ECONOMIC INJURY LEVEL FOR COLORADO POTATO BEETLE, *LEPTINOTARSA DECEMLINEATA* (SAY), ON 'AGRIA' POTATOES IN ARDABIL, IRAN

Gadir Nouri-Ganbalani*, Aliasghar Fathi* and Alireza Nouri-Ganbalani**

* Faculty of Agriculture, University of Mohaghegh Ardabili, Ardabil, IRAN. E-mail: gadirnouri@yahoo.com
** Institute of Higher Education of Sabalane Ardabil, Ardabil, IRAN.

[**Nouri-Ganbalani, G., Fathi, A. & Nouri-Ganbalani, A.** 2010. Economic Injury Level for Colorado Potato Beetle, *Leptinotarsa decemlineata* (Say), on 'Agria' Potatoes in Ardabil, Iran. Munis Entomology & Zoology, 5 (2): 764-771]

ABSTRACT: The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), which had been a quarantine pest to Iran until 1984, has become the most injurious pest of potatoes in Ardabil plain at northwest of the country, where more than 25000 ha of irrigated land is allocated to potato production and more than 20% of the annual potato production of the country is produced. Uncontrolled populations of the first generation of the Colorado potato beetle may completely defoliate potato plant and destroy the crop. Potato growers in Ardabil region almost always apply insecticides to control the pest, yet little information on the economic benefits of these control measures are available. This study was carried out in years 2004 and 2005 in Ardabil. At each of two study years experiments were conducted in three different locations in Ardabil plain. At each location a randomized complete block experiment with four replications and five treatments were used. Treatments were densities of zero, 5, 10, 15 and 20 late (3 rd and 4 th instars) larvae per plant of the first generation that were caged on a potato plant. The purpose of this study was to determine the relationship between different densities of the first generation larvae of the Colorado potato beetle and the yield of the potato cultivar 'Agria' and to establish economic injury level for the pest. A linear relationship was observed between the insect density and the marketable yield in 2004 and 2005 at all three locations. The overall linear regression of two study years for three locations accounted for 93.39% of variation among the treatments. Economic injury levels of the pest were calculated as 5 and 6.458 late larvae per plant for 'Agria' cultivar in years 2004 and 2005 respectively. Therefore, based upon the results obtained in this research the control measure for the Colorado potato beetle is not recommended at pest densities of lower than 5 late larvae per plant , because the chemical control at lower densities is not only economically unfeasible but also by producing deleterious effect on natural enemies causes damage to the environment.

KEY WORDS: *Leptinotarsa decemlineata* (Say), potato, economic injury level, regression.

Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is the most injurious defoliating insect pest of potato in Ardabil (Nouri-Ghanbalani, 1989). This insect had been a quarantine pest to Iran until 1984. At that time it was noticed for the first time in some of the potato fields of Ardabil (North – East of Iran). Eradication campaign of the government and potato farmers was not successful and the pest spread to all of the approximately 25000 ha potato farms of the province within a two year period. Since then it has spread to other potato growing parts of the country. Its biology, natural enemies and population dynamics has been studied in the province (Nouri-Ganbalani, 1989; Nouri-Ganbalani et al., 1998; Golizade et al., 2005). So far the Colorado potato beetle is the only insect pest that causes serious damage to the potato yield in Ardabil province and warrants control measures. The pest has two generations per year. Larvae are most abundant in late June and early July that coincides with early blooming of the potato, and adults of first generation emerge from pupation in late July (Nouri-Ganbalani, 1989). Uncontrolled populations of the first generation larvae may completely defoliate potato plants and destroy the crop. The effect of Colorado potato beetle on potato yield has been studied extensively. Hare (1980) has reported that yield is little affected by relatively severe insect defoliation early or late in the season, whereas even a moderate mid-season defoliation causes a considerable reduction in yield. Similar results were obtained in mechanical defoliation studies (Cranshaw & Radcliffe, 1980; Shields & Wyman, 1984). Potato tuber yield is closely related to leaf area duration which is the leaf area index integrated over time (Bremner & Radley, 1966). Leaf area duration can be strongly influenced by loss of active photosynthetic area as a result of defoliating factors such as insect, hails, and foliar disease such as early and late blight (Oijen, 1990; Shtienberg & Fry, 1990). Some defoliating agents may also reduce leaf area duration by inducing early leaf senescence (Johnson & Teng, 1990). For defoliated plant canopies, a reduction in light interception is most likely the primary cause for yield reduction (Peterson & Higley, 2001). Yield losses as a result of single episode of defoliation have been studied by simulating real insect defoliation (Skuhravy, 1968; Cranshaw & Radciffe, 1980; Shields & Wyman, 1984). A general result of these studies is that plants can recover from early season defoliation, but defoliation at the middle of the season has the most severe effect on yield, and defoliation has diminishing effects on yield as harvest is approached. Defoliation of upper portions of the potato canopy reduces yield by more than the removal of equivalent leaf areas from the middle or lower parts of the canopy (Cranshaw & Radcliffe, 1980). Hence, defoliation by Colorado potato beetle, which feeds on the upper new leaves, may have more effect on yield than equal amounts of leaf area duration loss attributable to early blight, which causes premature senescence of lower older leaves (Johnson et al., 1986). Ziems et al. (2006) concluded that yield losses from defoliation in potato are associated with reduction in canopy light interception. Economic injury levels and economic thresholds are key components in decision-making for insect pest management (Pedigo, 1999). Stern et al. (1959) defined the economic injury level as the lowest population density of a pest that will cause economic damage, and the economic threshold as the density of the pest population at which pest must be controlled to prevent damage from reaching this density. Thresholds from single episode defoliation studies have been used in pest management programs (Connell et al., 1991). Economic injury level for the Colorado potato beetle have been recommended either on the base of leaf damage caused by insect feeding (Bremner & Radley, 1966; Ferro et al., 1983; Johnson & Teng, 1990; Connell et al., 1991; Boiteau, 1994; Zehnder et al., 1995) or on the base of insect number per plant (Hare & Moor, 1988; Martel et al., 1986; Senanayake & Holliday, 1990; Mailloux et al., 1991; Holliday, 1994). Potato growers in Ardabil almost always apply insecticide for Colorado potato beetle control, yet little information on the economic benefits of this control measure is available. Therefore, the purpose of this study was to quantify the effect of different densities of the first generation larvae of the Colorado potato beetle on the yield of the potato cultivar 'Agria' and to establish economic injury level for this cultivar in Ardabil.

MATERIALS AND METHODS

Each year in 2004 and 2005, a plot (70 by 70 m) of 'Agria' potatoes (a medium maturing variety) was planted at three different locations in Ardabil (Hassan Barogh, University farm and Alarogh). Plot preparation and farming practices in the experiment were similar to that in commercial fields of 'Agria' potato in the same area, except that no insecticide was applied to the experimental plots. At each of the three locations a randomized complete block experiment with four replications and five treatments were used. Treatments were densities of zero, 5, 10, 15, and 20 late larvae (third and fourth instars larvae) per plant that were used at early blooming stage of potato. At the early blooming stage of potato in commercial fields of Ardabil most eggs of Colorado potato beetles hatch and more than 50% of the larvae enter to the third or fourth instars stage, and the density of larvae is at peak. Therefore, a practical economic threshold must be available to growers at the time of early blooming stage. Larvae were collected from the nearby commercial fields on the potato leaves and the desired numbers were transferred with the leaves to the upper part of the randomly selected plants. Before inoculation each plant was carefully searched for any egg mass, adult or larvae and they were hand-picked and excluded from the treatment plants. After the introduction of the larvae to the plants each plant was individually caged. A wood-framed screen cage of 80×80×100 cm in height was established on top of each treated plant. Cages were covered with white nylon screen (30 squares per cm) with 15 cm diameter sleeves on two opposing sides to give access to plant without moving the cage. Earth was banked against the bottom of the cages to prevent insect entry or exit. Caged plants were subjected to one of five treatments at the early blooming stage of potato in a random manner. The larvae were allowed to eat on the treated plants inside the cages. After the emergence of the first generation adult, each cage was removed carefully and all the adults and egg masses were removed by hand and the cage was re-established on the top of the plant and left intact until the end of the season. At harvest time (first week of September) each cage was removed, the foliage of the plant was cut and the tubers were dug by a hand shovel. Except the tubers of less than 4 cm in diameter, which were regarded as unmarketable, the remaining tubers of each plant was put in a paper bag separately and transferred to the laboratory, where it was weighted and recorded. The economic injury level was estimated using Pedigo, s (1999) equation as follows: EIL= $C/V.b.K$, where C is the control cost (insecticide + insecticide application cost per ha), b is the slope of regression line of pest number to yield loss and *K* is the relative effect of control measure. Control cost per ha was estimated by inquiry from 40 farmers in different crop growing areas and the mean cost was calculated as 50 $ per ha. Crop value was estimated via survey in wholesale markets for 15 days at harvest time of each of study years and the mean value was 0.2 $ per kg. The *K* value was determined via inquiry from the Department of Plant Protection of the Ministry of Agriculture and it was 0.8. The slope of regression line was calculated through the regression analysis. Among the above characters, market value (v) is the most uncertain variable in Iran's market situations. The management cost is less uncertain because the price of insecticide and the cost of application are relatively constant.

