced the average number of leaf miner adults during the two-growing season (Fig. 1c)

Number of larvae

The average number of larvae leaflet^{-1} during the 2020 and 2021 seasons showed fluctuating patterns in treated and untreated plots with insecticides. In 2020, the average number of larvae did not exceed than 2 larvae leaflet^{-1} in the 1st and 2nd weeks, then it started to increase and stayed around 6 larvae leaflet^{-1} from 3rd to 6th week. The average number of larvae was continued high until it reached the maximum last week 10 larvae leaflet^{-1}. In insecticide-treated plots, the number of larvae was gradually increased from the first week until the 8th week, reaching 7 larvae leaflet^{-1} and remaining around 6 larvae leaflet^{-1} until the end of the season.

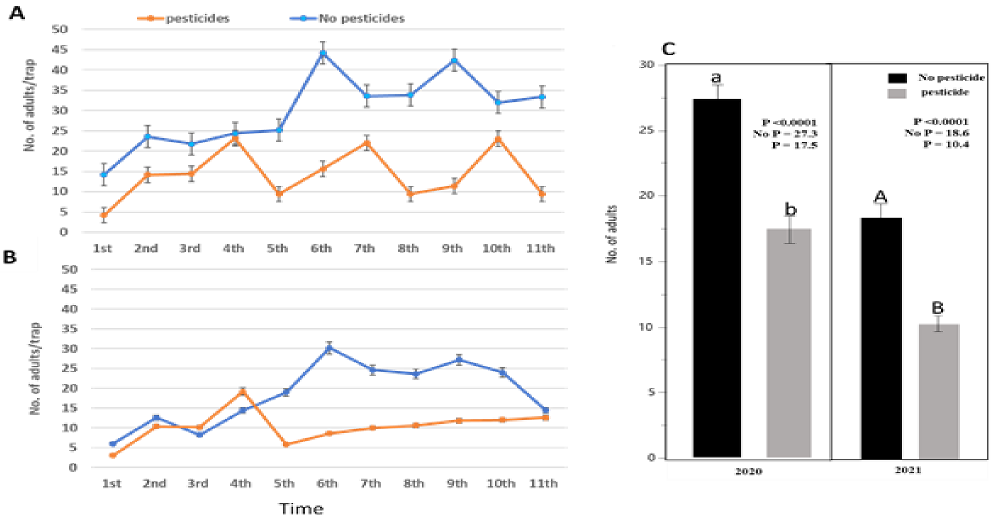

Fig. 1. Effect of insecticide applications on adult population of the leaf miner, *Liriomyza huidobrensis* during 2020 (A) and 2021 (B) growing seasons, and the average number of leaf miner adults (C) in both treated and untreated plots with insecticides during the two growing seasons.

In 2021, the average number of larvae was less than 4 larvae leaflet^{-1} until the 5th week, which increased gradually to reach the maximum in the 7th week (8 larvae leaflet^{-1}). The average number of larvae decreased less than 6 larvae leaflet^{-1} while increased again in the last week, being 8 larvae leaflet^{-1}. In insecticides treated plots, the number of larvae fluctuated during the season it was lower than 2 larvae leaflet^{-1} during the first 3 weeks and exceeded than 2 larvae leaflet^{-1} in the 4th week, then decreased again in the 5th week then remained between 4 -6 larvae leaflet^{-1} until the end of the season except week, 10th which showed the last peak in the season and recorded approximately 8 larvae leaflet^{-1}. In addition, the average number of larvae in each growing season was significantly decreased in insecticides treated plots (Fig. 2c)

