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# ORIGINAL ARTICLES

## Impact of two bio-products on *Meloidogyne javanica* and their influence on yield components of some sugar beet varieties

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**ABSTRACT**

Two experiments were carried out throughout 2010/2011 and 2011/2012 seasons at Nubariya region,Behera governorate, Egypt (Latitude = 30°37'33.43"N, Longitude = 30° 2'2.49"E), to evaluate five of sugar beet cultivars, viz., AS0081, AS0082, HN627, SN626 and Ravel to infection with *Meloidogyne javanica* under naturally field infection. Host susceptibility rating revealed that sugar beet varieties AS0081, AS0082, HN627 and SN626 can be considered as susceptible varieties, while the variety of Ravel can be considered as highly susceptible one. These results may be due to variance in gene make-up of the tested varieties. Therefore, the effect of two commercial bio-products namely Fornem x5® and Pacile-Bio-Nematicide® for controlling *M. javanica* infesting five sugar beet varieties, compared to Nemacur® under *in vitro* and field conditions were studied. *In vitro*, the mortalities of *M. javanica* juveniles rated from 94 to 98 % at using bio-control products, compared to 96% with Nemacur®. In the field, all treatments greatly reduced the number of galls on the roots of five sugar beet varieties which recorded at 2, 4 and 6 months after sowing. The Ravel variety was attained highly percentages of gall reduction at using Pacile-Bio-Nematicide® (89.5 and 82.6 %) after 6 months during 2010/2011 and 2011/2012seasons, respectively. Plant growth components, viz. foliage weight, root length, root diameter, root weight and root yield, significantly increased in treated plots compared to untreated plots. Also, the treatments affected sucrose content, purity of roots and sugar yield. These results suggest the possibility of using the bio-nematicides in controlling root-knot nematode as an alternative of environmental friendly materials to decrease pollution resulted from using chemicals.

***Key words:*** *Meloidogyne javanica*, sugar beet, varieties, bio- products, growth and yield components.

### Introduction

Sugar beet (*Beta vulgaris* L.) is considered one of the most important winter crops and the 2nd source for sugar production after sugar cane and produce 28 % of sugar in Egypt. The root-knot nematodes, *Meloidogyne* spp. are economically important pests that affected sugar beet (Altman & Thomson, 1971 and Gohar & Maareg, 2005). Reduction of crop losses due to nematodes is one way of increasing crop yield. Host plant resistance to root-knot nematode, therefore, may be the most environmentally safe means to alleviate sugar beet production problems, but, the true that resistant sugar beet varieties to root-knot nematodes is still hard to pin down. El-Nagdi *et al*. (2004) classified some sugar beet varieties into susceptible, highly susceptible, resistant and moderately resistant to infection with *M. incognita* depending on the combination between host vigor and root damage index. Saleh *et al.* (2009) tested twenty seven sugar beet genotypes including 21 commercial varieties and 6 breeding against *M. javanica*. They found one commercial variety was highly susceptible (HS), nine genotypes were susceptible (S), thirteen genotypes were moderate resistant (MR), and four genotypes were resistant (R). Besides, nematicides due to their high costs, toxic effect on beneficial soil borne microorganisms and carcinogenic effect on human beings, alternative approaches were practiced mainly through environment-friendly means like biological control agents (Maareg & Badr, 2000, Youssef *et al*., 2008, El-Nagdi *et al*., 2011 and Abd El Fattah *et al*., 2012) against root-knot nematodes on sugar beet to minimize the environmental pollution and to keep the management processes more economical. So, this work is aimed to evaluate the reaction of five sugar beet varieties to infection with the root-knot-nematode, *Meloidogyne javanica* and role of Fornem x5® and Pacile-Bio-Nematicide® as commercial bio-products for controlling *M. javanica*, compared to the chemical nematicide (Nemacur®) and improvement of yield components.

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**Materials and Methods**

*1. Sugar beet genotypes:*

Four sugar beet varieties (*Beta vulgaris* L.) viz., AS0081, AS0082, HN627, SN626 as monogerm varieties and another variety namely Ravel as multigerm variety were used in this study. All sugar beet varieties imported from Netherlands.