Economic injury level was calculated using Pedigo, s (1999) formula:

$$EIL= C / V . b . K$$

Statistical Analyses

Data were subjected to analysis of variance (ANOVA). Analyses of regression were used to determine relationship between variation in insect density and yield and to estimate coefficient of regression lines (b) using MSTAT-C program. Separations were made using the Duncan, s (1955) multiple range test at $p<0.01$ (SAS Institute, 1988).

RESULTS

The tuber yield of 'Agria' potato under different densities of late instars of the Colorado potato beetle larvae at early blooming stage is given in Table 1. Feeding by the Colorado potato beetle larvae reduced the yield of marketable tubers with increasing insect density and there were significant difference among the treatments (Table 2). There were also highly significant differences among years and locations with respect to tuber yield. Also the effect of year * location and treatment * year * location were highly significant (Table 3). A linear relationship was observed between the insect density and the marketable yield in 2004 and 2005 at all three locations (Figs.1). The overall linear regression of two study years for three locations accounted for 93.39 of variation among treatments. There was a significant difference in mean yield per plant of different treatments ($P < 0.001$). The overall linear relationship between insect density and yield loss was:

$$Y = -43.172X + 1262.7 \quad (R2 = 93.39)$$

In control trial the mean yield of the tuber was estimated to be 23900 kg per ha. The overall control cost of the pest was estimated to be 50$ per ha, and the crop value was estimated to be 0.2$ per kg.

Using Pedigo, s (1999) method, economic injury level of the pest was calculated as 5 and 6.458 late larvae per plant for 'Agria' cultivar in year 2004 and 2005 respectively. Therefore, based upon the results obtained in this research the control measure for the Colorado potato beetle is not recommended at pest densities of lower than 5 late larvae per plant , because the chemical control at lower densities is not only economically unfeasible but also by producing deleterious effects on natural enemies and by damaging the environment considered unjustified.

DISCUSSION

To obtain a realistic economic injury level, plants must be exposed to known populations of Colorado potato beetles throughout the growing season. Such populations must have the same age structure and pattern of increase and decease as the field populations, but the density must be under the control of the researcher (Senanayake and Holliday, 1990). To achieve this degree of control, plants had to be placed in cages. However caged plant may not behave in the same way as plants in a field. We constructed the cages in a way to allow approximately the same amount of space for foliage as plants would have in the field. But competition for root space and nutrients was probably low in cages than in the field and this may account for the higher yield in cages. Sananayake and Holliday (1990) concluded that the cage studies overestimate the percentage yield reduction by 22% per larva.