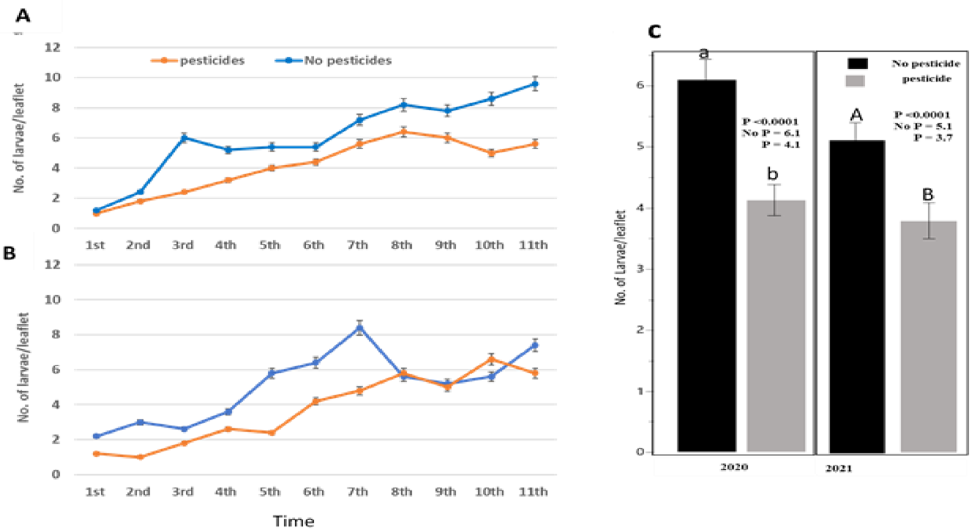

Fig. 2. Effect of insecticide applications on number of leaf miner, *L. huidobrensis* larvae leaflet^{-1} during 2020 (A) and 2021 (B) growing season, and C) the average number of leaf miner larvae in both treated and non-treated plots during the two growing seasons.

Number of mines.

The average number of mines leaflet^{-1} was also assessed in treated and untreated plots with insecticides during the 2020 and 2021 seasons. In 2020, the number of mines in the 1st and 2nd weeks was less than 5 mines leaflet^{-1}, then gradually increased in the 12th week to approximately 27 mines leaflet^{-1} in untreated and 10 mines/ leaflet for insecticides treated plots. In 2021, the average number of mines increased slower than in 2020, which ≤ 5 mines leaflet^{-1} in the first three weeks for untreated plots. In comparison, ranged from 8 to 12 until the end of the season in untreated plots. In insecticide-treated plots, the number of mines was ≤ 5 mines leaflet^{-1} in the first 6 weeks and from 5 to 7 mines leaflet^{-1} in the rest of the season. The average number of mines in 2021 was lower than in the 2020 growing season (Fig. 3c). Also, insecticides significantly alleviated the number of mines in treated plots compared to untreated in both seasons.