*2. The root -knot nematode:*

Females of *Meloidogyne javanica* were isolated from infested sugar beet roots collected from Nobariya district**.** Cultures of this nematode were established from single egg-masses that had previously been identified according to the morphological characteristics of the perineal patterns of the adult females as described by Eisenback *et al*. (1980). The nematode was reared on eggplant cv. Pusa Purple long in a glass-house at 30 ± 5 ºC. Second stage juveniles ($J_2$) of *M. javanica* were extracted from these cultures by incubating infected roots in water for three days at 30 ± 5 ºC and then hatched $J_2$ were collected and counted.

*3. Bio-products:*

Two commercial bio-products i.e. Fornem x5® (containing some bacterial strains i.e. *Rhodotorula pustula* at $2X10^3$cuf/ml, *Serratia entomophila* at $6x10^3$ cuf/ ml, *Serratia marcescens* at $9x10^8$cuf/ml, *Pseudomonas fluorescens* at $3x10^5$cuf/ml and *Pseudomonas putida* at $3x10^3$ cuf/ml) and Pacile-Bio-Nematicide® (containing the fungi of *Arthrobotrys* sp. and *Paecilomyces* sp.) were tested as aqueous concentrations at 1 and 2% against *M. javanica* juveniles comparison with the commercial chemical nematicide, Nemacur ® (fenamiphos) 10G [3-methyl -4- (methylthio) phenyl (1-methylethyl) phosphoramidate] at concentration of 1.25 ppm of suspended water.

*4. In vitro experiment:*

This experiment consists of six treatments as following:
1- Nine ml of Fornem x5® at 1 % concentration.
2- Nine ml of Fornem x5® at 2% concentration.
3- Nine ml of Pacile-Bio-Nematicide® at 1% concentration.
4- Nine ml of Pacile-Bio-Nematicide® at 2% concentration.
5- Nine ml of Nemacur ® 1.25ppm concentration.
6- Nine ml of distilled water (control).

To find out the relative importance of the above mentioned treatments on *Meloidogyne javanica,* one ml of a nematode suspension containing 500 $J_2$ of *M. javanica* was added to each treatment in a 50 ml plastic capsule and another treatment including distilled water to serve as a nematode only control. Each treatment was replicated five times in a completely randomized design. Numbers of viable and dead juveniles were counted under a light microscope after 24, 48 and 72 h exposure periods at 25 °C. Nematodes were considered alive if they moved or assumed a winding shape and dead if they were straight and immobile. After the various exposure periods the nematodes in each treatment were transferred to distilled water and left for 24 h to see whether immobile nematodes resumed activity or not. The corrected percentages of nematode mortality were calculated according to Abbott's formula (Abbott, 1925):

$$\text{Mortality (\%)} = (m - n)/ (100 - n) \times 100$$

Where *m* and *n* indicate the percentages of mortality in treatments and control, respectively.

*5. Field Experiment:*

Two field experiments were conducted during 2010/2011 and 2011/2012 seasons at Nubariya region, Behera governorate, Egypt (Latitude = 30°37'33.43"N, Longitude = 30° 2'2.49"E), naturally infected with *Meloidogyne javanica* under for irrigations an overhead sprinklers. Soil of the experimental sites was loamy sand soil and non-saline, non-sodic, alkaline in reaction and had low organic matter, phosphorus (P) and nitrogen (N) contents**.** Soil analysis of the experimental site are given in the Table (1).

**Table 1:** Soil analysis of the experimental sites over the two seasons.

| Characteristic | Unit | Value |
|---|---|---|
| Soil texture | -- | Loamy sand |
| EC | dS $m^{-1}$ | 0.86 |
| pH | -- | 8.01 |
| Organic Matter | % | 0.67 |
| P | mg $kg^{-1}$ | 5.10 |
| K | mg $kg^{-1}$ | 89.00 |
| NO3-N | mg $kg^{-1}$ | 0.31 |

*Experimental field's treatments:*

Each trait consists of twenty treatments which represent the combination between five sugar beet varieties and two commercial bio-products comparing to nematicide and control (untreated) as follows:

1- Fornem x5® at 5 liter/ 100 liter water /fed.
2- Pacile-Bio-Nematicide® at 5 liter/ 100 liter water /fed.
3- Nemacur ® at 10 kg /fed.
4- Tap water (control)

Each plot was 3 m wide × 3.5 m long (= 10.5 $m^2$ = 1/400 fadden). Treatments were replicated three times and arranged in a randomized completely block design. Seeds of five sugar beet varieties were sown on the 1st week of October in each experiment at a spacing to provide the normal density of 40,000 plants/fed. All other agricultural practices for growing sugar beet crop were done as recommended by Sugar Crops Research Institute, Egypt.

