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Side Effects of Pre-Plant Incorporated Herbicides on The Population of Root-Knot Nematode in Cucumber Plants Under Field Conditions

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El-Sagheer, A. M.*

Agricultural Zoology and Nematology Department, Faculty of Agriculture, Al-Azhar University, Assiut, Egypt.

ABSTRACT

The high economic costs of agricultural production, especially with the high prices of nematicides, have led many researchers to find alternative strategy management to the root-knot nematode. The current study aimed to evaluate the effect of some commercial pre-plant incorporated herbicides; Benefin, Cobex, Devrinol, Prefar and Treflan as nonspecific treatment as a part of strategy of integrated pest management on the root-knot nematode, *Meloidogyne javanica* infesting cucumber plants in commercial open fields conditions. All the tested pre-plant incorporated herbicides caused a significant reduction in the root-knot nematode criteria with varying degrees compared with the control. The treatments by Treflan showed the highest effect on the reduction percentage of root-knot nematode (75.8%, 81.8% and 77.4%) in descending three tested rates through the progress of the plants growth, followed by other treatments down to at the least effect associated with Prefar at double rate treatment (40.1%). In conclusion, in the case of the need to weeds control preferred pre-plant herbicides, especially Treflan , Benefin and Devrinol where it has a side effects on decreasing the population of the root-knot nematode.

Kaywords: Herbicides, Root-knot nematode, *Meloidogyne javanica*, cucumber

INTRODUCTION

Plant parasitic nematodes are the most destructive group of plant pathogens and their control is extremely challenging. They parasite a large variety of crops through worldwide and their impact on yield losses have been estimated to a billion of euros annually (Bernard *et al.*, 2017). The genus *Meloidogyne* (Tylenchida: Meloidogynidae) widespread distribution and success as parasites of economically important crops. The species, *Meloidogyne javanica* (Treub) Chitwood, (1949) consider the most common pest nematode species in vegetables (Koenning *et al.*, 1999). In the open fields the weeds can be considered as alternative hosts , carriers and point sources for plant-parasitic nematodes and have long been recognized for their ability to maintain plant parasitic nematodes populations targeted for suppression by various management strategies (Kokalis and Rosskopf, 2012).

Some of these investigations showed that the soil population densities of Meloidogyne spp. appeared to be correlated with the density of weeds (Kremer, 2000). Were, the exclusion of those weeds can efficiently prevent nematodes infestation (Schroeder et al. 1993). A considerable number of investigations where focused on the impacts of herbicides on root-knot nematodes (Schroeder *et al.*, 2005 and Gilreath *et al.*,2004). Herbicides represent a wide diversity of components varying in chemical, physical, and toxicological properties (Altman and Campbell, 1977).

Pre-plant incorporated herbicides affect directly or indirectly on the soil community as a chemical components added to the soil and perhaps the indirect effect is greater than the direct effects on the rhizosphere of roots (Curl and Truelove, 2012 and Thomas *et al.*, 2005). Through varied levels of interaction, pre-plant incorporated herbicides can have some of inimical effects on the plant parasitic nematodes (Altman and Rovira, 1989 and Gilreath *et al.*,2004). Through the application of herbicides, the changes on structural and metabolic of soil food webs of non-target organisms was related directly or indirectly with the application rate and type of active ingredient materials (Norris, 1982 and Subhani *et al.*, 2000). Where changes occur in the physical and chemical properties of soils including; fluctuation in soil pH (Patel *et al.*, 2008) ; secondary materials resulting from the degradability of the active ingredient materials in the soil, and its interactions with soil organic and mineral components (Janaki, 2015); effect on the soil capacity and the ability to retain water (Blumhorst *et la.*, 1990).

Recently, the challenge that faces weed scientists and nematologists is to identify effective, compatible integrated pest management strategies that address weed and nematode management collectively, combined with environmental considerations, increasingly necessitates the use of integrated pest management strategies in many crops, therefore, current study aims to the evaluation of some common pre-plant incorporated herbicides on the population of root-knot nematodes under field conditions.

