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Original Article

Effect of the Leaf miners Flies on the Productivity of Field Crops Grown under Center Pivot Irrigation System

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Abstract *- Leaf miners are serious pests on vegetable and field crops worldwide. A comparative study for the effect of wheat leaf miner fly (WLM) Agromyza spp on the productivity of wheat and barley crops are grown under a Centre pivot irrigation system showed a significant yield increase by a range of 13.14 – 22.11% on wheat and 7.72 – 17.50% on barley as a result of WLM and aphids control through the injection of Dimethoate 1.5 + Agral 0.1 Liter/Ha with irrigation water. The implementation of the IPM program on alfalfa and potato crops through the application of selective insecticides Nomoult or cascade to control leaf miner flies and worms improved the productivity of both crops as it increased the yield by a range of 5.18 – 23.49% on alfalfa; it also increased the yield by a range 9.57 – 66.83% on spring potato, and it increased the yield by a range of 27.83 – 79.79% on autumn potato.*

Keywords *- Alfalfa Crop, Injection with Irrigation, Potato crop, Wheat crop, Wheat leaf minor.*

1. Introduction

Leaf miners flies are cosmopolitan pests on different plant species. Most of these pests belong to several genera under the family Agromyzidae, order Diptera including *Liriomyza*, *Agromyza*, *Phytomyza*, etc. Different *Liriomyza* species are common pests on vegetable and field crops, including leaf miner *L trifolii*, serpentine leaf miner *L. Sativa*, and pea leaf miner *L. striga*. Vegetable leaf miner is a pest on Cucurbitaceae, Leguminaceae, and Solanaceae. Serpentine leaf miner is a pest on beans, beet, carrots, chard, tomato, cucumber, eggplant, pepper, lettuce, melon, squash, Potato, onion, peas, chrysanthemum, gebera, and marigold.
Wheat leaf miner fly (WLM) *Agromyza ocularis* is a pest on wheat, barley, and wild grasses in South Africa (Adendrof, 2010; Pinsloo, 2018); wheat leaf miner flies *Agromyza spp* has been reported to cause serious damage to wheat in different countries: in Saudi Arabia (El-Hag et al., 1987); in Poland (Kamila et al. 2015). Alfalfa blotch leaf miner flies *Agromyza frontalis* is a serious pest on alfalfa in the Eastern and Midwest United States (Vanette et al., 1980; Pears, 2015). Potato leaf minor *Liriomyza huidobrensis* is a serious pest on potatoes in South Africa (Visser, 2017), Australia (Vegetable Aus. 2019), and Indonesia (Stewart, 2020).

Generally, the leaf miner fly species are small, 2 – 3 mm, with dark body color. The larva is a maggot that lives inside the leaf-feeding on the mesophyll tissue between the leaves' upper and lower epidermal layers. Thus creating damage to the plants manifested by the presence of mines on the leaves, which affect the assimilate supply to the plants leading to leaves drying, stunted plants growth, consequently affecting the yield. Indirect damage is caused when fungi or bacteria enter the feeding areas. TADCO was growing vegetable crops: cucumber, tomato, pepper, eggplant, lettuce, etc., in protected plastic tunnel houses during the period 1986 – to 1996, and these crops were heavily attacked by the leaf miner flies, which were difficult to control. Leaf miner flies were not native to the area, and they were believed to be introduced through imported plants and shipments of peat moss imported from Europe for raising vegetable crops seedlings in the soil mixed substrates. Field crops such as wheat, barley, alfalfa, potato, and onions have been the main crops in the company since 1984, occupying an area of more than 10000 hectares and grown under a center pivot irrigation system. The company has enjoyed high yields of wheat and barley crops from 1993 onwards. Heavy leaf miner infestations were observed on alfalfa in July 1999 and on wheat and barley in the mid of March 2002.

This case report aimed to investigate the effect of the leaf minors flies on the productivity of wheat, barley, alfalfa, and potato crops grown under a center pivot irrigation system.

