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PEST MANAGEMENT

Antibiosis and Antixenosis of Six Commonly Produced Potato Cultivars to the Green Peach Aphid, *Myzus persicae* Sulzer (Hemiptera: Aphididae)

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Abstract

The antibiotic and antixenotic resistance of six commonly produced potato cultivars in Iran including Aozonia, Agria, Cosima, Cosmos, Kondor and Savalan to the green peach aphid, *Myzus persicae* Sulzer, were investigated under laboratory conditions at 20 ± 2°C, 65 ± 5% RH and 16:8h (L:D) in 2009. Antibiosis experiments showed significant differences in the developmental time, nymphal survivorship, fecundity, adult longevity of the green peach aphid among the potato cultivars. Intrinsic rate of natural increase (r_m) for apterous aphids varied significantly with the potato cultivars on which the aphids were reared. This value ranged from 0.225 to 0.293 females/female/day, which was lowest on Cosmos and highest on Aozonia. Additionally, the estimated net reproductive rate (R_0) and finite rate of increase (λ) for apterous aphids were the lowest on Cosmos. For the antixenosis experiment, no significant difference was found in aphid's preference to the potato cultivars. However, Aozonia was preferred more than the other five cultivars by the apterous aphids. Therefore, our results demonstrated that among the investigated cultivars the Cosmos cultivar is moderately resistant to the green peach aphid.

Introduction

Potato is one of the major food crops in many parts of Iran. Many insect pests damage the potatoes in the field, one of which is the green peach aphid, *Myzus persicae* Sulzer. This aphid is heteroecious and uses *Prunus persica* (Rosaceae) as primary host and several herbaceous plants as secondary hosts (Blackman & Eastop 2000). As a polyphagous insect, it attacks a broad range of plant families such as Solanaceae, Brassicaceae, Chenopodiaceae, and Fabaceae (Hodjat 1993, Khanjani 2005). A prevalent distribution of the green peach aphid has been observed in the potato crop (Berlandier 1997, Kuroli & Lantos 2006, Boukhris-Bouhachem *et al* 2007). The population of *M. persicae* fluctuates in potato growing areas of Iran and several other countries in the world and its density depends on temperature, relative humidity and natural enemies' occurrence (Kavallieratos *et al* 2004, Kuroli & Lantos 2006, Niaz & Ayub 2007, Sabbaghan & Soleymannejadian 2007, Carlo & Batyr 2008).

The importance of this aphid species is due not only to the direct damage to plants by feeding on phloem sap, but also to the indirect damage by transmitting several viruses, especially the potato virus Y (PVY), potato virus X (PVX), and potato leafroll virus (PLRV) (Castle & Berger 1993, van den Heuvel *et al* 1993, Blackman & Eastop 2000, Novy *et al* 2002, Ngumbi *et al* 2007). These viruses cause expressive yield loss in the potato crops (Cupertino & Costa 1970, Killick 1978).

The widespread use of insecticides to control this pest and selection pressure has resulted in developing resistance to the insecticides (Sykes 1977). The development of insecticide resistant biotypes and other harmful effects of chemical control methods to the environment require alternative control strategies (Margaritopoulos *et al* 2007). Using resistant cultivars is one of the alternative control methods for this aphid. Several factors in potato plants may contribute to its resistance to aphids, such as the existence of resistance factors on the plant surface (Gibson 1971, Alvarez *et al* 2006) or at the mesophyll/phloem tissues. In addition, the age and different parts of the plant and infection of potato crop with PLRV virus can influence the aphid population on plant (Eigenbrode *et al* 2002, Alvarez *et al* 2006, 2007).

Plant resistance also varies with nutritional quality of phloem sap (primary plant metabolites) or on the amount and nature of secondary metabolites (Gibson & Pickett 1983, Ave & Tingey 1986, Karley *et al* 2002). So far, resistance of several wild potatoes and their related accessions and also some commercial cultivars have been assessed to *M. persicae* and some of them have shown various degree of resistance to the aphid, Alvarez *et al* 2006, Leroux *et al* 2007, 2008).

The use of resistant cultivars in potato fields will help to reduce direct aphid damage and virus transmission and enhance production yield, what is valuable to develop a successful integrated pest management (IPM) programme for the green peach aphid. The objective of this study was to determine the resistance mechanism of six commercial potato cultivars in Iran and to measure the biological parameters of the green peach aphid on these cultivars to select the most resistant cultivar.

