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Antibiosis effects of 20 potato cultivars to the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Col. Chrysomelidae)

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Abstract

The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is a serious pest of potato, *Solanum tuberosum* L. worldwide. In this study, to determine the probable antibiotic effects of 20 potato cultivars on *L. decemlineata*, life predestination of neonate larvae were investigated until emergence of adults on studied cultivars. Tubers of different cultivars were planted in pots in a greenhouse. After the emergence of the plants, one sleeve cage was set on each pot and 15 neonate larvae were released and reared. Weight of larvae on 12th day after release, developmental time of larvae and pupae and mortalities of these stages were determined as antibiosis indices of the cultivars. Data was analyzed with SAS statistical software and comparison of means was performed with Turkey's HSD procedure in 5% level. It was found that reciprocal effect of cultivar × year was significant for all of the studied indices (P<0.001). The comparison of means showed that the least weight of larvae on 12th day after releasing was observed on the Carlita, Delikat and Raja cultivars in 2007 and on the Delikat, Bright and Carlita cultivars in 2008. The highest larval mortalities were observed on Delikat and Carlita cultivars in 2007 and on the Carlita, Sinja and Delikat cultivars in 2008. The longest developmental time in 2007 was observed on the Morene, Romina and Carlita and in 2008 this time was observed on the Carlita, Aparret and Bridjet. With cluster analysis on the basis of mortalities of immature stages and developmental period by using UPGMA procedure based on Euclidean distance, 20 studied cultivars were grouped in 5 distance clusters.

Key words: Antibiosis, plant resistance, potato, cultivar, Colorado potato beetle.

Introduction

Potato, *Solanum tuberosum* L. is an important crop with 5.24 million tons of production on 210,000 hectares of irrigated land in Iran [1]. Numerous pests attack the potato crop, among them the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is the most important pest in Iran [2]. This is a cosmopolitan pest and the most dangerous pest of potato and other solanaceaeous crops in many areas of the world [3] that can cause yield reduction of 30 to 50 percent [4]. Chemical control method continues to be the main component of the potato production system [5], but the pest has become resistant to all registered insecticides [6]. For this reason and numerous side effects of insecticides on humans' health and environment has necessitated the investigation of alternative control methods for effective managing of Colorado potato beetle [7]. Plant resistance is considered to be an important part of any integrated pest management system, which is compatible with sustainable control methods and can reduce the use of chemical insecticides [8]. Any reduction in the susceptibility of the crop to an insect pest lowers pressure from insect pests and allows the use of biological and physical control methods, that generally have a slower or lower impact on the pest population [4].

Potato breeding programs and transgenic techniques have produced a large number of potato cultivars with some degree of resistance to the Colorado potato beetle [9, 10] and many trends are available to integrate resistant plants and other controlling methods in an IPM program [11]. To integrate these methods effectively, it is necessary that information in the kinds of resistance mechanisms of cultivars is available [12].

Three types of plant resistance to insects are commonly referred to in plant resistance literature. These resistance types were originally defined by Painter [13] as mechanisms and included antixenosis, antibiosis and tolerance [14]. In antibiosis the biology of the pest insect is adversely affected [15]. The antibiosis effects of a resistant plant range from mild to lethal. Lethal effects may be acute, in which case they often affect young larvae and eggs. The chronic effects of antibiosis often lead to mortality in older larvae and prepupae that fail to pupate, and in pupae and adults which fail to eclose. Individuals surviving the direct effects of antibiosis may also suffer the debilitating effects of reduced body size and weight, prolonged periods of development in the immature stages and reduced fecundity [14].

Antibiosis may be related to the existence of allomones or absence of kairomones, and cultivars with antibiosis resistance may be absent of nutritients that are necessary to insect or exist chemical substances that are toxic effects for insect [16].

Antibiosis effects of potato cultivars and wild species of potato to the Colorado potato beetle have been investigated extensively [4, 12, 17-21].

The main objective of this study was the comparison of probable antibiotic effects of 20 commercial cultivars of potato to the Colorado potato beetle and to delineate the cultivar with the highest antibiotic effects on the Colorado potato beetle that can be used in the IPM program of the pest.