2. Materials and Methods

Plants samples were collected from infected wheat and barley pivots in the mid of March 2002 and sent to the lab. We took photographs of the infested leaves and plant samples; symptoms showed leaf scorch on the plants with white spots (scars) on wheat leaves Figure 1.

Infested samples were incubated in the lab. After two days, the samples showed maggots typical to the Agromyza spp fly were dislodged out of the infested leaves and crawled on the tissue paper in preparation for pupation Figure 2.

We surveyed infested wheat and barley pivots and prepared recommendations for aphid and leaf miner control. Each infested pivot was treated with Dimethoate 1.5 liter + Agral 0.1 Liter per ha through injection with irrigation water at low pressure 20 psi, speed 100%. During the summer months and after harvest, we arranged for two rounds of disc cultivation to crush and bury the straw, dormant stages of insects, and fungal diseases into the soil.

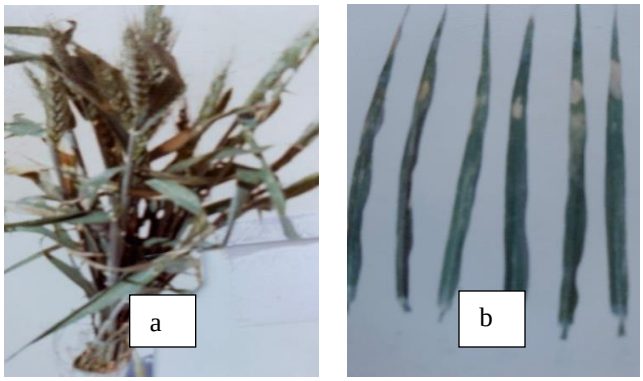

Fig. 1 Wheat leafminer symptoms on wheat plants: 1a. leaf schorch symptoms; 1b. White spots (blotches) on wheat leaves.

Fig. 2(a) Agromyza leafminer larva magnified; Fig. 2(b) Agromyza leafminer adult flies magnified.

For the infestation of leaf miners on potatoes, we sprayed Cascade or Nomolt 0.3 liter/ ha to control leaf miners, potato tuber moth, and worms; we applied the same chemicals on alfalfa to control leaf miners and alfalfa worms.

3. RESULTS

A comparison of data collected on the wheat crop yield for eleven years during the period 1995 – 2005 is presented in Table 1. We observed productivity of the wheat crop was high in 1995 and 1996 with 8.69, 8.49 M.T / Ha respectively, then a gradual decrease in the yield of the wheat crop appeared during the period 1997 until 2001, which reached 7.15 M.T/ Ha. In the mid of March 2002, we treated the wheat pivots against leaf miners and aphids after observing a high infestation of the leaf miner on this crop. We realized a yield increase of 0.96 M.T/Ha or 13.43% in this season compared to the 2001 season. Increased yield continued in the following years of study and ranged from 13.14 to 22.11%, see Figure 3.

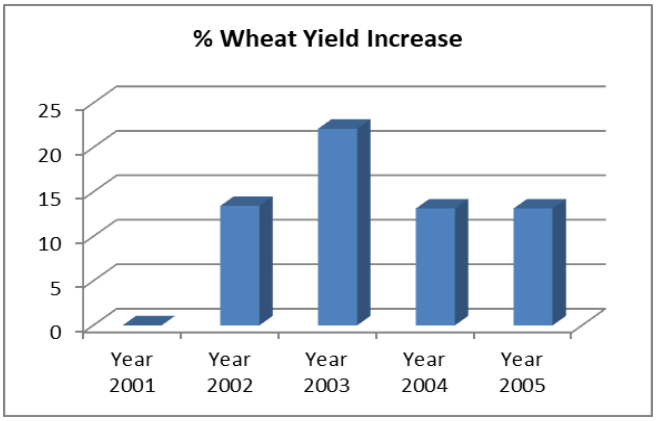

Fig. 3 Wheat yield increases after leafminer control.

In the mid of March 2002, we treated barley pivots against leaf miners and aphids after observing high infestation with the leaf miner on this crop. We realized a yield increase of 0.6 M.T/Ha, which corresponds to 7.72% in this season, and 1.36 M.T in 2003, or 17.50% compared to the 2001 season, see Table 2 and Figure 4. We did not grow barley in the next seasons.

