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Research Article

Life history of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae), on four potato varieties in Iran

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Abstract: Colorado potato beetle (CPB), *Leptinotarsa decemlineata* (Say), is the most important insect pest of potato in Iran. If local potato varieties vary in susceptibility to the pest, host plant resistance may provide management benefits to potato growers. A life table study was carried out to determine the relative suitability of four common potato varieties (Agria, Marfona, Savalan and Satina) for CPB development and reproduction in northwest Iran under laboratory conditions at 23 ± 3 ºC, 62 ± 10% RH, and natural photoperiod. Development time and hence generation time was longest on Savalan (31.07 ± 0.48 d and 42.72 ± 0.71 d respectively) and shortest on Agria (27.8 ± 0.65 d and 35.99 ± 0.8 d respectively). Juvenile mortality was highest (47.5%) on Satina and lowest (22.5%) on Marfona. Intrinsic rates of increase (*r*) were 0.129 ± 0.005, 0.127 ± 0.005, 0.129 ± 0.006 and 0.104 ± 0.004, on Agria, Marfona, Satina and Savalan, respectively, that on Savalan being significantly lower than the others. The highest net reproductive rate was 145.26 ± 25.23 on Marfona and the lowest was 81.18 ± 2.71 on Savalan which was not significantly different among the cultivars. It seems that, among the four tested cultivars, the Savalan cultivar is less suitable to CPB, resulting in the poorest overall biological performance of the beetle, but the level of resistance did not appear sufficient to negate the need for other control methods.

Key words: Colorado potato beetle, potato variety, life table, mortality

Introduction

Colorado potato beetle (CPB), *Leptinotarsa decemlineata* (Say), is one of the most destructive pests of potato worldwide (EPPO/CABI, 1997). This invasive species has high reproductive capacity and both adult and immature can severely defoliate potato crops throughout the growing season (Hare, 1980). The CPB arrived in Iran around 30 years ago. It was reported for the first time in the potato fields of Ardabil (northwest Iran) in 1984 (Nouri-Ganbalani, 1989) and spread rapidly throughout other parts of the country. Studies in Ardabil revealed that the pest has two generations a year in this region. Peak abundance of larvae occurs in late June and early July, coinciding with the early blooming period of potato, and adults of the first generation emerge in late July (Nouri-Ganbalani, 1989).

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The principal method of CPB control in Iran and in most parts of the world has been chemical control, but since 1980's, populations have evolved resistance to commonly used insecticides (Yaşar and Güngör, 2005). Increased resistance and growing concerns over the environmental impact of insecticides prompted researchers to focus on alternative control measures with less environmental impact (Hare, 1990; Grafius, 1997). Host plant resistance (HPR) is one of the most fundamental techniques for managing insect pests and has been successfully utilized in many cereal and forage crops (Smith, 1989; 2006). Various mechanisms of antibiosis can reduce pest density by lowering growth and/or reproductive rates and reduce the probability of populations exceeding economic injury levels (Sanford and Trumble, 1994) and there is evidence of antibiosis to CPB in wild potato species (Brown *et al*., 1980; Casagrande, 1982; Groden and Casagrande, 1986; Hare and Kennedy, 1986; Mena-Covarrubius *et al*., 1996). Due to the ability to utilize a range of solanaceous plant species (Szentesi and Jermy, 1993), CPB also has the potential to overcome some forms of resistance expressed in potato cultivars (Hare, 1990) and evolve genetically distinct host races (Hsiao, 1978; 1981; Horton *et al*., 1988).

Host plants affect the fitness of herbivorous insects via their effects on development, survival, reproduction and life table parameters (Tsai and Wang, 2001; Awmack and Leather, 2002; Kim and Lee, 2002; Yaşar and Güngör, 2005; Kumar *et al*., 2009). Life table analysis is a valuable analytical tool in population ecology (Ali and Rizvi, 2007) which can be used for indicating plant resistance (Dent, 1997). Short developmental time, high fecundity and high fertility are all indicators of the host plant suitability for the pest (van Lenteren and Noldus, 1990; Liu *et al*., 2004). Few case studies on life history parameters of CPB have been reported. Yaşar and Güngör (2005), Ghasemi-Kahrizeh *et al*. (2010) and Fathi *et al*. (2013) studied the effects of 5, 20 and 7 potato cultivars respectively on life history parameters of CPB, and found some differences among them.