MATERIALS AND METHODS

Experimental site

Experiment were carried in normal growing season of cucumber cv. Waffir F1(hybrid h49, accession number:1690/2004) in open field naturally infested with root-knot nematode, *Meloidogyne javanica*, at the fields of Abnob , south of Assiut Governorate. It belongs to the arid

* **Corresponding author.**
E-mail address: atefelsagheer@azhar.edu.eg
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region of Egypt, which characterized by long and hot summer, cold winter, low rainfall, and high evaporation. The summer season is dry and very hot with maximum temperature reaching up to 43 °C. December to February is the coldest months when minimum temperature falls to 18 °C. The soil at this site is sandy clay loam texture (63%, 27% and 10% consecutively), which classified under sandy texture.

The experimental field was divided six main plots, measuring 4.20 m × 4m , every plot had been divided into nine sub-plots , measuring 1.40 m × 1m comprised four plants , treatments were arranged in randomized complete block design (five blocks) and completely random (three replicates). And infected control as dependent plot ,4.20 m × 4m , divided into three sub-plots , measuring 1.40 m × 1m comprised four plants.

Population dynamics of root-knot nematode

The nematodes extraction according to methods described by Christie and Perry (1951) and Southey (1964). Identification of *Meloidogyne* species was established after referring to morphological characteristics given by Chitwood (1949), Sasser (1954), Taylor and Netscher (1974), Taylor and Sasser (1978). The number of juveniles in soil, galls, developmental stages, egg masses per root were counted. Eggs often randomly selected egg masses of each root system was also counted. The rate of nematode reproduction and percentages of reduction in nematodes final population was calculated.

Preparation of pre-plant incorporated herbicides

Five commercial pre-plant incorporated herbicides; Benefin, Cobex, Devrinol, Prefar and Treflan were used in this experiment are described in the Table (1) .

Data analysis

The experiment designed with randomized complete design. All the data were subjected to Analysis of Variance (ANOVA) using Costat package version 6.311. The means were compared according to Duncan's multiple range tests at P ≤0.05 (Duncan, 1955). Correlation coefficient; equations and trend lines implemented using IBM SPSS using regression analysis the Pearson product moment correlation type at 0.05 which stipulates coefficient ('r') is a measure of the linear association of two variables. If the probability that r=0 this means no significant correlation between the variables, and r =1 this means completely significant correlation.

Table 1. Tested pre-plant incorporated herbicides

Herbicides	Tested Pre-plant incorporated herbicides		
	Recommended rate	**Chemical Names**	**Active ingredient**
Benefin	0.5 to 0.75 kg / feddan	N-butyl-N-ethyl-2,6-dinitro-4-trifluoromethyl-aniline	Benfluralin
Cobex	1 liter /feddan Dissolved	3-N,3-N-diethyl-2,4-dinitro-6-(trifluoromethyl) benzene-1,3-diamine	Dinitramine
Devrinol 50-DF	0.75- 1 kg /feddan	2-(a-Naphthoxy)-N,N-diethylpropionamide	Napropamide
Prefar	2.5 to 3 kg /feddan	N-[2-di (propan-2-yloxy) phosphinothio ylsulfanyl ethyl] benzene sulfonamide	Bensulide
Treflan 480 g/L	0.62-0.94 kg/feddan	2,6-Dinitro-N,N-dipropyl-4-(trifluoromethyl)aniline	Dinitroanilines

RESULTS AND DISCUSSION

RESULTS

The effect of five commercial pre-plant incorporated herbicides; Benefin, Cobex, Devrinol, Prefar and Treflan as nonspecific treatment as a part of strategy of integrated pest management against root-knot nematode, *Meloidogyne javanica*, infesting cucumber plants were evaluated under commercial open fields conditions over three months, which represents a period of economic production of the cucumber.

Generally, the current study showed that all the tested pre-plant incorporated herbicides caused significantly reduction in root-knot nematodes criteria; numbers of root galls, final population and nematode reduction compared with the control. Where, the results indicate that the significant effect especially at the beginning of the evaluation, this is often associated with the higher rates of application , then with the progress of plants growth noted the increasing in the final population of root-knot nematodes with varying degrees, which it seems obvious to effect in the number of developmental stages which has succeeded in penetrating the roots, where less than the developmental stages in the soil. Generally, correlation coefficient (Pearson's correlation at 0.05) studies showed positive and significant correlation between number of galls and both of final population and percentages nematode reduction with different significant degrees which ranges from moderate to low as shown in (Figs., 1:6).