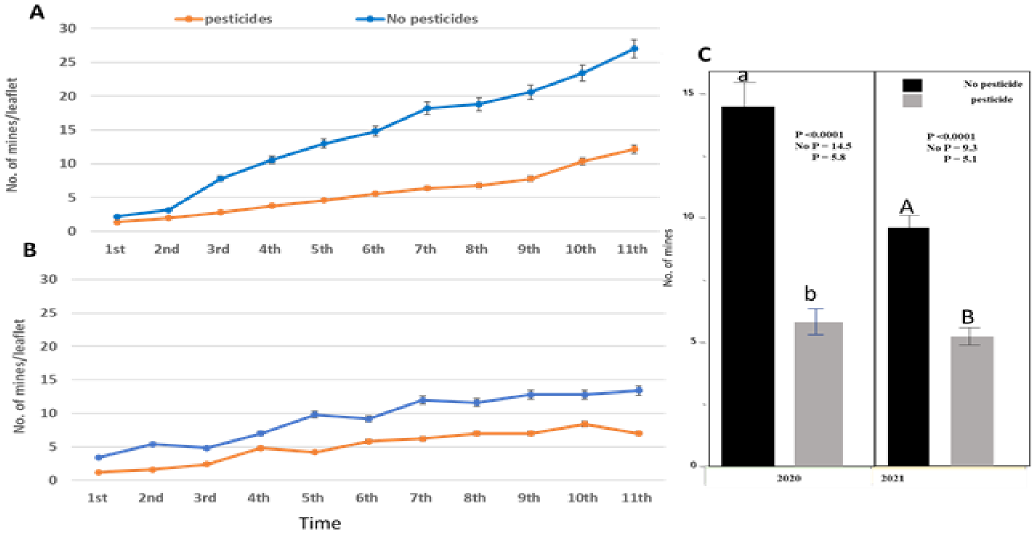

Fig. 3. Effect of insecticides application on the number of mines leaflet^{-1} during 2020 (A) and 2021 (B) growing season, and the average number of mines during the two growing seasons (C).

Potato-minded leaf area.

The minded leaf area (cm^2)/potato leaflet was ascendingly increased during the 2020 growing season in insecticides treated and nontreated plots. It started from less than 1 cm^2 in the 1st week and gradually increased, reached approximately to 6 cm^2 in the last week in untreated plots. However, in insecticides-treated, the minded area reached the maximum by the last week of the season and did not exceed than 2 cm^2. High reduction was observed in minded areas in potato plots treated with insecticides compared to untreated plots during the 2020 and 2021 growing seasons (Fig. 4c).

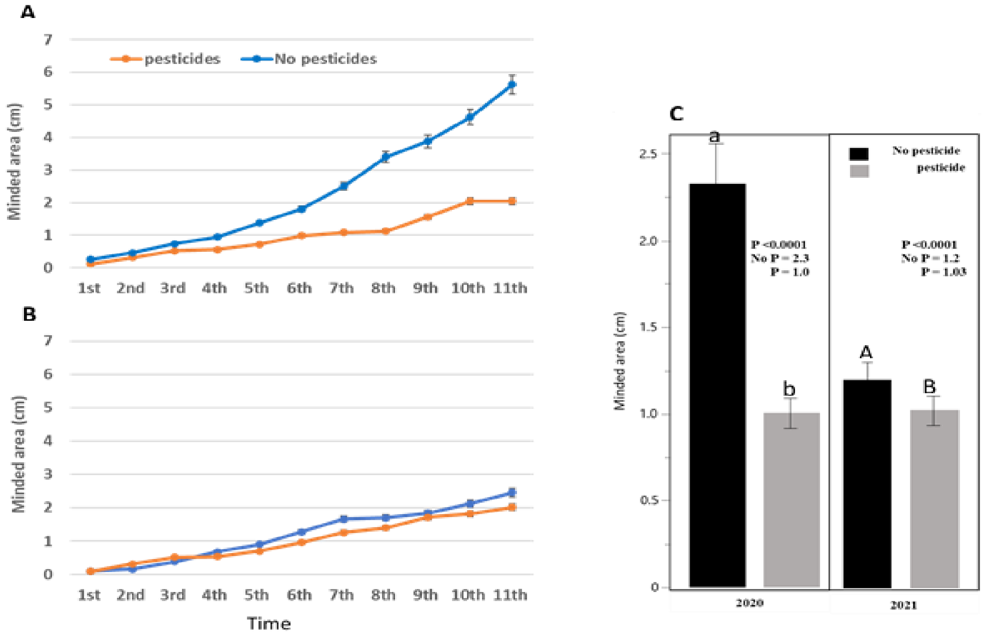

Fig. 4. Effect of insecticides application on the minded area (cm^2) potato leaflet^{-1} during 2020 (A) and 2021 (B) growing season, and the minded area leaflet^{-1} on the average during the two growing seasons (C).

The impact of insecticides application on early blight incidence, severity and area under disease progress curve.

High disease incidence (DI) was observed during 2020 compared with 2021 growing seasons (Fig. 5). During the 2020 growing season, insecticides treated and untreated plots showed a similar range of disease incidence until 6th week (40%), then recorded higher DI values in untreated plots than insecticides-treated plots. However, in the 2021 growing season, the DI in insecticides treated plots was more elevated than untreated plots until week 8th. Starting from 9th week the DI of potato early blight due to insecticides treatment stayed stable and the DI in untreated plots increased to 70% in the 11th week.