The economic injury levels we have obtained for 'Agria' are different from those obtained by other researchers for most other production regions of the world. For example, Martel et al. (1986) determined the economic threshold to be 20 late larvae per plant in Canada and Wright et al. (1987) used an action threshold of 1.5 late larvae per stalk. A two year study of a bivoltine population of Colorado potato beetle on Superior potato in Massachusetts revealed that profits are maximized by treatments that prevent defoliation exceeding 10% until final two weeks before harvest (Ferro et al., 1983). Growth stage specific action thresholds have been derived for Superior potato in eastern Virginia as: 20% defoliation for emergence to early bloom, 30% for early bloom to late bloom and 60% for late bloom onwards (Zehnder et al., 1995). A visual index of defoliation has been developed in New Brunswick of Canada as an action threshold (Boiteau, 1994). This approach recognizes that action must be taken when up to 2% of the plants have compound leaves that are at least 50% defoliated (Boiteau, 1995). Some action thresholds based on counts of the Colorado potato beetle have been developed. A threshold of 20 larvae per plant for first generation Colorado potato beetle on Katahdin potato unimpaired yield without the need for insecticide applications to the second generation of a bivoltine population in Connecticut (Hare & Moor, 1988). Martel et al. (1986) also used a threshold of 20 larvae per plant in Quebec of Canada, which is equivalent to yield losses of 10-27%. In North America, a preventable yield loss of 10% would cause a reduction in gross revenue of 220-500 $/ha, which is considerably more than the cost of a control measure (Holliday, 1994). Economic thresholds, based upon damage curves also have been used in Canada and economic injury levels found were 5 and 11 larvae per plant for susceptible and tolerant cultivars respectively in Manitoba. Mailloux et al. (1991) concluded that a larval population of 50 per plant is associated with 50% yield reduction in Superior and 90% yield reduction in Norland (Senanayake & Holliday, 1990).On the other hand Sananayake and Holliday (1990) concluded that the economic injury level for Colorado potato beetle for 'Norland' variety in Manitoba (Canada) varied from 0.14 to 0.82 late larvae per plant depending on the control cost and expected yield of the potato. A number of factors may contribute to these disparities. Climatic conditions, soil fertility, variety characteristics, specially the maturation duration of the variety and plant height may influence the economic injury level. In Ardabil plain currently a single application of insecticide at the early bloom stage of potato is the only economically justifiable control option. Since resistance to insecticides currently used in Ardabil is not evident, potato producers can achieve adequate control with single application of insecticide. The relatively lower control costs in Ardabil results in higher economic injury levels. In some countries where insecticide resistance has become a problem, costs of controlling Colorado potato beetle may exceed $500/ha (Wright et al., 1987). We concluded that the economic injury levels for Colorado potato beetles on 'Agria' potatoes in Ardabil are relatively higher than some other parts of the world, but we strongly believe that their adoption will reduce insecticide use in this region.

LITERATURE CITED

Boiteau, G. 1994. Visual index for the estimation of defoliation in the potato crop. Pp 6-7. In: Entomology Group Research Summary 3, Federicton Research Centre, Agriculture and Agri – Food Canada.

Boiteau, G. 1995. When are there too many Colorado potato beetle on a potato plant pp. 12-13. In: Entomology Group Research Summary 3, Fredericton Research Centre, Agriculture and Agri – Food Canada.

Bremner, P. M. & Radley, R. W. 1966. Studies in potato agronomy II. The effect of variety and time on planting on growth, development and yield. J. Agric. Sci., Camb. 66: 253-262.

Bremner, P. M. & Taha, M. A. 1966. Studies in potato agronomy I. The effect of variety, seed size and spacing on growth, development and yield. J. Agric. Sci., Camb. 66: 241-252.

Connell, T. R., Koenig, J. P., Stevenson, W. R., Kelling, K. A., Curwen, D., Wyman, J. A. & Binning, L. K. 1991. An integrated system approach to potato crop management. J. Prod. Agric., 4: 453-460.

Cranshaw, W. S. & Radcliffe, E. B. 1980. Effect of defoliation on yield of potatoes. J. Econ. Entomol., 73: 131-134.