After 21 days of planting, all nematodes criteria was observed and tabled in tables (25) , based of galling formation, the minimum galls/plant was recorded in treated soil with Treflan in 2x, x and ½x rate (7,6 and 5) respectively, followed by Devrinol (8,9 and 7) and Benefin (8,7 and 9) respectively, compared with control. While, Cobex and Prefar (at 2x, x ½x rates) were recorded the highest means of galls (10 , 8 and 9) and (11,9 and 10) respectively. Generally, Treflan treatments showed the highest affecting on number of galls/root system, no. of juveniles/250g soil, developmental stages/root, no. of egg masses/root and no. of eggs/egg mass at high dose (7, 97, 17, 4 and 46) respectively, also in final population of nematodes and nematode reduction (282 and 71.6) , respectively. On the other hand, the minimum effecting results were recorded with Prefar in the previous criteria in same rates, (11,202,60,8 and 61) respectively, and (740 25.7) also in recommended dose x (9,212,53, 8 and 66) respectively, and(793 and 20.3) respectively, and with lowest rate ½x (10,217,50,10,67) and (947 and 5.9) , respectively.

While, Benefin , Cobex and Devrinol treatments in the three studied rates recorded the middle effect on all root knot nematode criteria. Data noted that developmental stage/root were most affected by all herbicides treatments compared with number of juveniles in soil to same treatment, for example, were at high dose in Treflan the developmental stages per root and number of juveniles in soil were (17 & 97) , in Devrinol (30 &197) , in Prefar (60

& 202) Benefin (27 and 111) and Cobex (30 and 152) respectively. When studding the correlation between the effect of all studied herbicides and no. of juveniles in soil and developmental stages/root the data showed that there is no significant correlation (Figs. 1&2).

Table 2. Effect of some of pre-plant incorporated herbicides on the population of root-knot nematodes in cucumber plants. after 21 days of planting

Treatments	Rates	Nematode criteria: No. of galls/root system	No. of Juveniles/ 250 g soil	Developmental stages/root	No. of egg masses/root	No. of eggs/egg mass	Final population
Benefin	2X	8 bc	111 f	27 bc	4 b	29 b	171
	X	7 bc	102fg	30 bc	4 b	28 b	244
	½X	9 bc	123e	36 b	6 ab	33 b	357
Cobex	2X	10 b	152d	30 bc	5 b	61 a	487
	X	8 bc	167c	33 bc	6 ab	54 ab	524
	½X	9 bc	180bc	40 b	7 ab	58 ab	626
Devrinol	2X	8 bc	197bc	30 bc	4 b	54 ab	443
	X	9 bc	131de	37 b	5 b	50 ab	418
	½X	7 bc	153d	42 b	6 ab	45 ab	465
Prefar	2X	11 b	202bc	60 a	8 ab	61 a	740
	X	9 bc	212ab	53 ab	8 ab	66 a	793
	½X	10 b	217ab	50 ab	10 a	67a	947
Treflan	2X	7 bc	97g	17 c	4 b	46 ab	282
	X	6 bc	102fg	20 c	3 b	40 ab	242
	½X	5 c	107fg	24 bc	3 b	38 b	245
Control (untreated)		19 a	230a	66 a	10 a	70 a	996

Means at each column followed by the same letter are not significantly different at (P≤0.05) according to Duncan multiple range test.
Nematode final population = [Egg masses no. /root × Eggs no. / Egg masses] +[Developmental stage/root] + [Developmental stages. /soil]+ [Adult female/root]

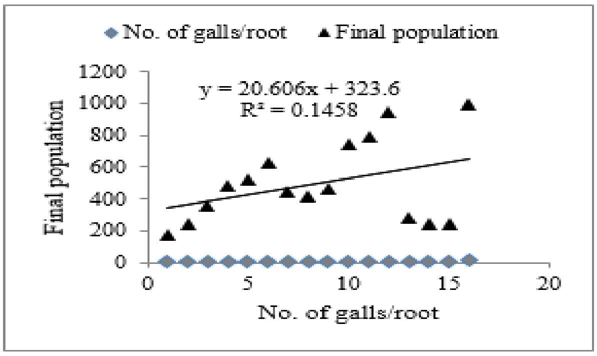

Fig1. Correlation between number of galls and final population as affected by PPI herbicides at 21 DAP, which shows a moderate correlation