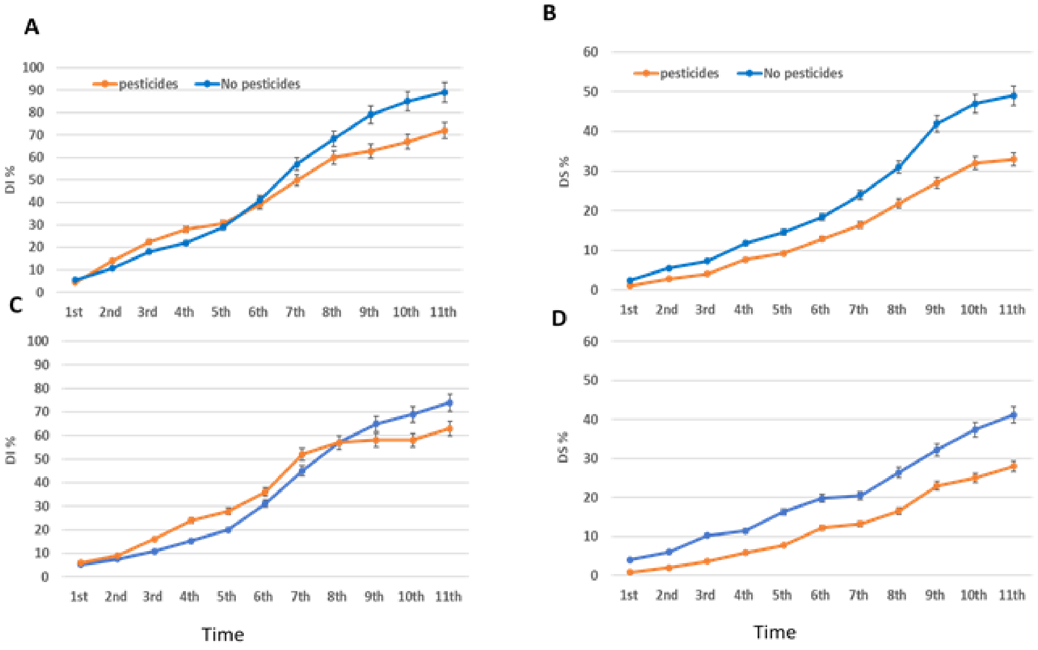

Fig. 5. The impact of insecticide applications on the early blight incidence and severity during 2020 (A, B) and 2021 (C, D) growing seasons, respectively.

Similar performance of diseases severity (DS) was observed in 2020 and 2021 growing seasons in respect to the insecticide's application. High DS was observed in insecticides-untreated compared with treated plots. The difference between the DS values increased by the time as shown in Fig. (5). Insecticides application significantly alleviated the final diseases severity compared with untreated (Fig. 6a). Furthermore, the application of insecticides significantly impeded the development of early blight during the two-growing season by decreasing the area under disease progress curve (AUDPC) values (Fig. 6b)