The objective of the present study was to assess biological performance and life table parameters of CPB on four commercial potato cultivars of Agria, Marfona, Savalan and Satina, the most frequently cultivated varieties in East Azerbaijan, Iran. Knowledge of the relative susceptibility of these traditional potato cultivars to CPB will assist growers with varietal selection in infested regions and in adjusting IPM strategies for CPB in commercial potato fields.

Materials and Methods

Field plants

Potato cultivars were obtained from the Agricultural Research Institute of Aralogh in Ardabil, Iran. The varieties Agria, Marfona, Savalan and Satina, were selected on the basis of being the most widely cultivated varieties in East Azerbaijan. An experimental field (18.0 × 28.0 m) was divided into four sub-plots (7.0 × 18.0 m), each of which was planted to one of the four cultivars. No pesticide treatments were applied during the growing season and this field served as the source of leaves for the laboratory study. The experimental field was tilled on 14 May, 2011, and planted two days later. Based on the results of soil analysis, 33 kg/ha of urate fertilizer were applied preplant, and two more applications at the same rate later in the growing season. Weeds were controlled by manual removal.

Laboratory observations

Due to facultative reproductive diapause of CPB in the study region, the experiment was conducted in two distinct phases during which larvae and adults were tested simultaneously under the same conditions. The original cohort of CPB eggs as well as adults was randomly selected from individuals collected by monitoring emergence of overwintered adults. Approximately 300 adult CPB and 30 egg masses were collected from potato fields in Bostanabad (East Azerbaijan, Iran) on 30 June, 2011. Experiments were conducted during May 30th to July 22nd, 2011 on a laboratory bench under natural summer day conditions (an ambient temperature range of 23 ± 3 ˚C, and RH 62 ± 10%). In order to assess development, 160 neonate *L. decemlineata* (n = 40 per variety) eclosing from the field-collected eggs were confined individually in ventilated plastic containers (4.0 × 6.0 × 9.0 cm). Larvae were fed *ad libitum* diets of field-harvested potato leaves of one of the four varieties with leaf petioles immersed in a water-soaked piece of cotton to maintain turgor. All leaves were replaced and all events (mortalities, molts, etc.) recorded daily until all surviving individuals emerged as adults.

Since it was not possible to follow a single cohort through to adult mortality (due to adult reproductive diapause), reproduction data were obtained from overwintered adult females (n = 20 per variety), that were confined in similar containers and assigned to the same feeding treatments. Food replacement and egg collection was conducted daily around noon and, during this period, each female was permitted access to a male for a period of about one hour. Eggs from each replicate were placed in a plastic Petri dish (9.0 cm diameter) and held until hatching under the same environmental conditions as the adults. Offspring were sexed after adult emergence according to Yaşar and Güngör (2005). Since more than 20 adults were obtained per treatment in developmental assays, some eggs were randomly excluded from each treatment in the life table analysis so that survival would yield 20 adults. This resulted in a total of 121 eggs (28, 26, 29 and 38 eggs for Agria, Marfona, Savalan and Satina respectively) being included in analysis.

Data analysis

Life table parameters were calculated according to Carey (1993), intrinsic rate of increase (r), net reproduction rate (R_0), finite rate of increase (λ), gross reproductive rate (GRR), doubling time (DT), and mean generation time (GT). Variance and confidence intervals of r, R_0, DT, and GT values were estimated using the Jackknife procedure (Meyer *et al*., 1986; Ebert, 1999). Effects of host plant on the duration of immature stages and adult longevity were tested with a one way-ANOVA based on a Completely Randomized Design (CRD) for unequal sample sizes using the PROC GLM procedure (SAS, 2002). Duncan multiple range test was used to separate means.

Results

With the exception of the prepupal stage, there was significant variation in the duration of various juvenile CPB stages on the various potato varieties (Table 1). Total development time was shortest on Agria and longest on Savalan with Marfona intermediate and Satina not significantly different from either of the latter two. However, the highest rate of juvenile mortality was observed on Satina (Table 2). There was only a marginally significant effect of host plant on adult longevity (F = 2.64; df = 3, 77; P = 0.055) which was shortest on Satina (52.0 ± 3.4 d) and longer on Agria (61.5 ± 1.9 d) and Marfona (59.7 ± 2.0 d); longevity on Savalan (56.0 ± 2.8 d) did not differ significantly from any of the other treatments.