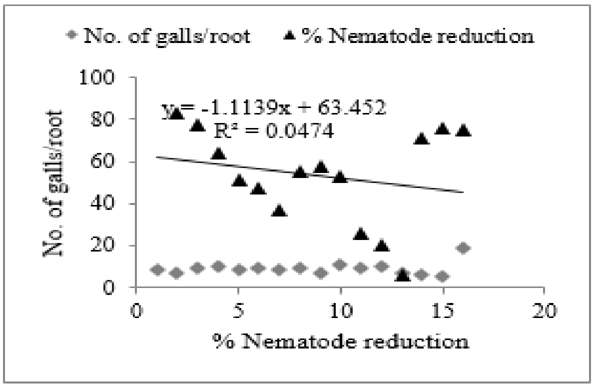

Fig. 2. Correlation between number of galls and nematode reduction percentage as affected by herbicides at 21 DAP, which shows a low correlation.

After 42 days of planting, the results (Tables 3&5) somewhat similar with previous stage of experiment, where, the minimum galls/plant was recorded in treated soil with Treflan in ½x (6) , flowed by Devrinol in x (10) , and ½x (10) and Benefin in x (10) , and ½x(10) and Cobex ½x (10). However, the different number of juveniles in soil from this was showed in Treflan at ½x (103), achieved more effect flowed by Treflan in x (110) and Benefin in x (113) and ½x (117). While, the treatment with Cobex ½x , Benefin in 2x and Devrinol in x ½x were showed the best effect on Juveniles in soil (105,139,143 169) respectively, flowed by Cobex in x (194) . The treated by Benefin in x , Cobex in 2x ½x, were appeared moderate effects (117,185 and 208) respectively, flowed by Prefar ½x, x and 2x (223,231 and 237) respectively, as minimum effects when compared with other treatment and control.

However, number of egg masses/root was significantly affected by all treatments compared with control, were the best results associated with Treflan in x, Treflan in ½x and Devrinol in 2x (5,66) flowed by Devrinol in x and Cobex in 2x (9 7) respectively. Also, Treflan in x, 2x ½x and Benefin in 2x recorded as best treatments flowed by Devrinol in 2x , ½x x and Cobex in 2x and x (727,804 881) respectively in effecting on nematode final population . Regression studies showed positive and significant correlation between number of galls and final population (r^2 = 0.0838), and between final population and no. of juveniles in soil (r^2 = 0.0741), also between number of galls and developmental stages in root (r^2 = 0.0016) and are shown by regression equations and trend lines in (Figs. 3&4).

Table 3. Effect of some of pre-plant incorporated herbicides on the population of root-knot nematode in cucumber plants after 42 days of planting

Treatments	Rates	Nematode criteria					
		No. of galls/root system	No. of Juveniles/ 250 g soil	Developmental stages/root	No. of egg masses/root	No. of eggs/egg mass	Final population
Benefin	2X	11bc	139 d	52 c	8 b	41 d	519
	X	10 bc	117 ef	48 cd	9 b	38 de	507
	½X	10 bc	123 e	41 cd	8 b	30 e	404
Cobex	2X	14 ab	208 b	48 cd	7 b	93 a	907
	X	11 bc	194 b	40 cd	10 b	75 bc	984
	½X	10 bc	185 bc	55 c	10 b	67 bc	910
Devrinol	2X	12 bc	189 bc	46 cd	6 c	82 b	727
	X	10 bc	143 d	45 cd	9 b	77 bc	881
	½X	10 bc	169 c	45 cd	10 b	59 c	804
Prefar	2X	17a	237 a	87 a	12 b	85 b	1344
	X	15 b	231 a	73 b	10 b	77 bc	1074
	½X	14 ab	223 ab	68 bc	11 b	70 bc	1061
Treflan	2X	9 c	118 ef	25 d	6 c	57 c	485
	X	8 c	110 ef	34 cd	5 c	47 d	379
	½X	6 c	103 e	37 cd	7 b	48 d	476
Control (untreated)		16 a	540 a	89 a	19 a	93 a	1559

