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Efficacy of plant-soil exposure to electric current against Agrotis ipsilon, Bemisia tabaci and Meloidogyne sp

Asmaa Mansour Al-Hakeem [1*], Mohammed Yousuf S.Ghani [2], Nabil Mustafa AlMallah [2]

[1] AL-Karkh University of Science, College of Science, Department of Microbiology, IRAQ
[2] University of Mosul, College of Agriculture and Forestry, Department of Plant Protection, IRAQ
*Corresponding author: asmaa.mansoor@kus.edu.iq

Abstract

A series of experiments were conducted during the years 2014 and 2016 to evaluate the effect of exposing plant soil to electric current for different periods 2 and 5 min on the black cutworm larvae on tomato, 4 and 8 min on whitefly nymphs on cucumbers and for 5, 10 and 15 min against the second stage juvenile J2 of root-knot nematodes *Meloidogyne* spp. on olive trees. Normal electric current 220V was used directly after irrigation with or without nitrogen fertilization in the case of tomato and cucumber. The results showed that the electric current regardless of the exposure period was highly effective and led to a significant ($P \leq 0.05$) increase in mortality of black cutworm larvae of tomato and white-fly nymphs. The highest numbers of dead larvae were in the fertilization treatment and exposure period of 5 min. No live larvae were recorded in this treatment, which did not differ from the 2 min exposure, but did significantly differ from the control (not exposed to electric current). As for whitefly on cucumber, the highest mean of dead nymphs (48,00 nymphs/leaf) and the lowest number of live ones (13,66) were in the fertilization treatment and 8min exposure to electric current, which differed significantly ($P \leq 0.05$) from all the other treatments. The same treatment resulted in the highest value of dry shoot weight and total leaf area of the cucumber plant compared to other treatments. The results of the laboratory experiment showed that incubation of RKN eggs and J2s in electrified water led to stopping egg hatching and to the death of most J2s for all periods of exposure (5, 10 or 15 min) compared to the high rate of hatching and vitality of most J2s in untreated water. Similarly, the treatment of olive trees with electric current resulted in a significant decrease ($P \leq 0.05$) in some RKN live males and J2s/100 g soil and a significant increase in the number of dead individuals. Whereas, the highest numbers of active RKN J2s and males and lowest numbers of dead individuals were recorded in the control treatment where the soil of the olive tree was not treated with electrical current.

Keywords: Electrical Shock, black cutworm, whitefly, RKN

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INTRODUCTION

Among the globally spreading insect pests, *Agrotis ipsilon* (Hufn.) it's one of the most important worms spread in the Nineveh Governorate (Al-Jalal, 2005). *Bemisia tabaci* is other pests of widespread economic importance (McKenzie *et al*., 2009). The two insects are characterized by a multiplicity of their food hosts and great harm to.

crops due to the high food binge (Capinera, 2008). The damage of the black cutworm is serious, especially at later ages, unable to climb, which disappears during the day and goes out for feeding at night, cutting the stem of the plant in the area near the surface of the soil (Binning *et al*., 2015). As for the white-fly insect, its damage comes primarily from its transmission of viral diseases (David, 2014) during its continuous feeding by absorbing the succulents of the host plant even during mating and laying eggs. Studies indicate that the white fly transmits at least nine important viral diseases in the Arab region (Al-Mallah and Nabeel, 2018).

The plant nematode is also an important settlement in the soil that attacks the roots of plants and causes economic losses on various crops all over the world (Agrios, 2005). Olive trees are affected by plant nematodes, especially the root-worms *Meloidogyne*, which has been found to cause high losses in affected trees in Iraq (Ismail *et al*., 2019).

For environmental and health reasons related to the use of pesticides in general (Nayana and Ritu, 2017). physical control methods, including electrocution, may provide a suitable alternative to the possibility of their inclusion in the integrated control program. In addition to

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being able to be used as an alternative to chemical pesticides, physical methods are characterized by their limited or little impact on the environment and insects' inability to form resistant strains. as is the case with pesticides (Weintraub and Berlinger, 2004).