All life table parameters varied as a function of host plant cultivar (Table 3) and generated different survivorship curves (Fig. 1). Age-specific fecundities were roughly triangular with the highest egg production occurring early in adult life (Fig. 2). Lifetime fecundities were not significantly different among cultivars, (F = 2.44; df = 3, 76; P = 0.071). Savalan appeared to express the most antibiosis towards CPB, yielding the highest values for DT and GT and the lowest values for r, R_0, λ and GRR. The other three cultivars appeared similarly suitable for CPB based on these measures.

Table 1 Developmental time (Mean ± SE) of *Leptinotarsa decemlineata* reared on four potato cultivars.

Cultivar	Life stage duration (d)[1]						
	1st	2nd	3rd	4th	Prepupa	Pupa	Total
Agria	2.0 ± 0.00b	4.1 ± 0.05ab	2.3 ± 0.07b	6.2 ± 0.27a	7.5 ± 0.74a	5.8 ± 0.24ab	27.8 ± 0.65c
Marfona	2.1 ± 0.10b	4.3 ± 0.14a	2.3 ± 0.13b	6.5 ± 0.31a	8.3 ± 0.64a	6.2 ± 0.23a	29.6 ± 0.37b
Savalan	6.3 ± 0.09a	3.7 ± 0.18b	3.2 ± 0.18a	4.3 ± 0.35b	8.4 ± 0.68a	5.4 ± 0.27b	31.1 ± 0.48a
Satina	6.2 ± 0.06a	3.5 ± 0.18b	3.6 ± 0.19a	4.3 ± 0.33b	6.9 ± 0.78a	6.0 ± 0.28a	30.5 ± 0.46ab
F	1014.30	5.24	18.47	14.50	0.90	2.97	8.03
df	3, 156	3, 145	3, 137	3, 133	3, 106	3, 105	3, 105
P	< 0.001	0.039	< 0.001	< 0.001	0.443	0.035	< 0.001

[1] Means followed by the same letters in each column are not significantly different (Duncan's MRT, α = 0.05).

Table 2 Juvenile mortality of *Leptinotarsa decemlineata* reared on four potato cultivars (n = 40 neonates).

Cultivar	Stage- specific mortality (%)						
	1st	2nd	3rd	4th	Prepupa	Pupa	Total
Agria	0.0	2.5	0.0	25.6	0.0	0.0	27.5
Marfona	0.0	5.0	0.0	18.4	0.0	0.0	22.5
Savalan	15.0	8.8	6.4	3.4	0.0	0.0	30.0
Satina	12.5	5.7	6.0	29.0	4.5	0.0	47.5

Table 3 Life table parameters (Mean ± SE) of *Leptinotarsa decemlineata* fed on four potato cultivars.

Cultivar	r (d^{-1})	R_0	λ (d^{-1})	*GRR*	*DT* (d)	*GT* (d)
Agria	0.129 ± 0.005a	101.6 ± 19.4ab	1.14 ± 0.006a	143.9 ± 22.1b	5.37 ± 0.23b	36.0 ± 0.80c
Marfona	0.127 ± 0.005a	145.3 ± 25.2a	1.13 ± 0.005a	190.9 ± 26.2ab	5.47 ± 0.20b	39.4 ± 1.14b
Savalan	0.104 ± 0.004b	81.2 ± 2.7b	1.11 ± 0.005b	123.0 ± 15.8b	6.67 ± 0.28a	42.7 ± 0.71a
Satina	0.129 ± 0.006a	121.8 ± 14.7ab	1.14 ± 0.007a	238.2 ± 30.0a	4.96 ± 0.45b	39.8 ± 1.19ab
F	4.71	2.09	4.70	4.65	4.80	4.71
df	3, 117	3, 117	3, 117	3, 117	3, 117	3, 117
P	0.004	0.105	0.004	0.004	0.003	0.004

Abbreviations: r = intrinsic rate of increase, R_0 = net replacement rate, *GRR* = gross reproductive rate, λ = finite rate of increase, *DT* = doubling time, *GT* = generation time.
Means followed by the same letters in each column are not significantly different (Duncan's MRT, α = 0.05).