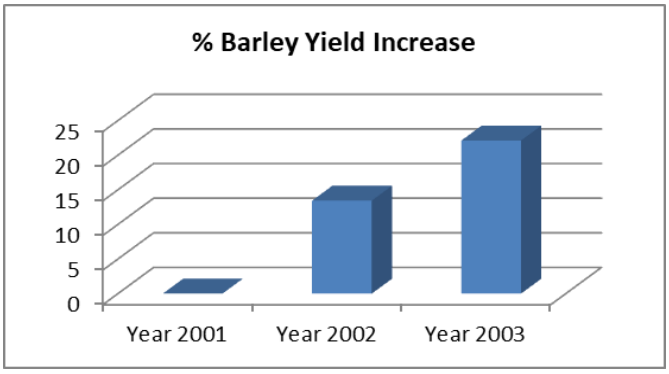

Fig. 4 Barley yield increase after leafminer control.

Table 1. Wheat Production: Sowing Date: Dec. to Jan 15; Harvesting Date June 5 to July 15.

Cropping season	1995	1996	1997	1998	1999	2000	2001	2002*	2003	2004	2005
Productivity M.T. /Ha.	8.69	8.49	7.77	7.08	7.61	7.41	7.15	8.11	8.73	8.09	8.09
Area (Hectare)	1500	4300	4083	3950	5250	4500	4547	5925	5540	6575	6965
% Yield Increase							Control	13.43	22.11	13.14	13.14

** High infestation with leaf miner in the mid of March 2002.*

Table 2. Barley Production: Sowing Date Nov.25 to Dec.10; Harvesting Date May 25 to June 10.

Cropping season	1995	1996	1997	1998	1999	2000	2001	2002*	2003
Productivity M.T. /Ha.	9.37	9.05	9.36	8.28	NC	8.95	7.77	8.37	9.13
Area (Hectare)	500	850	1000	1100	NC	1270	1250	1500	850
% Yield Increase							Control	7.72	17.50

** High infestation with leaf miner in the mid of March 2002.*

In July 1999, an epidemic infestation with the leaf miner insects appeared on alfalfa pivots at J30, J31, and J32 pivots after they applied the summer program, which extended the cutting period to two months to reduce the depletion of plants storage material occurred in short duration summer cutting off less than a month. The infected plants had symptoms of spiral mining on the leaves followed by yellowing and leave defoliation, see **Figure 5a**.