Material and Methods

Aphid colony. The rearing of *M. persicae* was started from virginoparous apterous females collected in summer 2008 from a potato field in Ardabil, Iran. Aphid colonies were maintained on *Solanum tuberosum* cv. Diamant (Solanaceae) in a climatic room at 20 ± 2°C and a photoperiod of 16:8h (L:D). To maintain the colony, every 15 days some aphids from the infested plants were transferred to a new young potato plant of Diamant cultivar.

Antibiosis experiment. Seeds of six commercial potato cultivars that are commonly grown in Iran including Cosmos, Aozonia, Kondor, Agria, Cosima and Savalan were obtained from the Agriculture Research Station of Ardabil, Iran and evaluated in this research to determine their resistance by antibiosis to the green peach aphid. These cultivars were chosen based on our field observation (unpublished data) and seemed to present some degree of resistance to the green peach aphid.

In the greenhouse, ten replicates of each cultivar were planted in plastic pots (25 cm diameter × 20 cm height) which were filled with suitable field soil, and used when they reached the 5-6 leaf stage. The leaflets from the second and third compound leaves from the apex of each plant were excised and used in the experiment. Excised leaflets were placed upside down in Petri dishes (Kuo *et al* 2006) (9 cm diameter × 1.5 cm height) and lined with cotton and filter paper and moisturized with distilled water. On the lid of each Petri dish a circular opening (2 cm in diameter) was cut and covered with muslin (50 meshes) for ventilation.

Viviparous apterous adults were randomly selected from the colony and transferred with a brush to the leaflets. Then, the Petri dishes were placed in a growth chamber at 20 ± 2°C, 65 ± 5% RH and 16:8h (L:D). During the study, fresh leaflets were supplied to aphids every day and the filter papers were wetted. These adult parthenogenetic females were permitted to produce nymphs. After 24h, the adults and all nymphs except one were eliminated from the leaflets. The remaining nymphs (50 nymphs for each cultivar) were checked daily for their survival and developmental time. After reaching maturity, 20 adults for each potato cultivar were assessed for their fecundity and newborn nymphs were counted and removed daily. Observations continued until the death of the last aphid.

Antixenosis experiment. The six potato cultivars were planted in the perimeter of plastic basins (50 cm diameter × 15 cm height), which were filled with suitable field soil and maintained in the growth chamber at 20 ± 2°C, 65 ± 5% RH and a photoperiod of 16:8h (L:D). These plants were used in the experiment at the 3-4 leaf stage of development. The plastic basins were surrounded by clear cylindrical plastics covered with muslin (50 meshes) for ventilation. This experiment was conducted in five replicates in a randomized design. For each replicate 120 viviparous apterous adults were randomly selected from the colony and released in the centre of each plastic basin on the soil surface to choose the plants. After 24h, 48h and 72h, the number of aphids on each plant was counted and recorded (Laamari *et al* 2008).

Statistical analyses. Antixenosis data were square root transformed to standardize the variance before analysis. Data of antixenosis, developmental time, survivorship, fecundity and longevity of the green peach aphid were evaluated using the analysis of variance (ANOVA) using the MINITAB-13.1 statistical software (Minitab lnc. 1994 Philadelphia, PA) and comparisons among means were carried out by using the Tukey test at $\alpha = 0.05$.

The fertility life table parameters including net reproductive rate (R_0), intrinsic rate of natural increase (r_m), doubling time (DT), mean generation time (T) and finite rate of increase (λ) and their standard errors were estimated with the Jackknife method (Meyer *et al* 1986, Carey 1993, Maia *et al* 2000) using the SAS System Software V6.12 (SAS Institute 1989) and their mean values were separated by Tukey tests with the MINITAB-13.1 statistical software. The r_m for the green peach aphid on different cultivars was estimated by the following equation (Birch 1948):

$$\Sigma e^{-rx} l_x m_x = 1$$

where x is the age in days, r is the intrinsic rate of natural increase, l_x is the age-specific survival, and m_x is the age-specific fecundity.

Results

Antibiosis

Developmental time and survivorship. Significant differences were observed among the cultivars in the green peach aphid developmental time (F = 3.26, df = 5,114, P = 0.009). It was longer on Cosima, Kondor and Cosmos than on Aozonia (Table 1). The nymphal survivorship was 68% on Cosmos, 76% on Cosima and Savalan and 92% on Aozonia, Agria and Kondor (Table 1, Fig 1). The life expectancy of newly born nymphs was estimated to be 20.6, 20.2, 19.9, 16.0, 14.4 and 12.3 days on Kondor, Agria, Savalan, Aozonia, Cosima and Cosmos, respectively (Fig 2).