Discussion

The total development time of CPB was longest on Savalan and Satina shortest on Agria. Yaşar and Güngör (2005) reported notably longer total development times for CPB on five potato varieties in Turkey that included Agria and Marfona, despite rearing at a higher temperature (25 °C in their study). Their developmental times spanned a slightly greater range (4.5 d versus 3.3 d) with a median value 4 days longer than the present study (31.3-35.9 d compared with 27.8-31.1 d in our study). Furthermore, Yaşar and Güngör (2005) reported juvenile mortalities substantially higher than those observed in the present study – twice as high on Agria and three times as high on Marfona. This is also true in Fathi *et al*. (2013) results. Female emergence rate in their study was 50-60% on different cultivars including Agria and Savalan resembling that of the Satina in our study. Total immature mortality was 22-30% in the other cultivars in our study that is considerably lower than reported in previous studies. Mortality as well as development time of both larvae and pupae of CPB was studied on 20 potato cultivars with the Agria as the only common cultivar between our study and that of Ghasemi-Kahrizeh *et al*. (2010). In their study also both larval and pupal development (prepupa not separated) took similar period of time, but the mortality was much higher than present study. These discrepancies with our results are most likely attributable to some combination of regional differences between local CPB populations in host plant adaptation, development and thermal acclimation. In the present study, immature mortality was highest on Satina and lowest on Marfona (Table 2). Thus, of the four cultivars, Satina appeared to express the most antibiosis to developing stages of CPB in our East Azerbaijan population, with Savalan a close second. Previously, Esfandi *et al*. (2012) reported that the consumption rate of CPB larvae was significantly lower on Satina than on Marfona, and lower on Morfona than on Agria. The same study revealed higher biomass consumption by CPB larvae on Agria than on the other varieties, along with reduced frass output, results that suggest this susceptible cultivar not only elicits a strong gustatory response, but is also well assimilated.

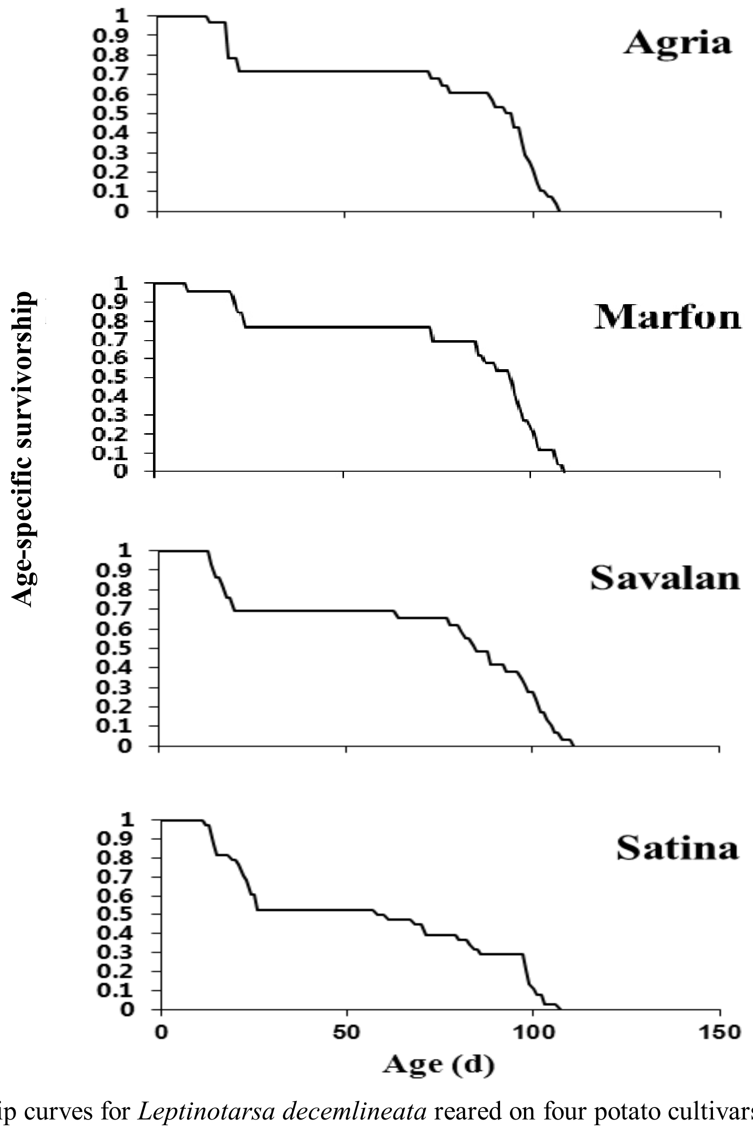

Figure 1 Survivorship curves for *Leptinotarsa decemlineata* reared on four potato cultivars at 23 ± 3 °C.