Means at each column followed by the same letter are not significantly different at (P≤0.05) according to Duncan multiple range test.
Nematode final population = [Egg masses no. /root × Eggs no. / Egg masses] +[Developmental stage/root] + [Developmental stages. /soil]+ [Adult female/root]

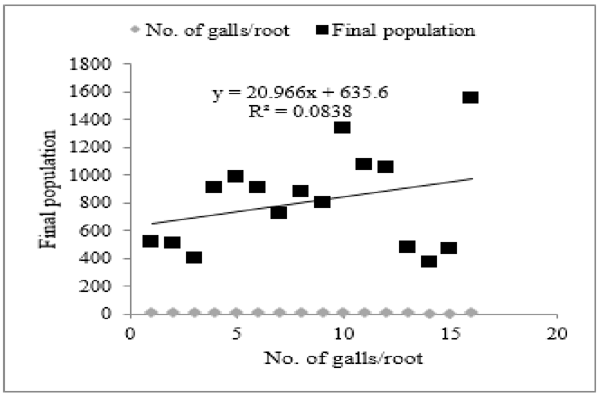

Fig. 3. Correlation between number of galls and final population affected by PPI herbicides at 42 DAP, which shows a moderate correlation.

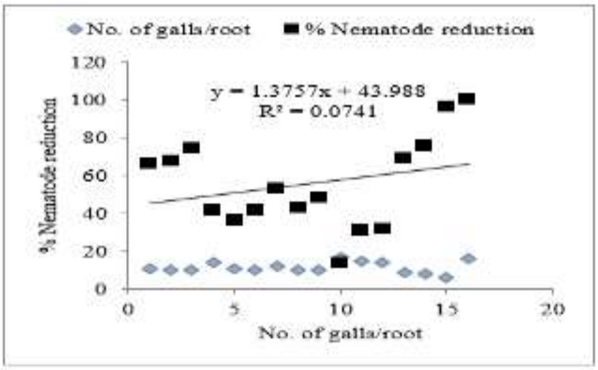

Fig. 4. Correlation between number of galls and nematode reduction percentage as affected by herbicides at 42 DAP, which shows a moderate correlation.

After 63 days of planting, current results in Tables (4&5), reported that the minimum galls/plant, juveniles in soil and developmental stages in root was recorded in treated soil by Treflan in 2 x (16, 120), ½x(19, 127) and x (20, 139) and Devrinol in 2x x (18 and 2) and (182 and 197) Treflan in ½x (19 and 139) and Benefin in 2x (19,138) , x (20, 141) ½x(21, 158) respectively for same previous criteria . Also, a moderate effect noted in Devrinol treatments at ½X (18 213) flowed by Cobex in 2x, x and ½x (23, 24 and 27) and (158,217 231) respectively, for same nematode criteria. In less level of same nematode criteria were noted in Prefar ½x (22, 231), x(25, 242) and 2x (213, 259) respectively. But, number of egg masses in root was recorded in Treflan in X 2x (7 and 9) respectively, treatments with significantly deference compared with control (23), and the minimum results associated with Prefar in all tested doses. Also, in effecting on nematode final population and nematode reduction percentages, the best results associated with Treflan at x (754, 81.8 %), 2x(902, 77.4 %) and ½x (965, 75.8 %), and Devrinol in ½x (1135) (71.5 %) and Benefin in ½x (1057 1386) and recommended rate (79.5 % and 80.3 %) flowed by Cobex in x (1380, 65.4 %) , ½x(1396, 65.1 %) and 2x (1410, 64.6%) respectively. In addition, the minimum decreases were associated with Prefar in all tested rates. When compared the number of eggs per eggmass results showed absence of a significantly differences between the tested treatments , but there was founded between the treatments and control, were the results indicate that the best results noted in Treflan in ½x , Benefin in x , Devrinol in ½x and Benefin in 2x (71, 71, 73 and 80), respectively.

Regression test showed positive and significant correlation between number of galls and final population (r^2 = 0.0838), and between final population and no. of juveniles in soil (r^2 = 0.0838), also between number of galls and developmental stages in root (r^2 = 0.0016) and are shown by regression equations and trend lines in Figs. (5&6).