Aphid longevity and fecundity. The adult longevity of *M. persicae* (F = 5.44, df = 5,114, P < 0.001) was significantly different on the cultivars. The shortest and longest longevity were observed on Cosmos and Kondor, respectively. The number of offspring per female per day also showed significant differences (F = 8.23, df = 5,114, P < 0.001) among the tested potato cultivars (Table 1, Fig 1). In addition, the total number of offspring indicated significant differences (F = 10.14, df = 5,114, P < 0.001) among potato cultivars; it was the lowest on Cosmos and highest on Kondor (Table 1).

Life table parameters. There were significant differences (F = 17.88, df = 5,114, P < 0.001) among cultivars in the net reproductive rate (R_0) values of the green peach aphid. The highest and lowest values for R_0 were observed on Kondor and Cosmos, respectively (Table 2). Also, significant differences (F = 13.37, df = 5,114, P < 0.001) were observed in the finite rate of increase (λ) values of aphid on the cultivars. It was lowest on Cosmos and highest on Aozonia (Table 2).

Furthermore, the intrinsic rate of natural increase (r_m) values of the apterous aphids indicated significant differences (F = 13.34, df = 5,114, P < 0.001) among cultivars. The r_m values of *M. persicae* calculated on the six potato cultivars in the current study ranged from 0.225 to 0.293 females/female/day (Table 2). Thus, the viviparous apterous aphids of *M. persicae* which were reared on Cosmos had the lowest $r_{m,}$ while those reared on Aozonia had the highest r_m. The doubling time (DT) values of apterous aphid was also significantly different (F = 11.86, df = 5,114, P < 0.001) among various cultivars. The longest and shortest DT was on Cosmos and Kondor, respectively (Table 2). Moreover, the potato cultivars had a significant effect on the mean generation time (T) values of viviparous apterous aphid of the green peach aphid (F = 2.36, df = 5,114, P = 0.044). The shortest generation time was observed on Cosmos cultivar (Table 2).

Antixenosis. No significant difference was found for the preference of *M. persicae* after 24h (F = 1.20, df = 5, 23, P = 0.34), 48h (F = 0.97, df = 5, 23, P = 0.45) and 72h (F = 1.43, df = 5, 23, P = 0.25) among the tested cultivars (Table 3). However, Aozonia attracted the highest number of apterous aphids as opposed to Agria and Cosmos, which attracted the lowest number of apterous aphids after 24h, 48h and 72h, respectively (Table 3).

Table 1 Percentage of nymphal survivorship, developmental time, adult longevity and fecundity (Mean ± SD) of *Myzus persicae* on six potato cultivars, at 20 ± 2°C and a photoperiod of 16:8h (L:D).

Cultivars	Nymphal survivorship (%) (n)	Developmental time (d)	Adult longevity (d)	Total no. of offspring/female	No. of offspring/ reproduction day
Agria	92 (50)	7.4 ± 0.68ab	18.4 ± 6.35a	55.1 ± 16.16a	3.4 ± 0.38ab
Aozonia	92 (50)	6.8 ± 0.52b	14.7 ± 7.99abc	47.7 ± 22.57ab	3.5 ± 0.62ab
Cosima	76 (50)	7.8 ± 1.15a	12.5 ± 7.34bc	36.0 ± 20.66bc	3.0 ± 0.87b
Cosmos	68 (50)	7.5 ± 0.76a	9.5 ± 7.74c	22.8 ± 19.09c	2.5 ± 0.68b
Kondor	92 (50)	7.6 ± 0.69a	18.9 ± 5.62a	60.7 ± 18.57a	3.6 ± 0.62a
Savalan	76 (50)	7.4 ± 0.99ab	17.0 ± 6.87ab	47.5 ±17.45ab	3.0 ± 0.55b

Differences among potato cultivars were determined by Tukey test. In columns, means followed by unlike letters are significantly different (P < 0.05). The n value in the parenthesis demonstrates number of nymphs; for the other parameters, n = 20.