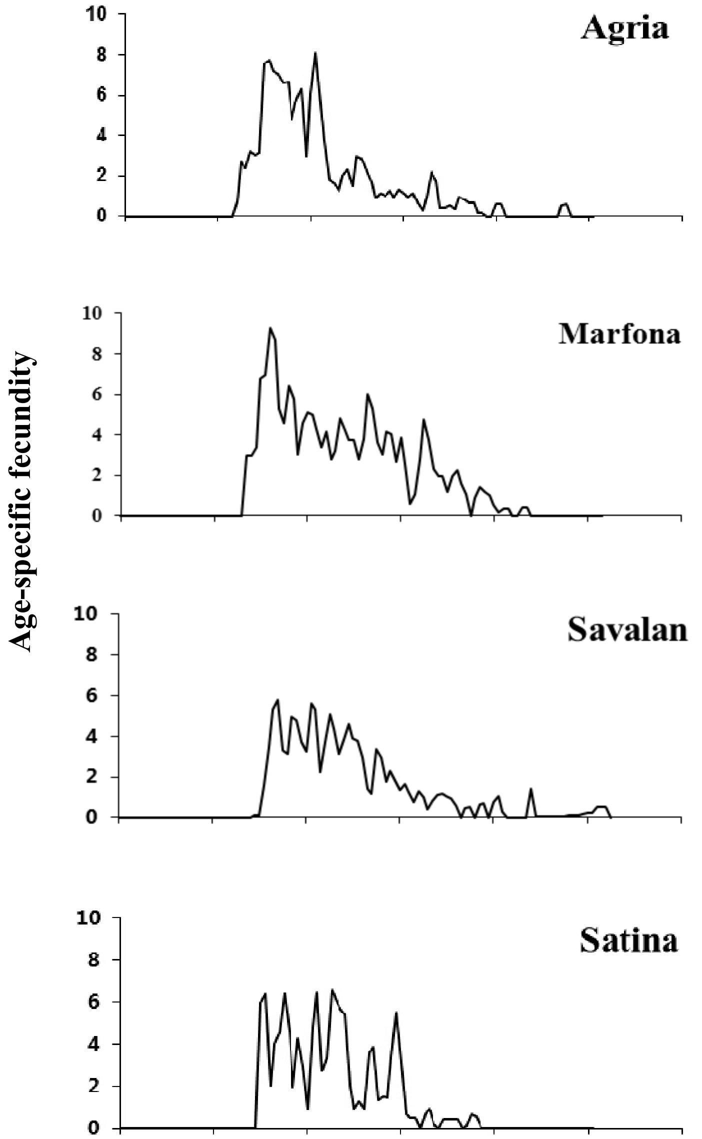

Figure 2 Age-specific fecundity of *Leptinotarsa decemlineata* fed on four potato cultivars at 23 ± 3 ˚C.

An interesting and mysterious point in our results is longer odd stages' development (particularly that of the first instar) compensated by shorter even stages' (particularly that of 4th instar) in Savalan and Satina compared to Agria and Marfona. It seems that larvae accelerate their development at a subsequent stage when it is delayed at a previous stage. This may be related to weaker mandibles in first instar larvae and thicker leaves of the mentioned cultivars. The four potato cultivars in this study differed in certain morphological characteristics such as leaf thickness. For example, Savalan and Satina leaves are thicker in comparison with those of Marfona and Agria and this may be partly responsible for the long time CPB larvae spent in early instars on these two varieties, as small larvae would likely be more negatively affected by thick leaves than larger ones.