Materials and Methods

This research was conducted in a greenhouse at 20±4°C, 65±5% RH and natural light for two years (2007-2008). The initial population of the Colorado potato beetle was collected from fields in west Azarbaijan province, Iran. Potato cultivars used in this study were obtained from the Agricultural Research Center of Ardabil province, Iran. These cultivars were: Estima, Morene, Bridjet, Delikat, Likaria, Desiree, Nicola, Diamont, Raja, Romina, Aparret, Bright, Sinja, Baltica, Fianna, Famosa, Arrancar, Carlita, Beluga and Agria. Experiments were initiated after one generation rearing of *L. decemlineata* under greenhouse conditions on each potato variety used in this study.

Potato tubers were planted in pots with 22 cm diameter and 18 cm height in the field. After the crucibles reached the eight leaf stage, the pots were transferred into the greenhouse. One sleeve cage was set on each pot and 15 newly emerged first instar larvae, selected randomly from stock cultures, were transferred into each sleeve cage and reared to maturity. Foliage of cultivars was replaced on 3 days intervals. The developed larvae were transferred into plastic dishes (20 cm ×10 cm × 5 cm) filled with soil and their lids had a hole covered with nylon mesh for ventilation for their pupae stages. Weight of larvae on 12th day after release was determined with digital balance with 0.001 g accuracy. The developmental time and percent mortalities of larvae and pupae stages were determined for all potato cultivars. The mortalities and developmental durations of each immature stage (larvae and pupae) were calculated separately.

This study was conducted in a Completely Randomized Design with 20 treatments each with 3 replicates in a two years period. Data of percentage mortalities were transformed to Arc sin $\sqrt{x}$. Data analysis of variance (ANOVA) was performed with SAS statistical software. The comparison of means was performed in Tukey's HSD procedure in 5% level. With paying attention to the studied indices (weight of larvae on 12th day after releasing, developmental time and percent mortalities of the larval and pupal stages) in the first and second year experiment and the two years mean of these indices, cluster analysis of cultivars was performed with MINITAB15 statistical software by means of UPGMA procedure based on Euclidean distance.

Results and Discussion

In this study, life predestination of neonate larvae was investigated until emergence of adults on the studied cultivars. Combined analysis of variance showed that reciprocal effect of cultivar × year was significant for all of the studied indices at P = 0.01 (Table 1), that with paying attention to difference in two experimental conditions (for purpose of photoperiod), this discrepancy is explainable. For the reason that reciprocal effect of cultivar × year was significant, comparison of means was performed separately each year (Tables 2- 3).

In the 12th day after the release of the neonate larvae, the least larvae weight gain was observed on the Carlita, Raja and Delikat cultivars in 2007 with mean weights of 97.67±4.18, 103.17±3.53 and 105.00±5.00 mg, respectively, that can be related to antibiotic effects of these cultivars [12]. In this year the larvae that were released on the Bright, Famosa and Fianna cultivars, showed the highest weight gain with the mean weights of 159.67±7.99, 159.67±6.78 and 159.17±4.64 mg, respectively, that showed the susceptibility of these cultivars to the Colorado potato beetle (Table 2). In 2008, the least larvae weight were observed on the Delikat, Carlita, Bridjet and Beluga with means of 110.83±5.20, 118.48±4.99, 118.80±1.82 and 120.32±6.51 mg, respectively, in the 12th day after the release of neonate larvae. The highest larvae weight gain was observed on Famosa, Estima and Raja cultivars with mean weights of 160.66 ±1.57, 158.00±3.93 and 150.96±1.80 mg, respectively (Table 3).

The increase of larvae weight, larval and pupal mortalities and duration of these periods were analyzed as antibiosis indices. Larval development and survivorship of developmental stages on wild *Solanum* species have been used as indices for measurement of antibiosis resistance to the Colorado potato beetle [12, 18].