Fig. 5(a) Alfalfa leaf miner

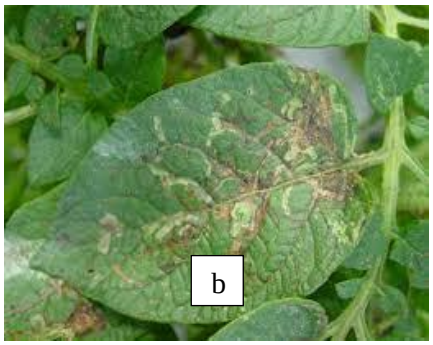

Fig. 5(b) Potato leafminer

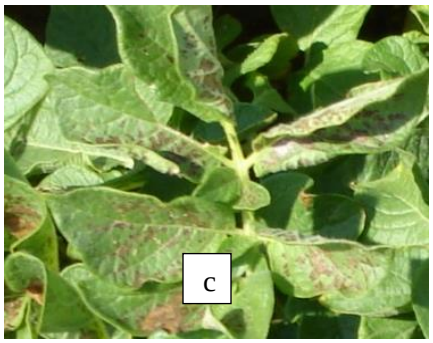

Fig. 5(c) Potato tuber moth

Leaf miners' infestation affected the alfalfa productivity qualitatively and quantitatively. We realized yield increase in the following seasons after applying the Integrated Pest Management program using selective chemicals like Dimethoate for aphids and Nomolt or Cascade to control the worms pests, including leaf miner fixed summer cuttings of no more than a month. The increased yield reached 2.01 M.T. /Ha in the 2000 season or 11.32%, and continued in 2001, 2002, 2003, and 2004 by 23.49, 5.18, 16.08, and 21.46% yield increase, respectively **Table 3** and **Figure 6**. Similar studies were carried out on potato crops affected by the infestation with leaf miners and potato tuber moth (**Figure 5b, 5c**) through data on spring and autumn potato planting yield during the period 2000 – 2006. We observed productivity of the spring potato was 27.72 M.T./Ha in the 2000 season, and then it dropped to17.62 in 2001 after leaf miner infestations, see Table 4.

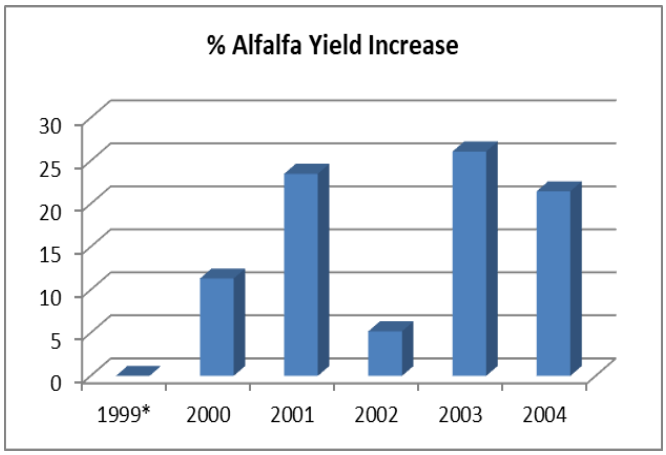

Fig. 6 Alfalfa yield increase after leafminer contr

Table 3. Alfalfa production: Sowing Date: Sep 20 to October 30; Harvest Cutting: Spring 40 -50 days, Summer 25 – 30 days.

Cropping season	1995	1996	1997	1998	1999*	2000	2001	2002	2003	2004
Productivity M.T./Ha.	20.0	17.62	20.35	19.70	17.75	19.76	21.92	18.67	22.38	21.56
Area (Hectare)	4565	3200	3750	4250	4250	3600	400	2250	2010	1850
% Yield Increase					Control	11.32	23.49	5.18	26.08	21.46

** High infestation with leaf minor in July 1999*

Table 4. Spring Potato Production: Planting Date Feb 1 to Feb 15; Harvesting Date May 25 to July 5.

Cropping season	2000	2001*	2002	2003	2004	2005	2006
Productivity M.T./Ha.	27.72	15.56	23.69	25.96	26.44	17.05	24.15
Area (Hectare)	25	50	150	305	300	300	76
% Yield Increase		Control	52.24	66.83	69.92	9.57	55.20

** High infestation with leaf minor in May 2001.*

Table 5. Autumn Potato Production: Planting Date Aug.1 to Aug 20; Harvesting Dec1 to Feb 5

Cropping season	**2000**	**2001***	**2002**	**2003**	**2004**	**2005**	**2006**
Productivity M.T./Ha.	**20.84**	**18.66**	**25.72**	**33.55**	**30.06**	**18.90**	**30.86**
Area (Hectare)	**675**	**325**	**200**	**400**	**412.5**	**500**	**400**
% Yield Increase		**Control**	**37.83**	**79.79**	**61.09**	**-3.05**	**65.38**

** High infestation with leaf minor in May 2001*

The yield was increased in 2002 to 23.69 M.T./Ha, which corresponds to 52.24%, after improving pest control measures against leaf miners and potato tuber moth through the application of Cascade Insecticide. Yields continued to increase in the following years, 2003, 2004, and 2005. 2006 with a yield increase of 66.83, 69.92, 9.57, and 55.20%, see Figure 7.