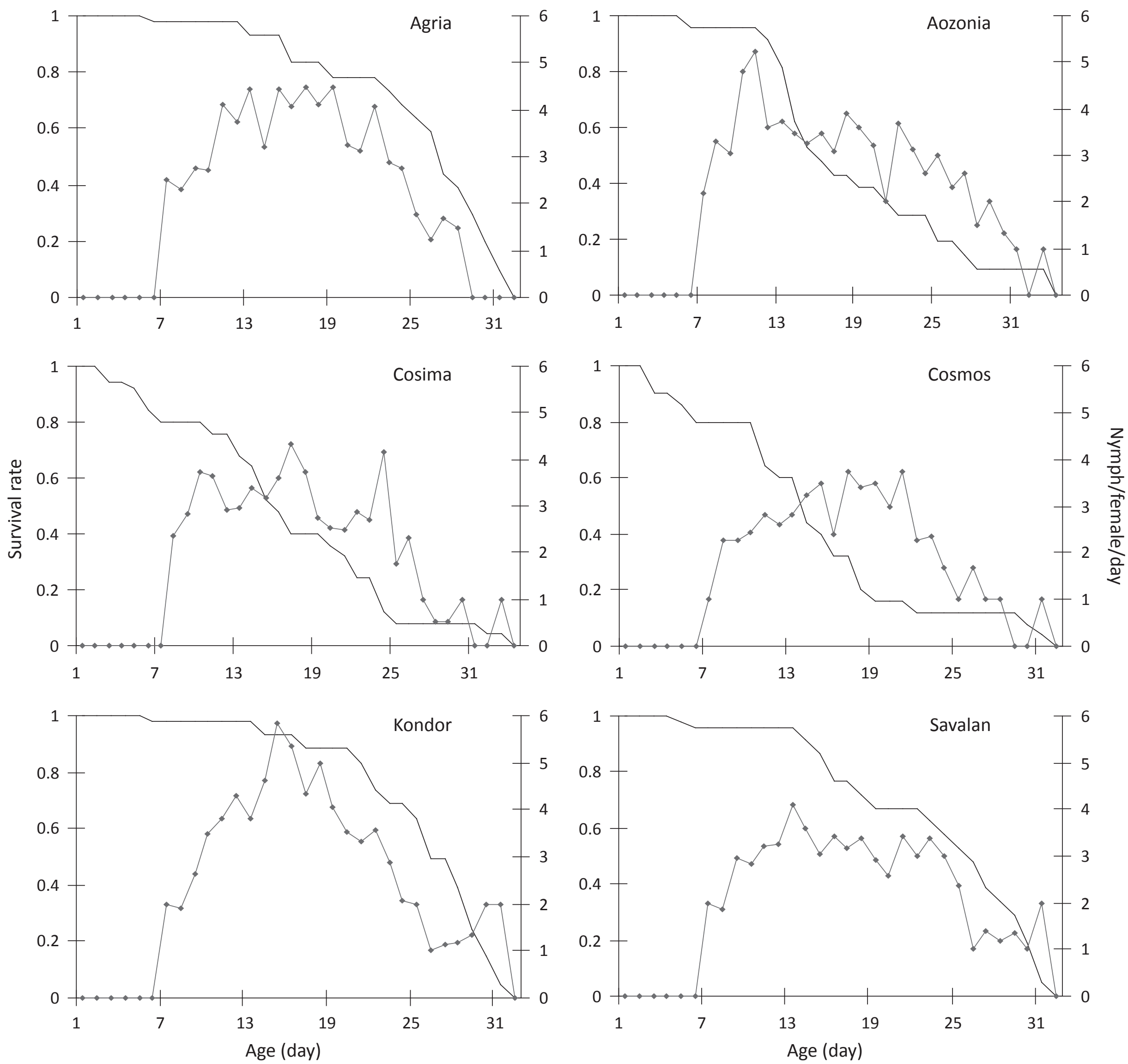

Fig 1 Nymph survival rate and number of offspring/reproduction day of *Myzus persicae* reared on six potato cultivars, at 20 ± 2°C and a photoperiod of 16:8h (L:D).

Discussion

Plant species are different with respect to their suitability as hosts for different insects when their performance and preference are measured on these plants (Storer & van Emden 1995, Frei *et al* 2003). Meanwhile, different cultivars of a plant species differ in chemical and morphological characteristics which influence their suitability as hosts (Ave & Tingey 1986). Therefore, assessing the resistance of different cultivars to the pests with respect to the plants differences can provide valuable information on their suitability or unsuitability to the insects.