Horton *et al.* [12] investigating the resistance of 8 potato lines to the Colorado potato beetle observed that on 3 lines weight of larvae was lower than in control line in 48 hours after release. Lyytinen *et al.* [20] did not observe antibiosis effects in the Van Gough, Timo and Nevesky cultivars to the Colorado potato beetle larvae, that with paying attention to the studied cultivars of them was few and differed with our studied cultivars, this difference is explainable. Karroubizadeh *et al.* [22] studied the resistance of 20 potato cultivars to the Colorado potato beetle observed no significant difference in larvae weight gain between cultivars in 48 hours after the release of larvae.

The comparison of means showed that in 2007, the longest total developmental (larvae and pupae) time was observed on the Morene, Carlita and Romina cultivars with means of 34.00±0.50, 33.44±0.34 and 33.37±0.77 day, respectively and the shortest total development time was observed on the Likaria and Estima cultivars with means of 29.25±0.27 and 29.80±0.07 day, respectively. In 2008, the longest total development duration was observed on the Carlita and Aparret with means of 35.80±0.53 and 35.25±1.10 day, respectively, and the shortest time of these stages was observed on the Likaria and Estima cultivars with means of 28.22±0.27 and 28.91±0.90 day, respectively (Tables 2-3). The ranges of developmental time of the Colorado potato beetle found in this research were similar to the findings of Yasar and Gongur [23] that the total development time of the Colorado potato beetle on Casper, Agria, Marfona, Pasinler and Granola potato cultivars wase

Table 1. Combined analysis of variance of studied indices in 20 potato cultivars.

Source of variance	Degree of Freedom	Weight of Larvae	Mortality of Larvae	Lavral Period	Mortality of Pupae	Pupal Period	Total Mortality	Total Period
Year	1	986.764 ^{ns}	1.840**	3.152 ^{ns}	0.512 ^{ns}	9.408 ^{ns}	0.103 ^{ns}	1.485 ^{ns}
Cultivar	19	1223.420*	0.247**	4.528 ^{ns}	0.059 ^{ns}	6.356 ^{ns}	0.105*	12.269 ^{ns}
Year × Cultivar	19	484.630**	0.055**	4.658**	0.061**	7.552**	0.042**	6.326**
Error	80	70.600	0.012	0.815	0.012	0.839	0.008	1.612
C.V.		6.32%	18.38%	5.47%	16.42%	6.09%	9.66%	4.02%

^{ns} non-significant, * and ** significant at 0.05 and 0.1 level, respectively.

Table 2. Means of the studied antibiosis indices of 20 potato cultivars in year 2007.