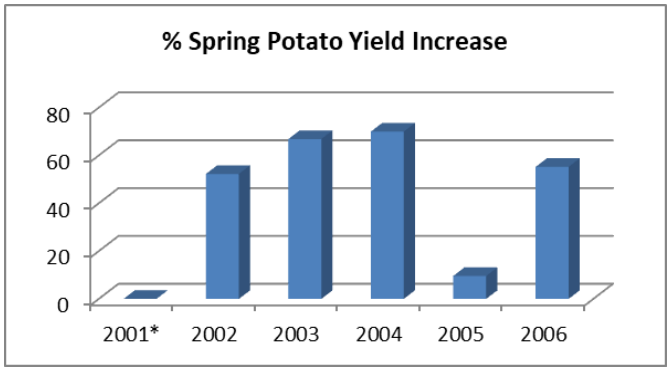

Fig. 7 Spring potato yield increases after leafminer and potato tuber moth control

Similar crop improvement was observed on the autumn potato as it was 20.84 M.T./Ha in the 2000 season, then it dropped to 18.66 in 2001 after leaf miner infestations, see Table 5. The yield was increased in 2002 to 25.72 M.T./Ha, which corresponds to 37.83%. After improving pest control measures against leaf miner and potato tuber moth, yield continued to increase in 2003, 2004, and 2006 with a yield increase of 79.79, 61.09, and 65.38%, respectively; however, there was a yield decrease in 2005 of 3.05%, see Figure 8.

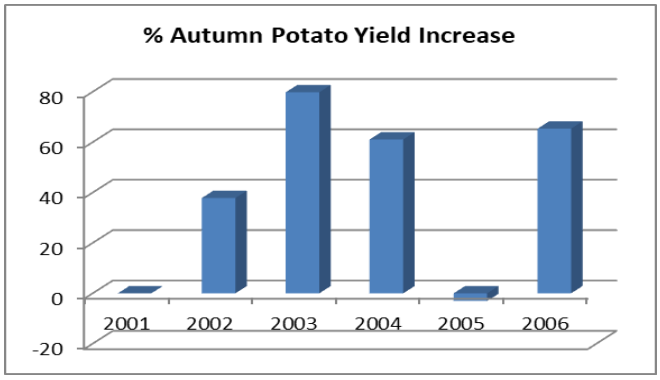

Fig. 8 Autumn potato yield increase after leafminer and potato tuber moth control

A comparison of weather data during the period 1999 to 2003 showed that the climate of the Tabuk region was characterized by moderate temperatures in most months of the year, except for the summer period, where the average temperature range between 37 - 40°C the period from June to the end of August; the temperature rise in July and August to a range 42 - 44°C for a few days of the month. The temperature drops in winter, and the minimum temperature range between 3 - 4°C in the period from December to February. However, the temperature drops below zero for a few days during December, January, and February; see **Table 6** and **Figure 9.**

A comparison of the monthly temperatures of the different years shows little difference. However, the average maximum temperature from January to May in 1999 was higher than the maximum average temperature of other years for the same period; and the average maximum temperature in July of 2000 was higher than the average temperature of other years for other years this month. The average minimum temperature of January 2002 was lower than the average minimum temperatures of other years.

Lower than the average minimum temperatures of other years for that month. So the weather was favorable to crop development during the years of study.

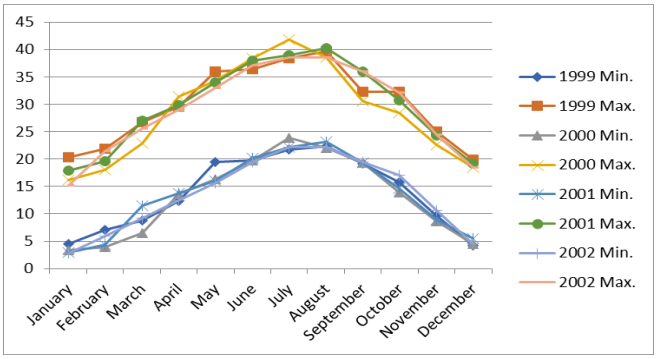

Fig. 9 Average monthly minimum and maximum mean temperatures at TADCO for the period

Table 6. Average monthly minimum and maximum mean temperatures at TADCO for 2000 – 2003.