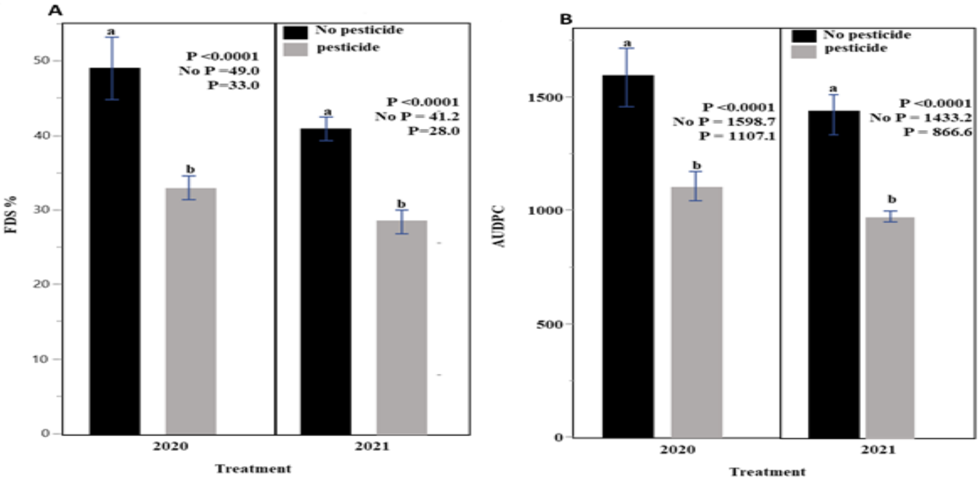

Fig. 6. The impact of insecticides application on final disease (A) and area under early blight progress curve (B) during 2020 and 2021 growing seasons

Effect of insecticide application on the relationship between leaf miner infestation and early blight incidence and severity

Correlation and regression analyses demonstrated the relationship between the number of leaf miner (adults, larvae, mines and minded area) and the incidence and severity of early blight with and without the application of insecticide program during the 2020 and 2021 growing seasons (Table 1).

Table.1. The relation between leaf miner infestation and early blight incidence and severity in response to insecticides application.

		R	*R^2*	*R^2adj*	Equation	*P*-value
2020 growing season						
Insecticides						
DI	LM adult	0.19	0.35	0.02	y = 33.09 + 0.55x	0.17
	Larvae	0.86	0.75	0.74	y = -0.98 + 10.15x	<.0001*
	Mines	0.93	0.86	0.86	y = 5.31 + 6.14x	<.0001*
	Mined area	0.94	0.89	0.89	y = 7.99 + 32.74x	<.0001*
DS	LM adult	0.14	0.02	0.00	y = 12.35 + 0.21x	0.32
	Larvae	0.78	0.61	0.60	y = -4.11 + 4.69x	<.0001*
	Mines	0.95	0.90	0.90	y = -3.34 + 3.21x	<.0001*
	Mined area	0.97	0.94	0.94	y = -2.08 + 17.25x	<.0001*
No-Insecticides						
DI	LM adult	0.67	0.45	0.44	y = -19.51 + 2.19x	<.0001*
	Larvae	0.85	0.72	0.72	y = -13.41 + 9.73x	<.0001*
	Mines	0.96	0.92	0.92	y = -7.98 + 3.71x	<.0001*
	Mined area	0.97	0.95	0.95	y = 6.89 + 16.74x	<.0001*
DS	LM adult	0.61	0.37	0.36	y = -9.69 + 1.09x	<.0001*
	Larvae	0.83	0.69	0.69	y = -6.06 + 2.00x	<.0001*
	Mines	0.94	0.89	0.88	y = -8.79 + 5.22x	<.0001*
	Mined area	0.98	0.95	0.95	y = 1.54 + 9.22x	<.0001*
2021 growing season						
Insecticides						
DI	LM adult	0.26	0.07	0.05	y = 25.83 + 1.08x	0.06
	Larvae	0.87	0.75	0.74	y = 5.89 + 8.30x	<.0001*
	Mines	0.90	0.81	9.15	y = -0.88 + 7.49x	<.0001*
	Mined area	0.97	0.93	0.93	y = 4.36 + 31.60x	<.0001*
DS	LM adult	0.25	0.06	0.04	y = 7.71 + 0.47x	0.0679
	Larvae	0.83	0.69	0.07	y = -0.79 + 3.56x	<.0001*
	Mines	0.84	0.71	0.71	y = -3.36 + 3.14x	<.0001*
	Mined area	0.98	0.96	0.95	y = -2.24 + 14.31x	<.0001*
No-Insecticides						
DI	LM adult	0.55	0.30	0.29	y = 5.31 + 1.67x	<.0001*
	Larvae	0.62	0.38	0.37	y = -0.43 + 7.25x	<.0001*
	Mines	0.88	0.78	0.77	y = -20.42 + 6.11x	<.0001*
	Mined area	0.97	0.94	0.94	y = -1.43 + 31.29x	<.0001*
DS	LM adult	0.53	0.28	0.26	y = 6.34 + 0.76x	<.0001*
	Larvae	0.61	0.37	0.36	y = 3.33 + 3.38x	<.0001*
	Mines	0.86	0.75	0.74	y = -5.98+ 2.85x	<.0001*
	Mined area	0.96	0.93	0.92	y = 2.63+ 14.79x	<.0001*