Ferro, D. N., Morzuch, B. J. & Margolies, D. 1983. Crop loss assessment of the Colorado potato beetle (Coleoptera: Chrysomelidae) on potatoes in western Massachusetts. J. Econ. Entomol., 76: 349-356.

Golizade, A., Nouri-Ganbalani, G. & Kamali, K. 2005. A study on the density and seasonal population dynamics of Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Col. Chrysomelidae), in Arasbaran region of East Azerbaijan, Iran. Iran. J. Agri. Sc., 34: 54-65.

Johnson, K. B. & Teng, P. S. 1990. Coupling a disease progress model for early blight to a model of potato growth. Phytopathology, 80: 416-425.

Johnson, K. B., Johnson, S. B. & Teng, P. S. 1986. Development of a simple potato growth model for use in crop-pest management. Agric. Sys., 19: 189-209.

Hare, J. D. 1980. Impact of defoliation by the Colorado potato beetle on potato yields. J. Econ. Entomol., 73: 369-373.

Hare, J. D. & Moore, R. E. B. 1988. Impact and management of late-season populations of the Colorado potato beetle (Coleoptera: Chrysomelidae) on potato in Connecticut. J. Econ. Entomol., 81: 914-921.

Holliday, N. J. 1994. Insect management, pp. 38-51. In: B. Geisel, [ed.] Manitoba Commercial Potato Production Guide. 1994. Manitoba Potato Council, Winnipeg.

Mailloux, G., Binns, M. R. & Bostanian, N. J. 1991. Density yield relationship and economic injury level model for the Colorado potato beetle larvae on potatoes. Res. Pop. Ecol., 33: 101-113.

Martel, P., Belcourt, J., Choquette, D. & Boivin, G. 1986. Spatial dispertion and sequential sampling plan for the Colorado potato beetle (Coleoptera: Chrysomelidae). J. Econ. Entomol., 79: 414-417.

Nouri-Ganbalani, G. 1989. Seasonal biology of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Col. Chrysomelidae), in Ardabil, Iran. J. Agric. Sc., 29 (1): 1-9.

Nouri-Ganbalani, G., Akbarian, J. & Sahragard, A. 1998. Preliminary studies on natural enemies of the Colorado potato beetle in Ardabil, Iran. Agric. Sc., 8 (2): 58-74.

Oijen, M. Van. 1990. Photosynthesis is not impaired in healthy tissue of blighted potato plants. Neth. J. Pl. Path., 96: 55-63.

Pedigo, L. P. 1999. Entomology and pest management (3rd Ed.), Prentice Hall, New Jersey. 691 pp.

Peterson, R. K. D. & Higley, L. G. 2001. Biotic stress and yield loss. CRC Press, Boca Raton, FL.

SAS Institute. 1985. SAS user's guide, statistics, version 5. SAS Institute, Cary, N. C.

Senanayake, D. G. & Holliday, N. J. 1990. Economic injury level for Colorado potato beetle (Coleoptera: Chrysomelidae), on Norland potatoes in Manitoba. J. Econ. Entomol., 83: 2058-2064.

Shields, E. J. & Wyman, H. 1984. Effect of defoliation of specific growth stages on potato yields. J. Econ. Entomol., 77: 1194-1199.

Shtienberg, D. & Ery, W. E. 1990. field and computer simulation evaluation of spray-scheduling methods for control of early and late blight of potatoes. Phytopathology, 80: 772-777.

Skuhravy, V. V. 1968. Influence of artificial defoliation and of potato beetle feeding on the yield of potatoes. Anz. Schadlingsk. Pflanz. Umwelt., 41: 180-188.

Stern, V. M., Smith, R. F., van den Bosh, R. & Hagan, K. S. 1959. The integrated control concept. Hilgardia, 29: 81-101.

Zehnder, G., Vencill, A. M. & Speese, J. 1995. Action thresholds based on plant defoliation for management of Colorado potato beetle (Coleoptera: Chrysomelidae) in potato. J. Econ. Entomol., 88: 155-161.