Cultivar	Weight of Larvae(mg)	Mortality of Larvae (%)	Larval Period (day)	Mortality of Pupae (%)	Pupal Period (day)	Total Mortality (%)	Total Period (day)
Estima	141.17 ±6.29 efg	8.89 h	16.70±0.15 abcd	48.53 ab	13.10±0.16 ef	53.33 defg	29.80±0.07 bc
Morene	132.63 ±8.88 cdef	24.44 efgh	17.70 ±0.40 ab	44.17 abc	16.30 ±1.01 abcd	57.78 cdefg	34.00 ±0.50 a
Bridjet	135.42 ±2.60 cdefg	46.67 bcdefg	17.77± 0.12 a	54.17 ab	14.65± 0.85 bcdef	80.00 abc	32.69 ±0.47 abc
Delikat	105.00±5.00 ab	75.56 ab	14.06± 0.34 d	64.45 a	16.17 ±0.44 abcd	91.11 a	30.22 ±0.15 abc
Likaria	112.58± 6.60 abc	68.89 abc	17.14±0.22 abc	36.11 abc	12.11±0.48 f	80.00 abc	29.25 ± 0.27 c
Desiree	151.00±4.93 fg	62.22 abcd	14.97± 0.24 bcd	23.41 bcd	15.68±0.19 abcde	71.11 abcde	30.65 ±0.28 abc
Nicola	114.17±7.33 abcd	53.33 bcdef	17.94±0.48 a	42.85 abc	13.99±0.33 cdef	73.33 abcd	31.93 ±0.81 abc
Diamont	151.63±6.84 fg	37.78 cdefg	17.00±0.52 abc	28.89 bc	14.67±0.19 bcdef	55.56 defg	31.67 ±0.71 abc
Raja	103.17±3.53 ab	64.45 abc	16.68±0.58 abcd	44.44 abc	15.19±0.61 abcde	80.00 abc	31.87 ±0.45 abc
Romina	120.25±3.07 abcde	22.22 fgh	17.92±0.74 a	26.01 bcd	15.45±0.65 abcde	42.22 g	33.37 ±0.77 ab
Aparret	137.07±3.58 cdefg	17.78 gh	17.48±0.80 abc	36.27 abc	13.54±0.42 def	46.67 efg	31.02 ±1.02 abc
Bright	159.67±7.99 g	31.11 defgh	16.58± 0.27 abcd	16.50 cd	13.60±0.29 def	42.22 g	30.18 ±0.55 abc
Sinja	117.83±7.22 abcde	53.33 bcdef	16.99±0.68 abc	28.97 bc	13.01±0.26 ef	66.67 cdefg	30.00 ±0.44 bc
Baltica	120.00± 2.89 abcde	55.56 bcde	14.78±0.43 cd	15.59 cd	17.02± 0.37 ab	62.22 cdefg	31.80 ±0.18 abc
Fianna	159.17±4.64 g	24.45 efgh	15.56± 0.74 abcd	26.51 bcd	17.54±0.48 a	44.45 fg	33.10 ±1.06 abc
Famosa	159.67± 6.78 g	57.78 bcd	16.00±0.29 abcd	26.11 bcd	14.41±0.64 bcdef	68.88 bcdef	30.41 ±0.38 abc
Arrancar	119.17±5.20 abcde	20.00 gh	17.04± 0.38 abc	38.83 abc	13.89±0.69 cdef	51.11 defg	30.93 ±0.82 abc
Carlita	97.27±4.18 a	86.67 a	16.94±0.54 abc	11.11 d	16.50±0.29 abc	88.89 ab	33.44 ±0.34 ab
Beluga	139.73±5.49 defg	37.78 cdefg	17.82±0.22 a	26.00 bcd	14.43±0.74 bcdef	53.33 defg	32.25 ±0.52 abc
Agria	125.00±3.46 bcde	24.45 efgh	16.05±0.81 abcd	43.94 abc	14.00±0.29 cdef	57.78 cdefg	30.05 ±0.81 bc

Means followed by the same letters in each column are not significantly different (P = 0.05, Tukey's HSD).

Table 3. Means of the studied antibiosis indices of 20 potato cultivars in year 2008.

