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THE BIOLOGICAL ACTIVITY OF SOME INSECT GROWTH REGULATORS AGAINST THE COTTON LEAFWORM *Spodoptera littoralis* (BIOSD.)

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ABSTRACT

The present study was undertaken to evaluate the initial and residual toxicity of Virtu 80% WP (chromafenozide), Nomolt 15% SC (teflubenzuron) and Match 5% EC (lufenuron), as well as their effects on food consumption and growth rate of the 4th, 5th and 6th larval instars of cotton leafworm using field-laboratory experiment. The tested IGRs were sprayed on potato plants in the field and their leaves were collected at four periods to conduct laboratory tests. Larvae were fed on treated leaves for two days and then on untreated leaves for another three days in each period. Data indicated that the tested IGR compounds were high efficiency against the fourth and fifth instars at the first period and gave long residual activity. On the other hand, residual activity of Virtu was more effective than the two benzoylphenyl urea insecticides against the sixth larval instar. The same trend of efficacy of the tested IGRs on the food consumption of the fourth and fifth larval instars was also found in the sixth larval instar of *S. littoralis.* Mean of consumption indexes of all intervals for sixth larval instar was 0.460, 1.096 and 1.219 for Virtu, Nomolt and Match, respectively, compared to 1.131 in check treatment. Also, it was found that the tested IGRs were able to suppress the growth rate of tested larval instars to different degrees in comparison to that of untreated control. Data indicated that feeding the different larval instars on treated potato leaves with Virtu compound resulted in high reduction in food consumption and growth rate. On the contrary, the both benzoylurea compounds; Nomolt and Match caused slight reduction in consumption index and growth rate.

Keywords: Cotton leafworm, IGRs, field-lab. test, food consumption, growth rate.

INTRODUCTION

The intensive use of conventional pesticides caused some side effects such as pest resistance, pest resurgence and outbreak of secondary pests. The need for specific compounds against economic pests is becoming more and more important. In this respect, some chemical groups with different mode of action such as insect growth regulators (IGRs) were introduced, which they act during sensitive periods of insect development, causing morphological abnormalities and physiological disorders, as well as death of treated insects. Several compounds that adversely interfere with the growth and development of insects have been synthesized. Concern over eco-toxicology and mammalian safety have resulted in a paradigm shift from the development of neurotoxic, broad spectrum insecticides towards softer, more environmentally friendly pest control agents such as IGRs (Dhadialla *et al*., 2010).

Insect growth regulators (IGRs) are compounds that can regulate the growth of insect pests and play an important role in integrated pest management systems (Kai *et al*., 2009). They are also called third-generation insecticides, as they disrupt the normal activity of the endocrine system of insects, affecting development, reproduction or metamorphosis of the target insects. IGRs include juvenile hormone (JH) mimics and chitin synthesis inhibitors (CSIs) (Hoffman and Lorenz, 1998 and Tunaz and Uygun, 2004).

The insecticides of benzoyl urea act on insects of various orders by inhibiting chitin formation, thereby causing abnormal endocuticular deposition and abortive molting. Studies of the mode of action of chlorfluazuron revealed that the compound alters cuticle composition especially that of chitin, thereby affecting the elasticity and firmness of the endocuticle. The reduced level of chitin in the cuticle seems to result from inhibition of biochemical processes leading to chitin formation (Ishaaya 1990). Wing *et al*. (1988) and Wing and Aller (1989) proved that the insecticidal active members of diacylhydrazines (tebufenozide and methoxyfenozide) functioned as agonists or mimics of the insect molting hormone, 20-hydroxyecdysone (20E). Methoxyfenozide is the latest commercially developed compound in this class commercially and is the most potent analogue against lepidoptera larvae (Ishaaya *et al*., 1995; Le *et al*., 1996; Trisyono and Chippendale 1997 and Smagghe *et al*., 1999). Nauen and Bretschneider (2002) reported that moulting accelerating compounds (MAC's) are chemically described as substituted dibenzoyl hydrazines directly acting on ecdysone receptors. Compounds such as methoxfenozide and chromafenozide induce a precocious moult in Lepidopteran larvae, this leads first to the cessation of feeding and weight gain and then, at the end of the intoxication process, to premature head capsule slippage and death. This study aimed to evaluate the efficacy of the insect growth regulators; chromafenozide, teflubenzuron and lufenuron against 4^{th}, 5^{th} and 6^{th} larval instars of cotton leafworm as well as their effects on food consumption and growth rate of these larvae.