The current study revealed that there were significant differences in the green peach aphid performance among the six potato cultivars tested. Antibiosis experiment revealed that the life table parameters of the green peach aphid were higher on Kondor and Aozonia cultivars and these cultivars were the most suitable hosts to the green peach aphid. But these cultivars yielded different life table parameters for the green peach aphid. The apterous aphids reared on Kondor had longer developmental time and mean generation time (T). Under natural condition, longer generation and developmental time will result in a slower population build up on this cultivar, increasing the exposure of the herbivore to natural enemies (Thomson *et al* 2010). The shortest developmental time and the highest intrinsic rate of natural increase (r_m) and finite rate of increase (λ) were observed on Aozonia, which lead to higher performance of the aphid on this cultivar.

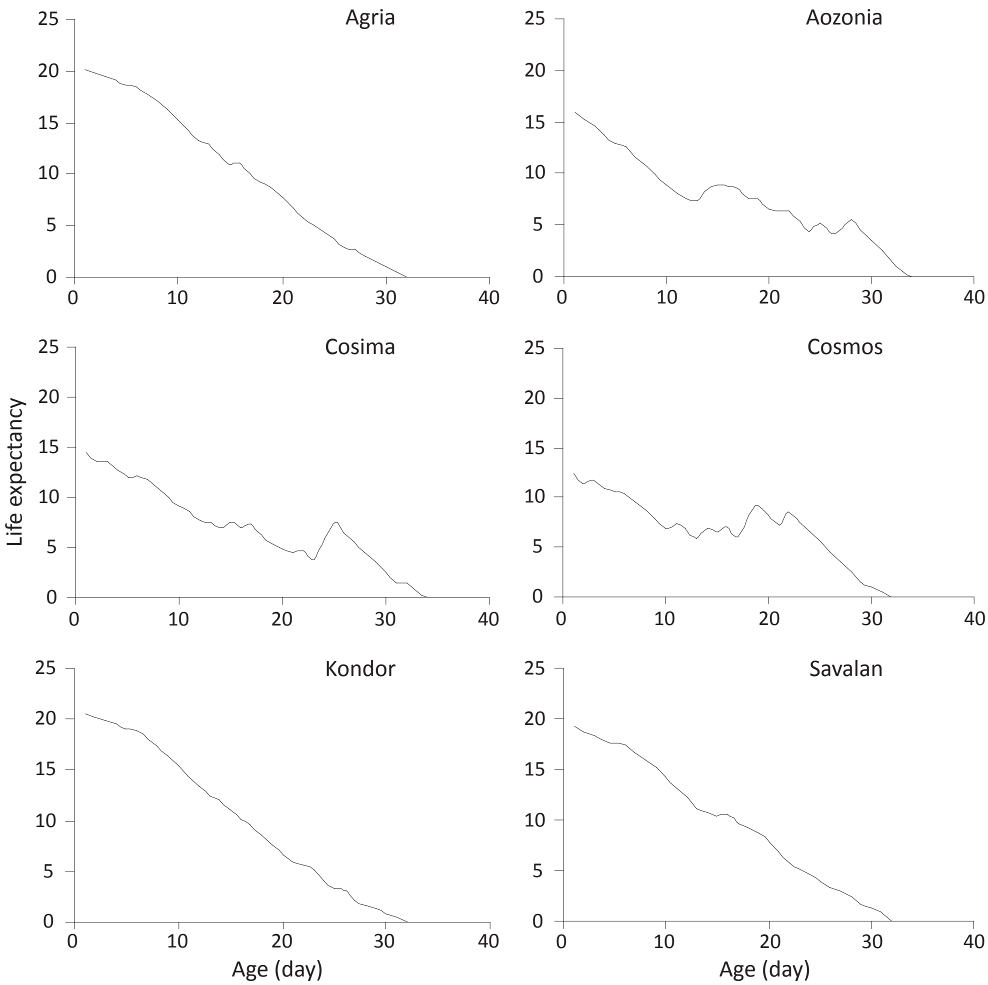

Fig 2 Life expectancy of *Myzus persicae* reared on six potato cultivars, 20 ± 2°C and a photoperiod of 16:8h (L:D).

Measuring life table parameters, especially the intrinsic rate of natural increase (r_m), is the best way to evaluate insect performance on host plants (Storer & van Emden 1995, Razmjou *et al* 2006, 2009). In the present study, r_m ranged from 0.225 to 0.293 females/female/day on the potato cultivars tested and was highest on Aozonia and lowest on Cosmos. These values are close to that estimated for the green peach aphid on Wilja (0.245 females/female/day) cultivar. In this case, the existence of glutamine in phloem sap of this cultivar at the pre-tuber filling stage was indicated to positively affect the aphid performance (Karley *et al* 2002). The

Table 2 Fertility life table parameters (Mean ± SE) of *Myzus persicae* on six potato cultivars, at 20 ± 2°C and a photoperiod of 16:8h (L:D).