Cultivar	Weight of Larvae(mg)	Mortality of Larvae(%)	Larval Period (day)	Mortality of Pupae(%)	Pupal Period (day)	Total Mortality (%)	Total Period (day)
Estima	158 ±3.93 ef	2.22 e	15.23±0.48 cd	48.89 abc	13.68±0.44 def	49.99 cdef	28.91±0.90 fg
Morene	149.32 ±2.95 cdef	31.11 abc	15.33 ±0.53 bcd	47.31 abc	15.61 ±1.11 bcde	66.67 abcd	30.93 ±1.06 cdefg
Bridjet	118.48 ±4.99 ab	31.11 abc	16.76± 0.53 bcd	51.82 abc	17.76± 0.51 abc	66.67 abcd	34.52 ±0.56 abc
Delikat	110.83±5.20 a	58.47 a	17.99± 0.56 ab	44.81 abc	14.75 ±0.49 def	73.75 abc	32.75 ±1.00 abcdef
Likaria	134.24± 2.95 abcde	10.83 cde	15.59±0.57 bcd	34.06 bc	12.64±0.44 f	41.25 def	28.22 ±0.27 g
Desiree	139.65±1.81 bcdef	31.11 abc	15.83± 0.48 bcd	44.54 abc	15.87±0.56 bcd	62.22 abcde	31.70 ±1.04 bcdefg
Nicola	139.45±1.65 bcdef	31.11 abc	16.95±0.42 bcd	46.67 abc	15.24±0.71 cdef	62.22 abcde	32.19 ±0.60 abcdef
Diamont	136.50±4.99 abcdef	2.22 e	15.89±0.50 bcd	56.03 ab	16±0.66 bcd	66.67 abcd	31.89 ±1.02 bcdefg
Raja	150.96±1.80 def	31.11 abc	16.10±0.61 bcd	38.48 abc	14.25±0.43 def	57.78 bcdef	30.36 ±0.22 defg
Romina	126.17±3.14 abcd	22.21 bcd	17.64±0.57 bc	41.82 abc	15.40±0.70 bcdef	55.56 bcdef	33.04 ±1.23 abcde
Aparret	133.11±2.93 abcde	21.53 bcd	17.14±0.51 bcd	54.85 abc	18.10±0.60 ab	62.92 abcd	35.25 ±1.10 ab
Bright	140.99±1.31 bcdef	12.92 cde	16.36± 0.39 bcd	22.70 c	15.23±0.37 cdef	32.36 f	31.58 ±0.75 bcdefg
Sinja	137.70±2.57 bcdef	55.56 a	15.57±0.46 bcd	46.55 abc	15.40±0.50 bcdef	77.78 ab	30.97 ±0.93 cdefg
Baltica	126.67± 3.97 abcd	17.52 bcde	16.75±0.51 bcd	25.19 bc	12.91± 0.61 ef	36.99 ef	29.67 ±0.72 efg
Fianna	138.37±3.51 bcdef	13.34 cde	16.05± 0.63 bcd	56.13 ab	14.15±0.57 def	62.22 abcde	30.20 ±0.23 efg
Famosa	160.66± 1.57 f	22.22 bcd	14.98±0.58 cd	40.15 abc	19.14± 0.59 a	53.34 bcdef	34.12 ±1.15 abcd
Arrancar	124.25±2.45 abc	6.67 de	16.01± 0.53 bcd	50.17 abc	14.42±0.34 def	53.34 bcdef	30.43 ±0.87 defg
Carlita	118.80±1.82 ab	45.56 ab	20.65±0.81 a	68.06 a	15.15±0.58 cdef	82.64 a	35.80 ±0.53 a
Beluga	120.32±6.51 ab	8.89 de	15.25±0.64 bcd	57.23 ab	15.20±0.50 cdef	62.23 abcde	30.45 ±1.14 defg
Agria	142.87±3.95 bcdef	11.11 cde	14.54±0.43 d	34.92 abc	15.55±0.36 bcde	42.23 def	30.09 ±0.20 efg

Means followed by the same letters in each column are not significantly different (P=0.05, Tukey's HSD).

31.33, 33.05, 33.39, 32.88 and 35.88 days, respectively. The long developmental time of the pest on one cultivar can be related to the existence of antibiosis effects in that cultivar [12, 20].

In 2007, the highest mortalities of developmental stages were observed on the Delikat and Carlita cultivars with means of 91.11 and 88.89 percent, respectively, and the least mortalities of immature stage on the Romina and Bridjet cultivars with means of 42.22 percent (Table 2). The highest mortalities of developmental stage were observed on the Carlita and Sinja cultivars with means of 82.64 and 77.78 percent, respectively, in 2008 and the least mortalities of immature stage on the Bright and Baltica with means of 32.36 and 36.99 percent, respectively (Table 3). The high mortalities of immature stage of the pest on one cultivar can show the antibiosis effects of the cultivar to that pest [12, 20]. These results are somewhat in agreement with findings of Yasar and Gongur [23]. They reported that the total mortalities of immature stages of Colorado potato beetle were on Agria, Pasinler, Marfona, Granola and Casper varieties with means of 56.10, 67.34, 78.19, 59.57 and 28.57 percent, respectively.

Cluster analysis on the basis of mortalities and period of developmental stages showed that 20 studied cultivars were grouped in 4 and 6 distance clusters in 2007 and 2008, respectively (Figs 1-2), and in two years grouped in 5 distance clusters (Fig. 3). The Carlita cultivar was placed in one cluster, alone and the Bridjet, Delikat, Beluga and Aparret cultivars were grouped in one cluster. These cultivars showed the highest antibiosis effects on the Colorado potato beetle.