MATERIALS AND METHODS

Tested insecticides

1- Chromafenozide (Virtu 80% WP)

Chemical name: 2'-tert-butyl-5-methyl-2'-(3,5-xyloyl) chromane-6-carbohydrazide.

2-Teflubenzuron (Nomolt 15% SC)

Chemical name: 1-(3,5-dichloro-2,4-difluorophenyl)-3-(2,6-difluorobenzoyl)urea.

3- Lufenuron **(**Match 5% EC**)**

Chemical name: (RS)-1-[2,5-dichloro-4-(1,1,2,3,3,3-hexafluoropropoxy) phenyl]-3-(2,6-difluorobenzoyl) urea.

Field-laboratory test

Potato tubers (Variety Sponta) were cultivated in the farm of Cairo University Experiment Station at Giza Governorate. The experimental area was divided according to complete randomize block design including three replicates for each treatment. All cultural methods were carried out according to good agricultural practice. The tested IGRs, Virtu 80% WP, Nomolt 15% SC and Match 5% EC were sprayed at their recommended rates; 25 g, 50 ml and 160 ml/fed., respectively. knapsack sprayer (CP-3) was used in applying the insecticides as foliar treatment. Potato leaf samples were collected randomly at four intervals; 0-1, 7-8, 14-15 and 21-22 days after spraying. Each time, leaf samples from the same treatment were placed in punched paper bag and transferred immediately to the laboratory.

At the laboratory, three experiments were conducted to evaluate the effect of tested insecticides on different biological aspects of the fourth, fifth and sixth larval instars of cotton leafworms. In each experiment, forty larvae were used for each treatment in four replicates. The susceptible laboratory strain of *Spodoptera littoralis* (Boisd.) - reared in the Economic Entomology and Pesticides Department, Faculty of Agriculture, Cairo University - was used in this study. Newly molted 4^{th}, 5^{th} and 6^{th} instar larvae were starved for 3-4h before using in the experiment. The larvae were allowed to feed on the treated leaves for 2 days and then for 3 days on untreated leave. Alive and dead larvae of *S. littoralis* were recorded after 5 days in each period. An untreated check was included in the test by feeding designated larvae on untreated leaves. The percent mortality was recorded in the fifth day and corrected by Abbott's formula (1925).

Effect on food consumption and growth rate of different larval instars

The weight of each larva and potato leaf was estimated before being used in this experiment. Larvae were confined with treated leaves in glass jars (12 cm high and 7 cm diameter) for 48h, and then they were fed continuously on untreated potato leaves until they either die or complete larval development. Fresh potato leaves were kept without larvae under the same condition to estimate the natural loss of moisture, which was used to calculate the corrected weight of consumed leaves. Every 2-day, the larvae were weighed after feeding. Also, fresh leaves were weighed before and after feeding. Feeding rate, which is the amount of food consumed during the feeding period of each instar, was expressed as per day per gram of larval weight. These parameters were calculated according to the equations described by Waldbauer (1968).

1- Corrected weight of leaf consumed (C) = W - aW

Where:

a = the percentage of moisture loss from the initial weight of the leaves.

W = the fresh weight of food introduced.

2- Consumption Index (CI) = C / (TA)

Where:

C= Fresh weight of consumed leaves, T = duration of feeding period (days).

A = mean fresh weight of larva during feeding period.

3- Relative Growth Rate (GR) = G / (TA)

Where:

G = fresh weight gain of the larvae during feeding period

Data were subjected to analysis of variance (ANOVA) and means were separated by Duncan multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

Efficiency of tested IGRs against *S. littoralis* larvae

Field-lab. test was conducted to evaluate the tested IGRs compounds; Virtu 80% WP, Nomolt 15% SC and Match 5% EC against fourth, fifth and sixth larval instars of cotton leafworm. The tested compounds did not show any phytotoxic symptoms on potato plants when applied at the recommended rates of application. The efficiency of tested IGRs was expressed as mortality percentage of *S. littoralis* larvae in each period as shown in Table (1). Mostly, the percentage mortality of fourth and fifth larval instars was 100% in the first and second periods using all tested insecticides. In contrary, the percentage mortality of sixth larval instar was 30 & 25% and 35 & 20% in the first and second periods using Nomolt and Match, respectively. Only Virtu gave complete mortality to fifth and sixth larval instar in the first, second and third periods. The percent mortality of the fourth larval instar after five days in the third period were 90, 97.5 and 100% using Virtu, Nomolt and Match, respectively. Complete mortality was found in the fifth larval instar in the third period using all the tested insecticides. The corresponding values for sixth larval instar were 100, 25 and 5%, respectively. In the fourth period, the percentage mortality reached to 90, 85 and 95% in the fourth, fifth and sixth larval instar using Virtu, while was 92.5, 97.5 and 5% using the both benzyl urea insecticides; (Nomolt and Match).