Table 4. Effect of some of pre-plant incorporated herbicides on the population of root-knot nematode in cucumber plants after 63 days of planting

Treatments	Rates	Nematode criteria					
		No. of galls/root system	No. of Juveniles/ 250 g soil	Developmental stages/root	No. of egg masses/root	No. of eggs/egg mass	Final population
Benefin	2X	19 b	141 e	65 c	11 bc	80 c	1086
	X	20 b	138 e	67 c	12 bc	71 d	1057
	½X	21b	158 d	64 c	12 bc	97 c	1386
Cobex	2X	24 b	217 c	63 c	10 bc	113 c	1410
	X	23 b	231 bc	57 c	12 bc	91c	1380
	½X	27 b	257 b	60 c	13 bc	83 c	1396
Devrinol	2X	18 b	182 cd	62 c	13 bc	99 c	1531
	X	20 b	197 c	57 c	12 bc	87 c	1298
	½X	22 b	213 c	46 cd	12 bc	73 d	1135
Prefar	2X	22 b	231 bc	104 b	17 b	12 b	2392
	X	25 b	242 bc	95 b	15 b	101c	1852
	½X	28 b	259 b	83 bc	14 b	102 c	1770
Treflan	2X	16 c	120 f	35 d	9 bc	90 c	965
	X	20 b	127 f	46 cd	7 c	83 c	754
	½X	19 b	139e	53 cd	10 bc	71 d	902
Control (untreated)		39a	420 a	123 a	23a	150 a	3993

Means at each column followed by the same letter are not significantly different at ($P \leq 0.05$) according to Duncan multiple range test.

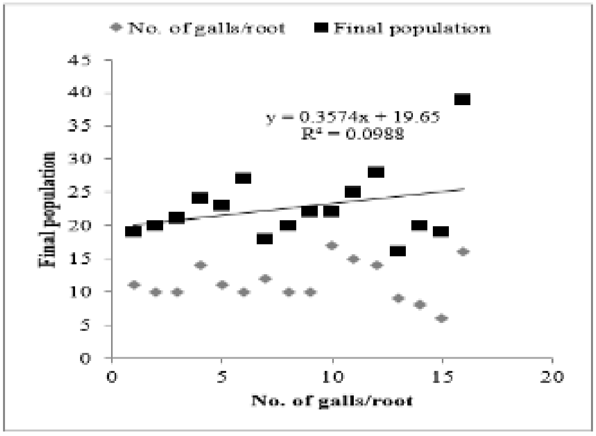

Fig. 5. Correlation between number of galls and final population as affected by weed control by herbicides at 63 DAP, which shows a moderate correlation.

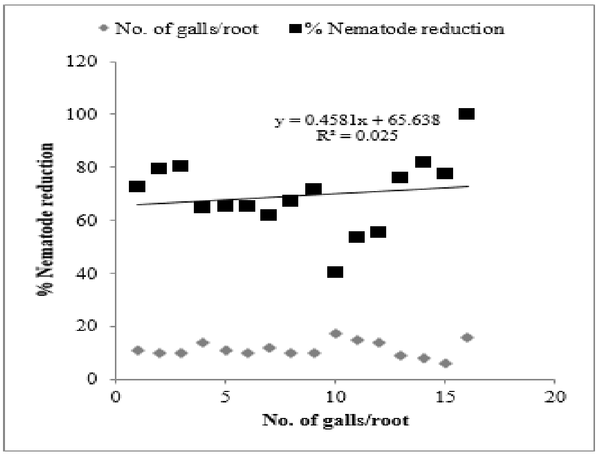

Fig. 6. Correlation between number of galls and final population and nematode reduction percentage as affected by herbicides at 63 DAP, which shows a low correlation.