The effect of the electric current has been studied in various fields of plant sciences where it was found that electro-shock can be used to stimulate plant growth, increase productivity and improve its quality (Leo, 2013) as well as in protecting plants from insects and diseases (Niamouris and Psirofonia, 2014). This is done by treating seeds, plants, soil, water, and nutrient solutions with the electric field (Al-Kargooli and Alwan, 2016). Although electrical current applications were introduced in the field of pest management, they were often limited to protecting plants from attacking insects inside greenhouses (Matsuda et al, 2011) especially to prevent the entry of whitefly (Takikawa et al, 2015), mosquito control or wood treatment against termite infestation. (Lewis and Haverly, 2001; Ebeling, 1983).

Electrocution against the plant nematode was used for the first time (Daulton and Stokes, 1952) to kill root-knot nematodes in water. An electric current of 200-700Hz was used. The current- voltage, exposure time, or temperature was not mentioned during the experiment. In another study by Lear and Jacob, (1955), it was found that all attempts were unsuccessful in killing J2s and eggs of roots knot nematode *Meloidogyne incognita acrita*.

Stockes and Martin (1954) also mentioned that electrocution does not affect *Meloidogyne javanica* nematodes when exposing a small amount of soil containing nematodes to electrical current. In 1970 Fields and Caveness showed that electrocution of 5v / mm for larvae and 10v / mm for adults resulted in the death of larvae and adults of *Panagrellus redivivus*, juvenile stages of the *Meloidogyne incognita acrita*, while a voltage of 20-60 vdc / mm for 2 seconds stimulated *Meloidogyne* eggs hatching.

Therefore, the current study, which is the first of its kind in the Arab region, aims to evaluate the possibility of using different methods of electric stun and for different exposures in the control of cutworms on tomato, white fly on cucumbers and roots knot nematodes on olive trees in field conditions.

MATERIALS AND METHODS

All experiments were carried out during the years 2014 at the College of Agriculture and Forestry, University of Mosul and 2016 at the College of Agriculture, University of Diyala. The study included laboratory and field tests to evaluate the use of electrical current in controlling three different pests.

The effect of electric current on black cutworm *Agrotis ipsilon* on tomato:

A field infested with *Agrotis ipsilon* was used where tomato seedlings were planted in lines with drip irrigation system in 1/3/2016. A metal wire was buried at a depth of 5 cm below and along the drip tube. After 25 days of planting and confirming the occurrence of plants infection, random plants from affected lines were chosen for electrocution treatments for 2 or 5 minute exposure period with 3 replications per treatment. Electrocution was done immediately after watering after adding nitrogen fertilizer, or not adding fertilizer while plants not exposed to electrical current served as control treatment. The results were taken after 24 hours of treatment for 5 infected random plants from each repeater and the number of live and dead larvae was calculated.

The effect of electrocution in *Bemesia tabaci* on cucumber plants:

Cucumber seeds were planted on 1/3/2016 in the same way with tomato plants. After the plants reached the branching stage (height 15-20 cm) and making sure that the pest of the white fly insect was present on the leaves, the electrocution was carried out in the same previous method, but the exposure periods 4 and 8 minutes for each treatment. Data were taken on the basis of the effect of preparing nymphs on five infected plants for each line (repeated) and five infected leaves from each plant after 24 hours of treatment. Samples were brought in polyethylene bags to the laboratory. The number of living and dead nymphs was calculated by direct examination of the leaf using the dissection microscope.

At the end of the season, before harvesting, five random option plants were sampled for each treatment from each experimental unit to calculate the dry weight and leafy area of the plant (Al-Habar et al. 2013; Al-Sahhaf et al. 2011).

The effect of electrocution in controlling root-knot nematodes on olive trees:

The laboratory part included testing the effect of electrocution on egg hatching and the vitality of second-stage juveniles (J2s) of *Meloidogyne* spp.

Samples were collected from the roots of the olive trees infected with root complications, they were washed thoroughly with running water and eggs were collected under the dissection microscope. The egg suspension was prepared from collecting egg masses in 50 ml beaker containing sodium hypochlorite 0.5% concentration with constant stirring for 3 minutes after pouring the suspension in a 20 micron sieve, wash with a slight stream of water for two minutes then collect in 50 ml beaker using distilled water (Stetine et al. 1997). A quantity of egg sprouts was taken to incubate the newly hatched juvenile suspension after placing it in the incubator at a temperature of 30 ± 2 ° C (Bird and Wallace, 1965). After completing the hatching, the suspension was prepared to contain 35 ± 5.