The mean of residual effect of Virtu, Nomolt and Match, on the fourth larval instar at the 2nd, 3rd and 4th intervals were 92.5, 96.7 and 97.5%%, respectively. The corresponding values on fifth larval instar were 95.0, 99.2 and 98.3%, and on sixth larval instar were 98.3, 18.3 and 10.0%, respectively. It is evident from the data that there are no differences between the recommended insecticides; Virtu, Nomolt and Match in their efficacy against the fourth and fifth larval instars of *S. littoralis.* In contrary, great difference was found in the efficacy of Virtu and the both benzoylurea insecticides (Nomolt and Match) against sixth larval instar. However, later on, all survived larvae in Nomolt and Match treatments were unable to complete metamorphosis and gave rise to malformed pupae.

The high residual toxicity of tested IGRs in most periods may be attributed to use of sensitive strain of *S. littoralis*. On the other hand, this experiment was conducted in December and January 2011/2012 where the minimum and maximum temperatures reached about 7 and 18ºC. This relatively cold weather may have increased the persistence of tested insecticides under field conditions. The tested IGRs were stable and effective during intervals of this study. These results are in agreement with the study of El-Sheikh and Aamir (2011) who found that lufenuron, flufenoxuron and triflumuron wer stable under field conditions and gave high percentages of mortality against second and fourth larval instars. The percentages of mortality were 100% at 10 days post-treatment in the case of lufenuron and triflumuron when field strain of *S. littoralis* was used.

Table 1: Initial and residual effect of the tested IGRs on the 4th, 5th and 6th larval instars of *S. littoralis* at indicated post treatment intervals

Larval instar	Tested IGRs	Initial effect	Residual effect			
		1st period 0-5 DAS**	2nd period 7-12 DAS	3rd period 14-19 DAS	4th period 21-26DAS	Mean
4th instar	Virtu 80% WP	100	97.5	90	90.0	92.5
	Nomolt 15% SC	100	100	97.5	92.5	96.7
	Match 5% EC	100	100	100	92.5	97.5
5th instar	Virtu 80% WP	100	100	100	85.0	95.0
	Nomolt 15% SC	100	100	100	97.5	99.2
	Match 5% EC	100	97.5	100	97.5	98.3
6th instar	Virtu 80% WP	100	100	100	95	98.3
	Nomolt 15% SC *	30	25	25	5	18.3
	Match 5% EC *	35	20	5	5	10.0

*** All survived larvae were unable to complete metamorphosis and gave rise to malformed pupae.**
**** DAS: Days after spraying.**

Effect of tested IGRs on food consumption

The results of food consumption of the three tested larval instars (4th, 5th and 6th) of *S. littoralis* after feeding on treated leaves with the tested compounds are set out in Tables (2, 3 and 4). Consumption index (C.I.) is one of the feeding activity parameters. Comparing the results of the three treatments against the 4th larval instar showed that there was a significant difference in C.I. between the untreated check and the treatment of Virtu in all experimental periods. Virtu caused high reduction in consumption indexes in the first, second, third and fourth period reached to 54.17, 69.18, 51.56 and 76.84%, respectively. There is no significant difference between the both compounds; Nomolt and Match and untreated check in consumption index through the first period. There were insignificant differences between Nomolt and Match in the 2nd, 3rd and 4th periods. Slight percent reduction was found in consumption indexes for fourth larval instar in the third and fourth period using Nomolt. Data of the mean of C.I. for the tested IGRs through all periods indicated insignificant differences between the both IGRs; Nomolt and Match with the untreated check. On the contrary, there was significant difference in the mean of C.I. between Virtu and untreated check. The mean of reduction percentage in C.I. through experimental periods was 62.86, 15.27 and 34.12% in the treatments of Virtu, Nomolt and Match, respectively.