The application of the insecticide program impacted only the relationship between the number of leaf miner adults and the early blight incidence and severity. No correlation was observed between the number of leaf miner adults and the disease incidence when insecticides were applied in the 2020 and 2021 growing seasons (r=0.19 and P=0.17) and (r=0.26 and P=0.06), respectively. Also, there was no significant correlation between the number of leaf miner adults and the disease severity when insecticides were applied in 2020 and 2021, (r=0.14 and P=0.32; r=0.25 and P=0.07, respectively). In contrast, the number of leaf miner adults showed significant correlation with disease incidence (2020 season: r=0.67, P< 0.0001 and 2021 season: r=0.55, P< 0.0001) and severity (2020 season: r=0.61, P< 0.0001 and 2021 season: r=0.53, P< 0.0001) in potatoes plots that did not receive insecticides during the two growing seasons.

Although the insecticide program alleviated disease incidence and severity. Also, the number of larvae, mines, and minded area showed a significantly high correlation with disease incidence and severity whether insecticides applied or not during 2020 and 2021 growing seasons (Table 1). High significant correlation was observed between the disease incidence and the number of larvae, mines and minded area (r=0.84, 0.929 and 0.94, P< 0.0001, respectively) in treated plots with insecticides in the 2020 season and 2021 growing season (r=0.87. 0.899, and 0.97, P< 0.0001, respectively). Likewise, untreated plots with pesticides in the 2020 season showed high significant differences between disease incidence and larvae, mines and minded area (r=0.85, 0.96 and 0.97, P< 0.0001, respectively) compared with 2021 growing season (r=0.62, 0.88 and 0.97, P< 0.0001, respectively). A similar relationship was observed between disease severity and the number of larvae, mines and minded area. In the 2020 growing season, highly significant correlations were found between DS and the number of larvae, mines and minded area in both treated plots (r=0.78, 0.95 and 0.97, P< 0.0001, respectively) and untreated plots with insecticides (r= 0.83, 0.94 and 0.98, P< 0.0001, respectively). In the 2021 growing season, the same results were observed; a high correlation was found between DS and the number of larvae, mines and minded area in both treated plots (r=0.83, 0.84 and 0.98, P< 0.0001, respectively) and untreated plots with insecticides (=0.61, 0.86 and 0.96, P< 0.0001, respectively).