Conclusions

The Carlita, Delikat, Bridjet and Beluga showed more antibiotic effects compared to the other cultivars used in this study and had more bad effects on the biology of the Colorado potato beetle

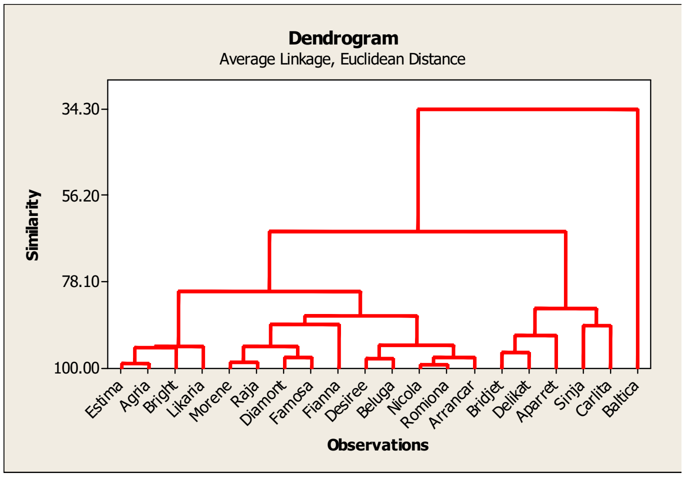

Figure 1. Cluster analysis of 20 studied cultivars in 2007.

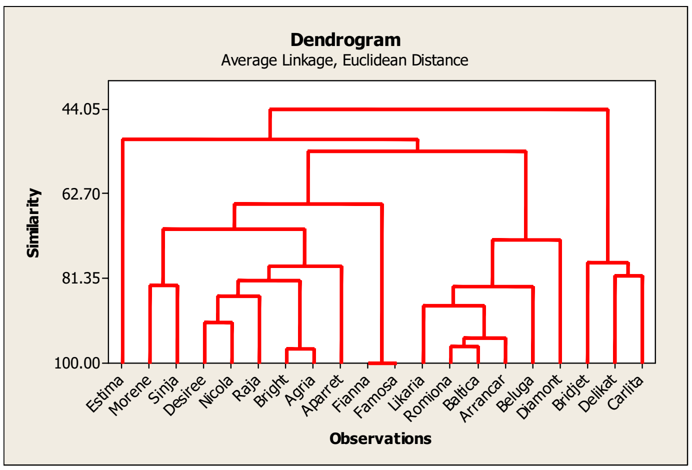

Figure 2. Cluster analysis of 20 studied cultivars in 2008.

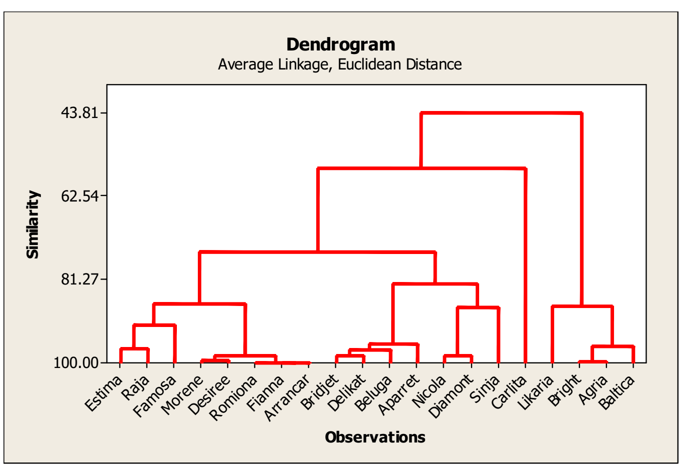

Figure 3. Cluster analysis of 20 studied cultivars in 2007 and 2008.

(low weight of larvae, more mortalities and period of developmental stages), therefore were recommended by farmers to cultivate because according to Horton *et al*. [12] measurement of immature development stages and survivorship of these stages are the best parameters for predicting of defoliation of potato by the Colorado potato beetle in field and the cultivars that caused more mortalities of Colorado potato beetle and long developmental period of this pest in laboratory conditions, tolerate the damage of the pest in the field very well.

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