Also, it was found significant differences between Virtu and untreated check in their effect on food consumption of the 5th larval instar of *S. littoralis* through all evaluation intervals (Table 3). It was clearly found that the consumption index of 5th larval instar significantly decreased from 0.949, 1.139, 1.060 and 1.285 in the control treatment to 0.464, 0.348, 0.516 and 0.324 in Virtu treatment at the 1st, 2nd, 3rd and 4th period, respectively. In the second period, data revealed a similar trend of the effect of tested IGRs on food consumed with high decrease in C.I. by using Virtu. No significant difference in the food consumption could be detected between the untreated check and Nomolt in the first, second and fourth period.

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On the other hand, the second compound of benzoylurea Match differed significantly from untreated check in the third and fourth period. It was also found that the mean values of C.I for the tested IGR through all periods indicated that the treatments were lower than those of check (1.108) and could be arranged according to their efficiency as Virtu (0.413), Match (0.789) and Nomolt (0.793). Virtu caused high reduction in consumption indexes in the first, second, third and fourth period reached to 51.11, 69.45, 51.32 and 74.79%, respectively. Nomolt caused reduction in C.I. ranged between 4.32 and 50.66%, while in Mach treatment was between -1.27 and 58.68% through the four evaluation intervals. The mean of reduction percentage in C.I. through experimental periods was 62.73, 28.52 and 28.70% in the treatments of Virtu, Nomolt and Match, respectively.

The same trend of efficacy of the tested IGRs on the food consumption of the fourth and fifth larval instars was also found in the sixth larval instar of *S. littoralis* (Table 4). No significant difference in the food consumption was found between Match, Nomolt and the untreated check in all intervals. On the contrary, significant differences were found at all experimental periods in C.I. between Virtu and untreated check. Reduction percentage in C.I. of sixth larval instar in the 1st, 2nd, 3rd and 4th period was 76.88, 55.86, 55.70 and 52.22%, respectively.

The corresponding values using Nomolt were 31.25, -0.44, 4.19 and -18.02%, while were 18.96, -24.51, -9.85 and -11.40% using Match, respectively. Great differences in reduction percentage of C.I. were found between Virtu treatment and the both tested IGRs in all experimental period.
Mean of consumption indexes (C.I.) of all intervals was 0.460, 1.096 and 1.219 for Virtu, Nomolt and Match, respectively, compared to 1.131 in check. Accordingly, the present data indicated that feed the different larval instars on treated leaves with Virtu compound resulted in high reduction in food consumption. On the other hand, the both benzoylurea compounds; Nomolt and Match caused slight reduction in C.I. These results especially in the fourth period attributed to great difference in the efficacy of Virtu and the both benzoylurea insecticides; Nomolt and Match against sixth larval instar as shown in Table (2).

Effect of tested IGRs on growth rate

The effect of the tested compounds; on growth rate (G.R.) of 4th, 5th, and 6th larval instars of *S. littoralis* after feeding on treated potato leaves are set out in Tables (5, 6 and 7). Results recorded in Table (5) showed the effect of Virtu, Nomolt and Match on growth rate of fourth larval instar in the 1st, 2nd, 3rd and 4th period. Data indicated that there were significant differences between the treatments and control at all experimental periods except Match at the 2nd period and Nomolt at 4th period. Virtu treatment showed high decrease in growth rate from 0.623, 0.562, 0.538 and 0.600 in control treatment to 0.225, 0.220, 0.201 and 0.080 in the 1st, 2nd, 3rd and 4th period, respectively. Virtu caused high reduction in growth rate of 4th larval instar reached to 63.88, 60.85, 62.64 and 86.67% in the 1st, 2nd, 3rd and 4th period, respectively.

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The corresponding values using Nomolt were 37.24, 29.89, 34.94 and 20.50%, while were 28.41, 6.05, 24.72 and 60.67% using Match, respectively.

It was observed that the application of potato plants with Virtu led to the highest significant decrease in growth rate of 4th larval instar during all experimental periods. The highest reduction percentage in growth rate was obtained at the fourth period using Virtu (86.67%). On the contrary, it was low using Nomolt, which reached to 20.50% only. The mean of G.R. through the experimental intervals indicated that there are significant differences between the treatments and control. They were 0.182, 0.403 and 0.404 in the treatments of Virtu, Nomolt and Match, respectively, compared to 0.581 in the check treatment.