Discussion

This study focused on the relationships between the population of leaf miner larvae, mines, and the leaf-damaged or minded area and their influence on the severity and development of the early blight of potatoes in the absence and presence of insecticides program (abamectin 1.8% EC, fipronil 20% SC and imidacloprid 35%SC). The results revealed that the insecticides program significantly decreased the number of leaf miner adults, larvae, mines, and the minded leaf area compared to untreated plots. Furthermore, applying insecticides indirectly alleviated early blight final disease severity (FDS) and area under the disease progress curve (AUDPC). The efficacy of applied insecticides on leaf miner was previously reported in various studies; where abamectin has provided effective against *L. huidobrensis* in several countries (Vandeveire, 1991; Hammad *et al.*, 2000; Weintraub, 2001 and Monica *et al.*, 2021). It led to a reduction in leaf miner without harmful effects on its parasitoids and predators in potatoes (Hidrayani *et al.*, 2005), 'Pod Squad' beans (Seal and McCord 1998 and Seal *et al.*, 2002), tomatoes (Variya and Patel, 2012) and cucumber fields (Desai *et al.*, 2018). Abamectin acts on insects by interfering with glutamate-gated chloride channel receptors; this interference paralyzes the muscles of targeted invertebrates and causes malfunction of neural and neuromuscular transmission (Crump and Omura, 2011 and Fent, 2014). Also, it acts on a specific type of synapse located only within the brain and is protected by the blood-brain barrier (Hayes and Laws, 1990). On the other hand, imidacloprid showed effective activity against American serpentine leaf miner and whiteflies (Sabry *et al.*, 2015 and Yang *et al.*, 2013). In addition, Schuster and Morris (2002) found that imidacloprid reduced the number of *L. trifolii* mines per plant in tomatoes. Furthermore, fipronil effectively controls *L. trifolii* in tomatoes (Variya and Patel, 2012). Fiprole group of chemicals is a potent disrupter of the insect central nervous system via interference with the gamma-aminobutyric acid (GABA-) regulated chloride channel. It prevents the uptake of chloride ions resulting in excess neuronal stimulation and death of the target insect (Cole *et al.*, 1993; Ratra *et al.*, 2001 and Who, 2007). Thus, the current insecticide program by the three-insecticide provided high protection and a significant reduction in the number of leaf miner adults, larvae, and mines as well the area of potato leaf minded area during the two-growing season.

On the other hand, this study achieved a significant reduction in early blight severity and AUDPC in the insecticide-applied plots. The indirect impact of insecticides more often comes from its influence on the population of an insect that plays a vital role in disease dispersal and development. The role of tested insecticides such as in indirect suppression of plant disease has been observed a long time ago. In this regard, imidacloprid showed an indirect influence on plant diseases, where it provided effective control of Stewarts disease in young corn plants (Munkvold *et al.*, 1996), protect tomato plants caged with viruliferous insects against tomato yellow leaf curl virus TYLCV (Rubinstein *et al.*, 1999), when imidacloprid long-lasting systemic activity protected tomatoes from infection by TYLCV and increased tomato yield (Ahmed *et al.*, 2001). In addition, the application of imidacloprid resulted in a high reduction of insect feeding as well as showing indirect protection of numerous field crops i.e., cotton, corn, sorghum, barley, wheat, rice, oats, against several diseases (Gourmet *et al.*, 1994, 1996; Gray and Bergstrom, 1992; Gray *et al.*, 1996 and Munkvold *et al.*, 1996). In addition to the indirect effect of abamectin on the reduction of plant diseases *in vitro* experiment, abamectin at concentration >62.5 µg/ml^{-1} caused a significant decrease in the growth of *Phaeoacremonium minimum;* one of the fungal causal agents of grapevine trunk diseases (Sebestyen *et al.*, 2021).

Our results showed a significantly high positive correlation only between the number of leaf miner adults and early blight incidence and severity insecticide-free plots. The high number of leaf miner, especially the females cause physical damage to potato leaflets because of puncture holes that created during oviposition. The presence of such holes facilitates the entrance of plant pathogens such as *Alternaria spp*. (Deadman *et al.*, 2002 and Durairaj *et al.*, 2010). Although the application of insecticides reduced the number of leaf miner adults, which makes it not correlated with DI and DS. These low numbers of adults produced a high number of larvae, mines and large-minded area. One adult individual can lay about 100 eggs during its life cycle (Hincapie-c *et al.*, 1993). Although, the number of adult is decreased by the application of insecticides, but the adult still have the ability to produce larvae which subsequently creates mines and increases the minded leaf area. The damaged leaf area facilitate the infection by *A. solani* and increase the DI and DS, which maintain the correlation between leafminer parameters and diseases parameters in positive status but the parameters significantly reduced compared with non-treated plots.