Table 1. Effect of electric current exposure period and fertilization on number of black cutworm larvae on tomato 24 hours post treatment

Mortality of Black cutworm			
Treatment	Electricity exposing period (min)	No. of dead larvae	No. of live larvae
Fertilized	0	0.0 d	8.33 a
	2	4.00 ab	0.66 b
	5	6.33 a	0.00 b
Unfertilized	0	0.0 d	9.00 a
	2	1.66 cd	1.00 b
	5	3.66 bc	0.33 b

Table 2. Effect of electric current exposure period and fertilization on number of white fly nymphs on cucumber and some growth parameters

Whitefly viability				Plant growth parameters	
Treatment	Electricity exposing period (min)	No. of dead nymph	No. of live nymph	Leaf area Cm^2	Shoot dry weight g/plant
Fertilized	0	0.00 d	97.6 a	832 d	64.33 c
	4	31.33 b	32.0 c	1224.0 b	91.66 a
	8	48.0 a	13.6 d	1277.0 a	94.66 a
Unfertilized	0	0.00 d	92.3 a	861.3 d	67.33 c
	4	16.3 c	41.66 b	1177.0 c	83.00 b
	8	31.0 b	27.66 c	1202 b	90.00 a

RESULTS AND DISCUSSION

The results showed that exposing tomato plants to electric current for different periods led to a variation in the numbers of dead and live larvae of the black cutworm, according to the different fertilization factors and periods of electric shock exposure (**Table 1**). The highest number of dead larvae was recorded in the presence of nitrogen fertilizer and a 5-minute exposure period, which was 6.33 larvae, with a significant difference from the number of dead larvae 3.66 larvae in the absence of fertilization and for the same period of exposure to electric current. Whereas, the lowest number of dead larvae was (1,667 larvae) recorded in non-fertilized plants after 2 min exposure period. Generally, the number of live larvae was significantly higher in the control treatment, which was not exposed to electric current regardless of fertilization.

Similarly, the results of the exposure test of cucumber plants against the whitefly insect (**Table 2**). Fertilization resulted in an increase in the effect of the electric current on the number of dead nymphs, which differed significantly in the presence of fertilization and the exposure period 4 minutes, compared with no fertilization and in the same exposure period. Generally, the highest rates of the number of dead nymphs were recorded in plants exposed to electrical current for 8 minutes in the presence of nitrogen fertilizer with a significant difference from that of non-fertilizing.

The same treatment resulted in reducing the number of live nymphs to 13.6 compared to 97.6 nymphs on leaves of plants not exposed to electric current (**Table 2**). The mortality of the black cutworm larvae on tomato and white fly nymphs on cucumber plants is mostly due to the direct effect of electric current which leads to dryness of insect bodies and death as results of stopping feeding. These findings were similar to the results of previous studies were using the electric current was effective in controlling insect pests on different crops (Niamouris and Psirofonia, 2014; Takikawa et al., 2015). The nitrogen fertilization on the other hand, increased the effectiveness of electric current against different stages of insects. This is undoubtedly due to the properties of these fertilizers, which are known to increase the electrical conductivity of EC for the soils added to (Naseem et al., 2019) especially when maintaining high humidity resulting in higher electrical conductivity and consequently much higher effect on the effect on insect pests.

The results (**Table 2**) also indicate that the treatment with electric current, regardless of the presence of fertilizer, indicates a significant increase in the average leafy area and dry weight of the cucumber plant compared to the treatment exposed to the electric current. Whereas, the highest increase in leaf area and shoot DW were recorded in the combined treatment of nitrogen fertilization and 8min exposure to electrical current. The results of the study agreed with Hussein (2009), which indicated the possibility of increasing the leafy area of chrysanthemum plants by introducing them to electric current. This is consistent with previous studies where exposing plants to electrical current for certain times and periods leading to improved growth characteristics (Leo, 2013; Al-Kargooli and Alwan, 2016).