Also, it was found that the tested IGRs were able to suppress the growth rate of the fifth and sixth larval instars to different degrees in comparison to that of untreated control. Generally, it was found that the growth rates of the 5th and 6th larval instars differed from the first interval up to the fourth interval. The percent reduction in G.R. in Virtu treatment was high at all intervals and ranged between 59.13 - 90.58% and 76.67 - 98.55% for fifth and sixth larval instars, respectively. On the contrary, it was found low percent reduction in growth rate of sixth larval instar during the fourth evaluation periods in the treatments of Nomolt and Match, which ranged between -20.44 - 14.90% and -29.31 - 22.16%, respectively. Means of growth rates of fifth larval instar in all intervals were 0.145, 0.350 and 0.372 for Virtu, Nomolt and Match, respectively, compared to 0.576 in check treatment. The corresponding values for the sixth larval instar were 0.061, 0.463 and 0.460 compared to 0.470 in control treatment. Accordingly, data indicated that feeding the different larval instars on potato leaves treated with Virtu resulted in high reduction in growth rate, while the both benzoylurea compounds; Nomolt and Match gave slight decrease in growth rate.

The results presented here indicate that Virtu was more effective than both benzoylurea compounds; Nomolt and Match against cotton leaf worms. Concerning the effect of chromafenozide on the food consumption and growth rate, it could be best interpreted according to the mode of action of bisacylhydrazine insecticides. The commercialized bisacylhydrazine insecticides are toxic to susceptible insects mainly as a result of ingestion. Toxicity via topical application is expressed only when very high doses are applied (Dhadialla *et al.,* 2010). In general, because bisacylhydrazines are more metabolically stable *in vivo* than ecdysteroids and because they are true ecdysone agonists at receptor level, ingestion of bisacylhydrazines creates “hyperecdysonism” in susceptible insects, thus inducing effects and symptomology of a molt event. One of the first effects of bisacylhydrazine ingestion by susceptible larvae is feeding inhibition within 3-14 h (Slama, 1995; Smagghe *et al.,* 1996; Retnakaran *et al.,* 1997), which prevents further plant damage. During this time, synthesis of a new cuticle begins and apolysis of the new cuticle from the old one takes place. Subsequently, the intoxicated larvae become moribund, slip their head capsule and in extreme cases, the hind gut may be extruded. The new cuticle is not tanned or sclerotized. One resulting consequence is that the mouth parts under the slipped head capsule remain soft and mushy, preventing any crop damage even if the head capsule came off from mechanical or physical force. The larvae ultimately die as a result of their inability to complete a molt, starvation and desiccation due to hemorrhage (Dhadialla *et al.,* 2010). This finding is compatible with the results in the present study, which Virtu caused high decrease in consumption indexes of 4^{th}, 5^{th} and 6^{th} larval instars of *S. littoralis* and of course resulting in high reduction in growth rates.

Nomolt 15% SC (teflubenzuron) and Match 5% EC (lufenuron) belong to the chemical group of benzophenylurea (BPUs) and identified as chitin synthesis inhibitors (CSIs). They alter cuticle composition, especially inhibition of chitin, resulting in abnormal endocuticular deposition that affects cuticular elasticity and firmness, and cause abortive molting. The reduced chitin levels in the cuticle seem to results from inhibition of biochemical processes leading to chitin formation (Retnakaran *et al.,* 1985; Grosscurt *et al.,* 1987; Retnakaran and Wright 1987; Londerhausen 1996; Oberlander and Silhacek 1988 and Palli and Retnakaran 1999). It was found in the current study that feeding of fourth, fifth and sixth larval instars on potato leaves treated with teflubenzuron and lufenuron led the intoxicated larvae to keep on feeding and growing in pattern similar to that in untreated checks; and sometimes C.I. and G.R. values were higher in intoxicated larvae than those in untreated checks. However, death occurred at the end of larval instar period when intoxicated larvae started the process of molting or pupation. These results are in agreement with Ishaaya *et al.*(1986) who reported that food consumed during the last instar of *S. littoralis* did not differ significantly when treated with chlorfluazuron, a benzoylphenyl urea compound, comparing to control larvae. Moreover, Gaaboub *et al.* (1985) reported that the rate of food utilization was significantly higher for the 4^{th} instar of *Bombyx mori* treated with diflubenzuron. They suggested that the treatment might have produced a nutritional unbalance in food that subsequently increased the coefficient of food utilization. Also, Radwan *et al.* (1986) observed an increase in the efficiency of conversion of ingested food in the 4^{th} instar of *S. littoralis* treated with diflubenzuron or trifluron.