The effect of cultivar was only marginally significant for adult female CPB longevity, which was greatest on Agria and Morfona, the more susceptible varieties. Adult leaf consumption of these cultivars was shown to be in the order of Agria > Morfona > Savalan = Satina, although frass output was similar across all varieties (Esfandi *et al*. 2012). Intrinsic rate of increase (r) did not differ among Agria, Marfona and Satina, but was reduced on Savalan due to the longest developmental time, which also yielded the lowest values for R_0 and λ (Table 3). Given that Savalan also yielded the longest doubling time and generation times, this cultivar showed the poorest overall biological performance of CPB in the study. However, this performance was still substantially superior to that of the CPB population studied by Yaşar and Güngör (2005) even on Agria and Morfona and suggests that Savalan does not express sufficient antibiosis to diminish the need for additional CPB control measures to prevent economic losses in Iran. Fathi *et al*. (2013) also estimated stable population parameters on seven cultivars with the Agria and Savalan common with this study. Although overall results are in relative agreement to our study, generation time was considerably longer in their study without any overlap in range between the two studies. The *GRR* had a larger value in their study while both r and R_0 were smaller. Net replacement rate estimates were similar for the Agria with Fathi *et al.* (2013) study. The Savalan was the most resistant cultivar based on the results of both studies and the Agria was more susceptible. The r-value was 0.055-0.082 in their study compared to 0.104-0.129 in our study. The differences are due to longer developmental time, higher mortality and lower reproduction in their population, in spite of a warmer condition during experiments that may imply a weaker physiological state of their population. A possible source for difference in mortality levels as well as the other parameters may be due to physiological state of different populations belonging to different years and places. Such spatio-temporal effects also have already been observed in other herbivorous insects like wheat bugs (Iranipour, 2008; Iranipour *et al*., 2011).

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جدول زندگی سوسک کلرادوی سیب‌زمینی *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae) روی چهار رقم سیب‌زمینی در ایران

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چکیده: سوسک کلرادوی سیب‌زمینی *Leptinotarsa decemlineata* یکی از مهم‌ترین آفات سیب‌زمینی در ایران است. چنان‌چه ارقام محلی سیب‌زمینی از لحاظ مقاومت به آفت تفاوت داشته باشند، مقاومت گیاه میزبان می‌تواند برای کشاورزان سود مدیریتی تأمین کند. برای تعیین میزان مناسب بودن چهار رقم سیب‌زمینی (آگریا، مارفونا، ساوالان و ساتینا) برای نشو و نما و تولیدمثل سوسک کلرادو در شمال غرب ایران، جدول زندگی حشره در شرایط آزمایشگاهی دردمای 23 ± 3 °C، رطوبت نسبی 62 ± 10 درصد و دوره‌ی نوری طبیعی بررسی شد. زمان نشو و نما و زمان یک نسل روی رقم ساوالان از همه طولانی‌تر (به‌ترتیب ۰/۴۸ ± ۳۱/۰۷ و ۰/۷۱ ± ۴۲/۷۲ روز) و روی رقم آگریا از همه کوتاه‌تر (به‌ترتیب ۰/۶۵ ± ۲۷/۸ و ۰/۸ ± ۳۵/۹۹ روز) بود. تلفات مراحل نابالغ در رقم ساتینا (۴۷/۵ درصد) بیش‌ترین و در رقم مارفونا (۲۲/۵ درصد) کم‌ترین بود. نرخ ذاتی افزایش جمعیت روی ارقام آگریا، مارفونا، ساتینا و ساوالان به‌ترتیب ۰/۰۰۵ ± ۰/۱۲۹، ۰/۰۰۵ ± ۰/۱۲۷، ۰/۰۰۶ ± ۰/۱۲۹ و ۰/۰۰۴ ± ۰/۱۰۴ بود که در رقم ساوالان به‌طور معنی‌دار کمتر از سه رقم دیگر بود. بیش‌ترین نرخ خالص تولیدمثل ۲۵/۲۳ ± ۱۴۵/۲۶ روی رقم مارفونا و کم‌ترین آن روی رقم ساوالان ۲/۷۱ ± ۸۱/۱۸ به‌دست آمد که این اختلاف معنی‌دار نبود. به‌نظر می‌رسد، رقم ساوالان در میان چهار رقم مورد بررسی نا مطلوب‌ترین رقم برای سوسک کلرادوی سیب‌زمینی باشد، ولی سطح مقاومت در حدی نبود که نیاز به سایر عملیات کنترل را منتفی سازد.

واژگان کلیدی: سوسک کلرادوی سیب‌زمینی، رقم سیب‌زمینی، جدول زندگی، مرگ‌ومیر