Ziems, J. R, Zechmann, B. J., Hoback, W. W., Wallace, J. C., Madson, R. A., Hunt, T. E. & Higley, L. G. 2006. Yield response of indetermined potato (*Solanum tuberosum* L.) to simulated insect defoliation. Agron. J., 98: 1435-1441.

Wright, R. J., Kain, D. P. & Moyer, D. D. 1987. Development and implementation of an extension IPM program for long Island. Bull. Entomol. Soc. Am., 33: 239-245.

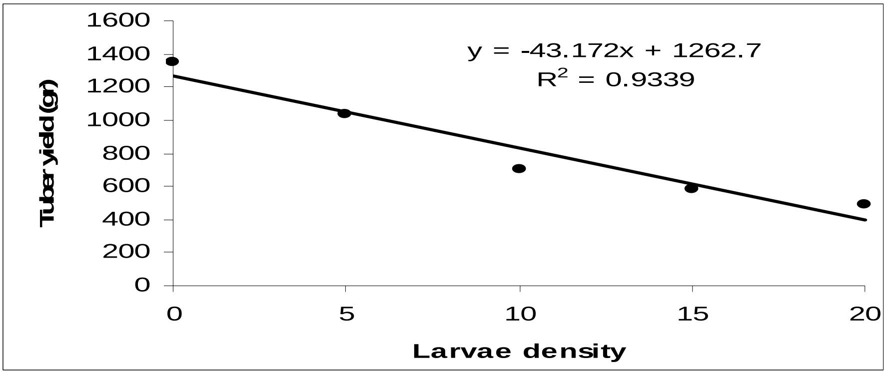

Figure 1. Linear relationship between late larvae density and mean tuber yield at three locations and two years (2004-2005).

Table 1. Effect of different densities per plant of late larvae of Colorado potato beetle on the tuber yield (gr) of caged potato in Ardabil province, Iran in years 2004 and 2005.

Treatments(larvae/plant)															
location	Zero larvae (check)			5 (larvae/ plant)			10 (larvae/ plant)			15 (larvae /plant)			20 (larvae /plant)		
	2004	2005	mean	2004	2005	mean	2004	2005	mean	2004	2005	mean	2004	2005	mean
Hassan Barogh	1087	1290	1188.5ᵃ	942	1083	990ᵃ	457	680	568.5ᵃ	398	527	462.5ᵃ	411	528	469.5ᵃ
University	2253	1888	2070.5ᶜ	1396	1399	1397.5ᶜ	1341	855	1098ᶜ	1158	819	988.5ᶜ	935	508	721.5ᶜ
Alarogh	932	627	779.5ᵇ	814	599	706.5ᵇ	585	292	438.5ᵇ	401	211	306ᵇ	315	180	247.5ᵇ
Overall mean		1346.07			1031.67			701.7			585.63			479.78	

Means in each column followed by similar letters are not significantly different at the 5% level of probability (SAS Institute 1988).

Table 2. Two years mean of the tuber yield (gr/plant) for different treatments for three locations.

Source of variation	Degrees of freedom	Mean squares
Year	1	493730.488**
Location	2	6137297.194**
Year. Location	2	611433.777**
Replication (Y.L)	18	41915.901**
Treatment	4	2993512.863**
Treatment. Year	4	18080.680**
Treatment. Location	8	205929.390ns
Treatment. Year. location	8	33099.462**
Error	72	15253.009

** and * indicate significant difference at the 1% and 5% levels of probability respectively, and ns indicates no significance.

Table 3. Analysis of variance of the treatments effects on tuber yield of potatoes

Treatment(larvae/plant)	Location			
	Hassan Barogh	**University**	**Alarogh**	**Mean**
Zero	1188.3375c	2070.5125a	779.3625a	1346.07a
5	991.125d	1397.425b	706.4875e	1031.67b
10	568.4875f	1098.0935c	438.525g	701.702c
15	462.3375	988.575d	305.9875h	585.63d
20	469.55g	752.6125e	247.20h	489.78e

Means in each column followed by similar letters are not significantly different at the 5% level of probability (SAS Institute 1988).