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التأثير الحيوي لبعض منظمات النمو الحشرية على دودة ورق القطن *Spodoptera littoralis* (Biosd.)

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أجريت دراسة حقلية معملية لتقييم التأثير المباشر و المتبقي لثلاثة منظمات نمو حشرية هي : Virtu (chromafenozide) 80%WP – Nomolt 15% SC (teflubenzuron) و Match 5%EC (lufenuron) ، بالإضافة لتأثيرها على استهلاك الغذاء و معدل النمو في يرقات العمر الرابع و الخامس و السادس لدودة ورق القطن (*Spodoptera littoralis*). عوملت المركبات المختبرة على نباتات البطاطس في الحقل و جمعت الأوراق في أربع فترات زمنية بعد الرش لإجراء الاختبارات المعملية . تركت اليرقات لتتغذى على الأوراق المعاملة ليومين ثم على أوراق غير معاملة لثلاثة أيام . تشير النتائج إلى أن جميع المركبات المختبرة كانت عالية الفعالية ضد اليرقات و كان لها تأثير متبقي كبير . من جهة أخرى كان لمبيد Virtu تأثير متبقي أكبر من تأثير مثبطات تخليق الكيتين Nomolt و Match على يرقات العمر السادس. نمط مشابه لفعالية منظمات النمو لوحظ على استهلاك الغذاء في يرقات العمر الرابع و الخامس لدودة ورق القطن . متوسطات مؤشر استهلاك الغذاء في العمر اليرقي السادس كانت 0.460 – 1.096 – 1.219 في اليرقات المعاملة بـ Virtu و Nomolt و Match ، على التوالي، مقارنة بـ 1.131 في يرقات الشاهد . أيضاً لوحظ كبح معدل نمو اليرقات بدرجات متفاوتة في معظم اليرقات المعاملة بالمبيدات المختبرة و ذلك مقارنةً مع يرقات الشاهد . تشير النتائج إلى أن مبيد Virtu (مشابه هرمون الإنسلاخ) أدى إلى إنخفاض كبير في استهلاك اليرقات للغذاء و كذلك معدل نموها . أما مثبطا تخليق الكيتين Nomolt و Match فكانا قليلي التأثير على معدل نمو اليرقات و مؤشر استهلاك الغذاء .

قام بتحكيم البحث

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Table 2: Food consumption (C.I.) for the 4th instar larvae of *S. littoralis* after feeding for 48 h. on treated potato leaves with IGRs

IGRs	Rate/fed.	First period		Second period		Third period		Fourth period		Mean	
		C.I.	Reduction %	C.I.	Reduction %	C.I.	Reduction %	C.I.	Reduction %	C.I.	Reduction %
Virtu 80% WP	25 g	0.56 b	54.17	0.335 b	69.18	0.623 b	51.56	0.302 b	76.84	0.455 b	62.86
Nomolt 15% SC	50 ml	1.621 a	-32.65	0.472 b	56.58	1.036 ab	19.44	1.022 ab	21.63	1.038 ab	15.27
Match 5% EC	160 ml	1.655 a	-35.43	0.477 b	56.12	0.569 b	55.75	0.527 b	59.59	0.807 ab	34.12
Control	---	1.222 a	---	1.087 a	---	1.286 a	---	1.304 a	---	1.225 a	---

Values within the same column having the same letter are not significantly different (P< 0.05)

Table 3: Food consumption (C.I.) for the 5th instar larvae of *S. littoralis* after feeding for 48 h. on treated potato leaves with IGRs

IGRs	Rate/fed.	First period		Second period		Third period		Fourth period		Mean	
		C.I.	Reduction %	C.I.	Reduction %	C.I.	Reduction %	C.I.	Reduction %	C.I.	Reduction %
Virtu 80% WP	25 g	0.464 b	51.11	0.348 b	69.45	0.516 b	51.32	0.324 b	74.79	0.413 c	62.73
Nomolt 15% SC	50 ml	0.908 a	4.32	0.994 a	12.73	0.523 b	50.66	0.744 ab	42.10	0.793 b	28.52
Match 5% EC	160 ml	0.961 a	-1.27	1.014 a	10.98	0.652 b	38.49	0.531 b	58.68	0.789 b	28.70
Control	---	0.949 a	---	1.139 a	---	1.060 a	---	1.285 a	---	1.108 a	---