	1999		2000		2001		2002	
Months	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
January	4.55	20.3	3.36	16.21	2.98	17.84	2.74	15.24
February	7.07	21.9	4	17.97	4.38	19.59	5.99	21.39
March	8.8	25.03	6.47	22.94	11.43	27.03	9.22	25.53
April	12.3	29.5	13.69	31.45	13.73	29.86	12.54	28.98
May	19.43	36	16.26	34.26	16.07	34.02	15.56	33
June	19.69	36.37	19.78	38.36	20.18	37.94	19.43	37.07
July	21.71	38.46	23.94	41.81	22.13	39.03	22.13	38.61
August	22.27	39.69	21.99	38.54	23.16	40.29	22.23	38.5
September	19.18	32.27	19.29	30.6	19.28	35.95	19.42	35.93
October	15.7	32.25	13.94	28.48	14.61	30.73	17.04	32.09
November	9.58	25.07	8.61	22.56	8.98	24.25	10.65	24.48
December	4.21	19.9	4.54	18.43	5.5	19.21	4.54	18.43

4. Discussion and Conclusion

Early Research work carried out in the Gassim area, Saudi Arabia, showed serious damage to wheat plants at the seedling stage to boot stage by leaf miner Agromyza spp (El-Hagg et al., 1987. 1991); damaged leaves lead to less tillering and less number of seeds per spike consequently affected yield significantly with final yield in infested fields ranged 2.2 to 3.5 M.T/Ha. Reports from South Africa, Australia, and Poland showed wheat leaf minor was a serious pest on wheat, but chemical control was not applied as the yield was not significantly reduced (Pinsloo, 2018; GRDC, 2014). The prevailing belief among the Field Crops Management at TADCO as well as the company's consultants that the leaf miner flies were a secondary pest on field crops due to the history of high productivity per hectare and the fact of high plants canopy density in field crops which makes them more tolerant to leaf miner infestation under the conditions of natural control. However, there was a period of wheat productivity decline from 1997 to 2001, ranging from 7.08 – 7.77 M.T./ Ha. This was significantly less than the 1995 and 1996 cropping seasons, with yields of 8.69 and 8.49 M.T./Ha, respectively. On the other hand, the situation was the opposite on vegetable crops grown in tunnel greenhouses with high infestation levels, which was difficult to control. Leaf miner damage to field crops occurred due to contact insecticides with a broad spectrum effect like Karate and Dursban for aphids and worms control. These chemicals killed the pest and its natural enemies and led to the insurgence of the leaf miner pests and other pests, turning leaf miner into a major pest on field crops.

In the mid of March 2002. symptoms of epidemic infestations with the leaf miner insect were observed on barley at the surrounding area of the pivots in the form of brown spots and scorched leaves, which alerted agronomy managers to survey the wheat crop. Results on wheat and barley crops showed a significant yield increase after we conducted chemical control using Dimethoate and Agral injected with irrigation water against leaf miner and aphid pests. The results showed the immediate response of wheat crop with increased yield by 13.43%, 22.11%, and 13.14%. 13.14% in 2002, 2003, and 2004 seasons respectively, Results on barley crop showed yield increase by 7.72%, 17.50% in 2002. 2003 seasons respectively.

Results on wheat crop encouraged us to study the effect of leaf miners on the productivity of alfalfa and potato crops as per leaf miners outbreak on alfalfa on July 1999 in comparison of historical production records and after the implementation of IPM program in 2000 season onwards using selective insecticides like Nomoult or Cascade which improved worms control. Results on alfalfa showed 11.32%, 23.49%, 5.18%, 26.08, 21.46% yield increase in 2000, 2001, 2002, 2003, 2004 seasons respectively. Results on spring potato showed significant yield increase by 52.24%, 66.83%, 69.92%, 9.57%, and 55.20% in 2002, 2003, 2004, 2005, and 2006 respectively. Results on autumn potato showed significant yield increase by 27.83%, 79.79%, 61.09%, -.3.05%, 65.18% in 2002, 2003, 2004, 2005, 2006 respectively.

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