The results of the laboratory experiment indicated that the exposure of water to electric current had an effect on egg hatching and the vitality of young worms of complexity (**Table 3**). The highest number of live J2s was recorded in the control treatment of non-electrified water regardless of the incubation period. Whereas, the lowest number of active J2s, ranging from 0 to 2, was recorded in dishes containing electrified water. The duration of the current exposure did not differ among each other in the number of active J2s. The reason for the death of the juveniles is due to their presence in the aqueous medium, which is highly conductive to the

Table 3. Effect of exposure period to electric current on RKN in vitro J2s viability and eggs hatchability and in vivo number of active J2s and males in soil of olive trees roots

Exposure period to electric current (min)	Laboratory experiment							Field experiment (Olive orchard)	
	No. of active J2/35±5			No. of hatched eggs/50±7				No. of J2 and males/100g soil	
	30 min	60 min	24 h	Day 1	Day 2	Day 4	Day6	Live	Dead
0	30 [a]	30 [a]	28 [a]	0	3 [c]	25.6[b]	43 [a]	130 [a]	1.3 [d]
5	2[b]	0 [b]	0 [b]	0	0 [c]	2 [c]	1 [c]	49 [d]	56.3 [c]
10	0 [b]	0 [b]	0 [b]	0	0 [c]	0 [c]	0 [c]	42.6 [d]	70 [b]
15	0 b	0 b	0 b	0	0 c	0 c	0 c	27.6 e	81.6 a

electric current. This electrical environment affected the vital activities of the nematode, leading to paralyzing their movement and thus death.

The effects of exposure to the electric current on the number of hatching eggs of root nematode complexes (**Table 3**). The results showed that all periods of exposure 5, 10 and 15 minutes of electric current did not differ between them and often resulted in a complete cessation of hatching. Whereas, the control treatment for the eggs of complex worms in non-electrified water had a high hatching rate with an increase in the incubation period, especially on the fourth day (25.6) and the sixth day is (43) and with a significant difference from the rest of the treatments. It appears from the results that the increased exposure period led to the killing of larvae inside the eggs or contributed to stopping their vital activities towards hatching (Fields and Caveness, 1970) In case of the field experiment, the results also showed that electric current affected the viability of RKN J2s and males associated with the roots of olive trees (**Table 3**). The highest number of J2s and males (130/100gm soil) was recorded in the soil of olive trees not treated by electrical current (control). While exposing the trees to the electric current for a period of 5 and 10 minutes resulted in a significant decrease in the number of juveniles and live males/100g soil which was 49 and 42.6 respectively. The 15 minutes exposure to electric current significantly resulted in the lowest number (27.6 J2 and male/100g soil) and the highest number of dead J2 and male (81.6).

The low efficacy of the electric current against J2s of RKN in previous studies (Stockes and Martin, 1954) may often be attributed to the field conditions upon treatment (Naseem *et al.*, 2019). In this study, the irrigation of the orchard was by the drip method, which provided a high moisture level and consequently a high-intensity electrical conduction, which led to the killing of large numbers of juveniles and males in the soil.

Exposing plants to electrical current in an accurate and thoughtful way generally helps to improve plant growth and productivity. Also, reducing plant parasitic nematodes population that associated with plants' roots will inevitably reduce the severity of infection and improve plant health (Timper et al, 2006; Ewaid; et.al 2019).

CONCLUSION

This study showed the efficiency of using electric current against insect pests black cutworm Agrotis ipsilon in Lepidoptera, whitefly Bemisia tabaci in Hemiptera and Root-knot nematodes Meloidogyne spp. which are among the important non-insect animal pests that attack the roots of many plants of economic importance. The results showed that the effect of electric current against pests under study increased in the presence of nitrogen fertilizer and high moisture content. Using an electric current as soil application in the rhizosphere zone of the plant did not affect plant vitality, but rather increased the growth indicators in the treated plants. The method used in our study is a very promising method in the field of using electric current to control pests and exceeded that negative impact on the plant in previous studies as for examples:

1-In a preliminary study of the effect of electric current in controlling the various stages of the red palm weevil Rhynchophorus ferrugineus, Niamouris & Psirofonia (2014) was mentioned this is the first time electric current is tested in date palms as a method to control an insect. But at the same time it pointed out several negative aspects or problems that must be solved in the future, including:

a-The death of half of the treated palm trees by electrocution due to adding water to the trees.

b-The very weak effect of the electrocution on insect adults compared to other incomplete stages, which are due to a cutical insect adult.

c-The necessity of conducting other studies using the forces and frequencies of the electrical current to determine the most appropriate ones, as well as the method itself, i.e. tree perforation and the method used

2- Four patented methods of controlling insects with electricity

a. US3826035
b. KR20100138535
c. JP2004141127
d. JPS53127173.

All of the above have major differences with the method described earlier in the paper and to our knowledge have not yielded any fruitful results.

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