Several studies confirmed the correlation between leaf miner infestation and plant disease development (Munkvold *et al.*, 1996; Ahmed *et al.*, 2001 and Deadman *et al.*, 2002). A high correlation between *L. huidobrensis* and early blight caused by *A. solani* (Soares *et al.*, 2019), where leaf miner and the incidence of *Alternaria* leaf blight lesions were observed on muskmelon plants (Chandler and Thomas, 1991). Also, our results are similar to the obtained results by Soares *et al.*, (2019), who reported a high correlation between the number of *L. huidobrensis* mines and *A. solani* spots and the dissemination of *A. solani* in potato plants. In addition to the previously reported roles of leaf miner adults and the number of mines in the occurrence of early blight, our results showed a high correlation between the number of larvae and minded area as both facilitate the infection by *A. solani* and other unstudied diseases. The results proved that leaf miner adults are not the main key influencing early blight incidence and severity. Also, it confirms that the number of larvae, mines and minded area has more impact on the incidence and severity of potato early blight than leaf miner adults.

CONCLUSION

A high correlation was observed between leaf miner infestation and the incidence and severity of early blight on potato fields. Application of insecticide programs when include, mainly, various insecticides chemical groups with different active ingredients and modes of action i.e., abamectin 1.8% EC, fipronil 20% SC and imidacloprid 35%SC were effective in reducing the number of leaf miner adults, larvae, mines, and minded leaf area which subsequently decrease the early blight incidence and severity of potato plants. Several management strategies could be used to manage leaf miner infestation and early blight disease. However, this study focused on the impact of the application of insecticides program on the relationship between leaf miner *L. huidobrensis* and early blight severity caused by *A. solani* on potato fields.

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دراسة تطبيق برنامج للمبيدات الِفحشرية وتأثيرة على العلاقة بين صانعات الانفاق ***Liriomyza huidobrensis*** والإصابة بمرض الندوة المبكرة فى حقول البطاطس

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الملخص

الندوة المبكرة التى يسببها الفطر *Alternaria solani* من الأمراض المهمة التى تهدد نباتات البطاطس خلال مواسم الزراعة.. تهدف هذه الدراسة للتعرف على العلاقة بين الإصابة بصانعات الأنفاق ونسبة وشدة الإصابة بمرض الندوة المبكرة فى حقول البطاطس بمحافظة المنيا بجمهورية مصر العربية. تم رصد تعداد الحشرة فى الحقول محل الدراسة بمحافظة المنيا بجمهورية مصر العربية خلال موسم الزراعة لعامي ٢٠٢٠ و ٢٠٢١. كما تم تقدير نسبة وشدة الإصابة ومنحنى تطور مرض الندوة المبكرة فى نفس الحقول محل الدراسة. تم دراسة تأثير تطبيق برنامج مبيدات حشرية يتضمن ثلاث مبيدات: abamectin 1.8% EC, fipronil 20% SC and Imidacloprid 35%SC على تعداد صانعات الأنفاق وأيضا علي نسبة وشدة الإصابة بمرض اللفحة. بينت هذة الدراسة وجود ارتباط معنوى وقوى بين كلا من عدد الحشرات الكاملة وعدد اليرقات والأنفاق لصانعات الأنفاق ومساحة الأنفاق وبين نسبة وشدة الإصابة بمرض اللفحة المبكرة فى البطاطس خلال الموسمين الزراعيين. تم انخفاض عدد الحشرات الكاملة ،اليرقات و الأنفاق لصانعات الأنفاق ومساحة النفق بشكل معنوي بتطبيق برنامج الرش بالمبيدات الحشرية كما خفض ايضا نسبة وشدة الإصابة بمرض اللفحة المبكرة. كما أثر ذلك ايضا على الارتباط بين عدد الحشرات الكاملة لصانعات الأنفاق و نسبة وشدة الإصابة بمرض اللفحة المبكرة. تساهم هذه الدراسة فى توسع المعرفة بالعلاقة بين الحشرات والإصابة بمسببات الأمراض فى الحقول المفتوحة وفي كيفية الاستفادة من ذلك في بناء برنامج مكافحة متكاملة فعال لمكافحة كلا من صانعات الأنفاق واللفحة المبكرة.