Cultivars	r_m	R_0	λ	DT	T
Agria	0.281 ± 0.005ab	50.7 ± 3.32a	1.32 ± 0.03ab	2.5 ± 0.04cd	13.9 ± 0.28a
Aozonia	0.293 ± 0.008a	43.9 ± 4.64ab	1.34 ± 0.05a	2.4 ± 0.06d	12.9 ± 0.56ab
Cosima	0.253 ± 0.008c	27.2 ± 3.50cd	1.29 ± 0.05c	2.7 ± 0.09b	13.1 ± 0.50ab
Cosmos	0.225 ± 0.010d	15.5 ± 2.90d	1.25 ± 0.05d	3.1 ± 0.13a	12.3 ± 0.63b
Kondor	0.289 ± 0.005a	56.1 ± 3.88a	1.33 ± 0.03a	2.4 ± 0.04d	14.0 ± 0.29a
Savalan	0.258 ± 0.005bc	35.8 ± 2.98bc	1.29 ± 0.03bc	2.7 ± 0.05bc	13.9 ± 0.35a

Differences among potato cultivars were determined by Tukey test, based on jackknife estimates of variance for each parameter. In columns, means followed by unlike letters are significantly different ($P < 0.05$).
Mean of 20 replications.

Table 3 Means (± SD) for the numbers of aphid attracted on six potato cultivars after 24h, 48h and 72h of release, at 20 ± 2°C and a photoperiod of 16:8h (L:D).

Cultivars	24h	48h	72h
Agria	5.4 ± 2.19	6.2 ± 3.03	6.6 ± 3.91
Aozonia	19.4 ± 20.21	19.2 ± 21.98	18.4 ± 22.32
Cosima	11.8 ± 10.62	10.8 ± 9.60	8.4 ± 7.47
Cosmos	6.0 ± 1.41	5.5 ± 3.70	3.0 ± 1.83
Kondor	9.8 ± 6.61	8.8 ± 4.27	7.4 ± 3.65
Savalan	11.2 ± 5.40	10.0 ± 6.16	9.4 ± 7.13
F	1.20^{ns}	0.97^{ns}	1.43^{ns}
df	5, 23	5, 23	5, 23
P	0.34	0.46	0.25

Differences among potato cultivars were determined by Tukey test. In columns, means followed by the same letters are not significantly different ($P < 0.05$); ^{ns} Non significant diference among potato cultivars.

intrinsic rates of natural increase reported in here fall well in the range reported for this insect when read on other cultivars, such as Russet Norkotah (0.167 females/female/day) and Red la Soda (0.350 females/female/day) (Davis *et al* 2007).

We also demonstrated in our antibiosis experiments that the apterous *M. persicae* reared on Cosmos cultivar had the poorest performance among all other cultivars tested. This was shown not only in developmental time, nymphal mortality, longevity and fecundity, but also in the net reproductive rate (R_0) and the intrinsic rate of natural increase (r_m) of the green peach aphid.

Several mechanisms such as morphological characteristics and quality of the host plant could be responsible for the variation in aphid's performance on different cultivars. Host plant quality is an important factor that is responsible for the antibiotic resistance of plants, as host plant suitability is affected by the level of amino acids or nitrogen in the phloem sap and the secondary metabolites that influence aphids' performance (Gibson & Pickett 1983, Ave & Tingey 1986, Dixon 1998, Cisneros & Godfrey 2001, Karley *et al* 2002). Although the nature of the possible mechanisms for antibiosis was not studied in our experiment, these factors may be involved with the low performance observed for the green peach aphid on Cosmos.

No significant differences for the preference of the green peach aphid were found in the antixenosis experiment, but there were fewer aphids on Cosmos, indicating its antixenotic traits against the green peach aphid. Several morphological and chemical traits such as trichomes on the plant surface or the toughness of the epidermic tissues and the presence of chemical compounds in the sieve tubes may influence the host acceptance by aphids (Smith 1989, Dixon 1998, Alvarez *et al* 2007).

As a result, the characterization and use of resistant cultivars can be an effective strategy to aid in the control of the population level of insect pests and in reducing the use of chemical treatments in the crop. Besides, it can be integrated with biological control and any onther control strategy devoted to IPM programs. Therefore, with respect to our findings, antibiotic and a partial antixenotic effect were observed in the Cosmos cultivar and this cultivar can be used as a moderately resistant cultivar in IPM of the green peach aphid.

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