Table 5. Effect of some of pre-plant incorporated herbicides on the reduction percentages of root-knot nematode in cucumber plants after 63 days of planting

Herbicides	Rates	Nematode reduction percentages (%)		
		21 DAP	42 DAP	63 DAP
Benefin	2X	82.8	66.7	72.8
	X	77.5	67.4	79.5
	½X	64.1	74.1	80.3
Cobex	2X	51.1	41.8	64.6
	X	47.3	36.8	65.4
	½X	37.1	41.6	65.1
Devrinol	2X	55.5	53.3	61.6
	X	58.1	43.3	67.4
	½X	53.3	48.4	71.5
Prefar	2X	25.7	13.7	40.1
	X	20.3	31.1	53.6
	½X	5.9	31.9	55.6
Treflan	2X	71.6	68.8	75.8
	X	75.7	75.6	81.8
	½X	75.4	96.4	77.4
Control (untreated)		100	100	100

DAP = days after planting

$$\text{Nematode reduction \%} = \left(\frac{\text{Final population in control} - \text{Final population in treatement}}{\text{Final population in control}}\right) x100$$

Discussion

The tested herbicides showed some effecting on the final population of root-knot nematode which deferent depending to nature of active ingredient materials that probably complex. These effects ranging from the alteration of the behavior of one chemical by the other chemical, altered physiology of the plant, and biological changes within the soil environment. So the mutual influence of nematode and weed management have many ways, based on understanding of the link between them (Kumar *et al.*, 2017) which the most widely recognized is by providing plant parasitic nematodes with additional substrate is alternative hosts his alternative host seduces the efficacy of management techniques designed to lower plant-parasitic nematode populations and there by enhances crop in jury that is proportional to the size of the nematode population (Riggs, 1992). Other directed effects of weeds include protection of certain nematodes from pesticides or the environment (Schroeder *et al.,* 1993 and Thomas *et al.,* 2005), nematode suppression by antagonistic weeds or by the incorporation of weed biomass into soil (Yeates *et al*., 1999), and perhaps through host-induced change in future nematode biotic potential (Thomas *et al.* 1997), or as the chemicals added to the soil environment can be said it changed the nature of the soil through the temperature and humidity may reflected negatively on the population of plant parasitic nematodes as a one of soil bio-community in soil (Sahoo *et al.,* 2016). In this study results showed the variation and difference in the effect of tested pre-plant incorporated herbicides on root-knot nematode outside the usual pattern of the developmental stages population during the life cycle , so if excepting the difference in the active ingredient materials perhaps due to most it have a deleterious effect by enhancing populations or the adaptability plant parasitic nematodes (Westwood *et al.,* 2010), or below-ground weed biomass may help protect endoparasites from pesticides and the factors of environment (Norris, 2005), which corresponds with Browde *et al.,* (1994) and (Riggs and Oliver, 1982), where reported that positive effecting of herbicides in plant parasitic nematodes reduction and referred to inconsistencies in its herbicide's ability to influence in some different stages of life.

CONCLUSIONS

The understanding of the interactions between the herbicides and bio-soil mass including plant parasitic nematodes are important for integrated crop management strategies, where some of them can be used to reduce the population densities of other pests or help in the timing of pest management. Therefore, there is an urgent need to further study these relationships to optimize the use of management strategies.

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الأثار الجانبية لبعض مبيدات الحشائش على نيماتودا تعقد الجذور*Meloidogyne javanica* التي تصيب نباتات الخيار في ظروف الحقل المفتوح

عاطف الصغير

قسم الحيوان الزراعي والنيماتودا , كلية الزراعة , جامعة الازهر بأسيوط , مصر

تهدف هذه الدراسة إلى تقييم الأثار الجانبية لبعض مبيدات الحشائش التجارية والتي تستخدم قبل الزراعة على نيماتودا تعقد الجذور *Meloidogyne javanica*التي تصيب نباتات الخيار في ظروف الحقل المفتوح. أظهرت الدراسة قدرة جميع المبيدات المختبره (بريفار, بنفين , تريفلان , ديفرينول و كوبكس) في الحد معنويا من تطور و زيادة أعداد النيماتودا وبدرجات متفاوتة خلال فترة الإنتاج الاقتصادي للمحصول , حيث أظهر استخدام مركب تريفلان أفضل معدل إنخفاض في أعداد النيماتودا بالتركيز الموصي به في نهاية فترة الإختبار (81.8%) يليه مركب بنفين (80.3%) وصولاً إلى التأثير الأقل والمرتبط بالمركب بريفار (40.1%). ولذلك توصى هذه الدراسة بضرورة مراعاة التأثير غير المتخصص عند تطبيق مبيدات الحشائش على المحيط الحيوي للتربة ومدى إمكانية توظيف هذه الأثار في الحد من النيماتودا كواحده من أهم أمراض النبات.