Values within the same column having the same letter are not significantly different (P< 0.05)

Table 4: Food consumption (C.I.) for the 6th instar larvae of *S. littoralis* after feeding for 48 h. on treated potato leaves with IGRs

IGRs	Rate/fed.	First period		Second period		Third period		Fourth period		Mean	
		C.I.	Reduction %	C.I.	Reduction %	C.I.	Reduction %	C.I.	Reduction %	C.I.	Reduction %
Virtu 80% WP	25 g	0.222 c	76.88	0.497 c	55.86	0.571 b	55.70	0.549 b	52.22	0.460 b	59.33
Nomolt 15% 15% SC	50 ml	0.660 b	31.25	1.131 b	-0.44	1.235 a	4.19	1.356 a	-18.02	1.096 a	3.10
Match 5% EC	160 ml	0.778 ab	18.96	1.402 a	-24.51	1.416 a	-9.85	1.280 a	-11.40	1.219 a	-7.78
Control	---	0.960 a	---	1.126 b	---	1.289 a	---	1.149 a	---	1.131 a	---

Values within the same column having the same letter are not significantly different (P< 0.05)

Table 5: Growth rate (G.R.) for the 4th instar of *S. littoralis* after feeding for 48 hours on potato leaves treated with tested IGRs.

IGRs	Rate/fed.	First period		Second period		Third period		Fourth period		Mean	
		G.R.	Reduction %	G.R.	Reduction %	G.R.	Reduction %	G.R.	Reduction %	G.R.	Reduction %
Virtu 80% WP	25 g	0.225 c	63.88	0.220 c	60.85	0.201 c	62.64	0.080 b	86.67	0.182 c	68.68
Nomolt 15% SC	50 ml	0.391 b	37.24	0.394 b	29.89	0.350 b	34.94	0.477 a	20.50	0.403 b	30.64
Match 5% EC	160 ml	0.446 b	28.41	0.528 ab	6.05	0.405 b	24.72	0.236 b	60.67	0.404 b	30.47
Control	---	0.623 a	---	0.562 a	---	0.538 a	---	0.600 a	---	0.581 a	---

Values within the same column having the same letter are not significantly different (P< 0.05)

Table 6: Growth rate (G.R.) for the 5th instar of *S. littoralis* after feeding for 48 hours on potato leaves treated with tested IGRs.

IGRs	Rate/fed.	First period		Second period		Third period		Fourth period		Mean	
		G.R.	Reduction %	G.R.	Reduction %	G.R.	Reduction %	G.R.	Reduction %	G.R.	Reduction %
Virtu 80% WP	25 g	0.129 b	76.02	0.176 c	71.98	0.217 b	59.13	0.057 c	90.58	0.145 c	74.83
Nomolt 15% SC	50 ml	0.468 a	13.01	0.549 b	12.58	0.157 b	70.43	0.226 b	62.65	0.350abc bc	39.24
Match 5% EC	160 ml	0.488 a	9.29	0.569 b	9.40	0.220 b	58.57	0.212 b	64.96	0.372ab ab	35.42
Control	---	0.538 a	---	0.628 a	---	0.531 a	---	0.605 a	---	0.576 a	---

Values within the same column having the same letter are not significantly different (P< 0.05)

Table 7: Growth rate (G.R.) for the 6th instar of *S. littoralis* after feeding for 48 hours on potato leaves treated with tested IGRs.

IGRs	Rate/fed.	First period		Second period		Third period		Fourth period		Mean	
		G.R.	Reduction %	G.R.	Reduction %	G.R.	Reduction %	G.R.	Reduction %	G.R.	Reduction %
Virtu 80% WP	25 g	0.119 c	76.67	0.030 b	92.61	0.089 b	81.46	0.007 b	98.55	0.061 b	87.02
Nomolt 15% SC	50 ml	0.434 b bbbab	14.90	0.489 a	-20.44	0.488 a	-1.67	0.440 a	9.09	0.463 a	1.49
Match 5% EC	160 ml	0.397 b	22.16	0.525 a	-29.31	0.483 a	-0.63	0.433 a	10.54	0.460 a	2.13
Control	---	0.510 a	---	0.406 a	---	0.480 a	---	0.484 a	---	0.470 a	---

Values within the same column having the same letter are not significantly different (P< 0.05)