*Data collected:*

*5.1.Nematode parameters:*

Nematode parameters of *M. javanica* i.e. numbers of galls and % reduction of galls on the roots of five sugar beet varieties were recorded at 2, 4 and 6 months after sowing. While, root gall index (GI), gall size (GS), extent of galled area of root (GA) and root damage index (DI) also were estimated to all tested sugar beet varieties after six months according to Sharma *et al.*, (1994).The damage index (DI) was calculated by dividing the sum of GI, GS and GA by 3 and then, DI rated into different values as follows: susceptible (5.1-7) and highly susceptible (7.1-9).

*5.2. Plant growth parameters:*

Plant growth parameters of each sugar beet variety such as foliage weight, root length, diameter and weight of root, in addition to root yield were recorded at harvest time.

*5.3. Technological parameters:*

Sucrose (S %) was recorded according to Le-Docte (1927), total soluble solids (TSS %) by using hand refractometer, while Juice purity (%) was determined as a ratio between S% and TSS% according to Carruthers & Oldfield (1961) in fresh weight of roots of all tested sugar beet varieties.

*6. Statistical analysis:*

Data were subjected to analysis of variance using Computer Statistical Package (CO-STATE) User Manual Version 3.03, Barkley Co., USA and the means were compared by the Least Significant Difference (LSD) test at $P = 0.05$ level of significance according to Snedecor & Cochran (1980).

*Results:*

*1. Effect of two commercial bio-products on Meloidogyne javanica, in vitro:*

The net mortality of *M. javanica* treated by Fornem x5® and Pacile-Bio-Nematicide® ranged from 94 to 98%, compared to Nemacur® (96 %) as in Table 2. Fornem x5® and Pacile-Bio Nematicide® were increased the mortality of the nematode after 24, 48 and 72 h from the exposure time, as compared to the control (Table, 2). The greatest mortality has already been after 72 hours of exposure. The nematode mortality increased with increasing of bio-product concentration.. This observation was completely true for the two commercial bio-

products, it is also cleared that the 2nd concentration of the bio-products, attained slightly effect than 1st concentrations.

**Table 2:** Effect of Fornem x5® and Pacile-Bio-Nematicide® on the mortality of second-stage juveniles of *Meloidogyne javanica* in vitro test.

| Treatment | | % nematode mortality after hours | | | Recovery (%) | Net mortality (%) |
|---|---|---|---|---|---|---|
| Product and nematicide | Concentration | 24 | 48 | 72 | | |
| Fornem x5® | 1 % | 91 | 94 | 97 | 0 | 97 |
| | 2 % | 95 | 96 | 98 | 0 | 98 |
| Pacile-Bio-Nematicide® | 1 % | 86 | 91 | 94 | 0 | 94 |
| | 2 % | 90 | 93 | 95 | 0 | 95 |
| Nemacur® | 1.25 ppm | 95 | 96 | 96 | 0 | 96 |
| Distilled water (control) | - | 0 | 0 | 0 | 0 | 0 |

*2-Field experiment:*

*2.1. Reaction of sugar beet varieties to Meloidogyne javanica infection:*

Reaction of the tested five sugar beet varieties to infection by root-knot nematode, *M. javanica*, as the number of galls as well as gall index (GI), gall size (GS), gall area (GA) and damage index (DI) after 6 months from sowing under field conditions during 2010/2011 and 2011/2012 seasons, are shown in Table (3).The GI values were ranged of 6 to 8 and from 5 to 8 in two seasons of 2010/2011 and 2011/2012, respectively (Table, 3).Also, the values of GS and GA were the same trend. The DI values were ranged of 5.3 to 8.7 in two seasons (Table, 3) , while AS0081 and HN627 varieties gave the lowest value (5.3) in the second season only. The variety of Ravel sustained the highest value about 8.7 in the two seasons. Results of host susceptibility rating revealed that the varieties AS0081, AS0082, HN627and SN626 had rated as susceptible (S) to *M. javanica* infection, while the variety of Ravel had highly susceptible (H.S) one (Table, 3).

**Table 3:** Relative susceptibility of some sugar beet varieties for *Meloidogyne javanica* during 2010/2011 and 2011/2012 seasons under field conditions.

| Sugar beet varieties | Seasons | No. of galls | Gall index (GI) | Gall size (GS) | Gall area (GA) | Damage index (DI) | Host susceptibility rating |
|---|---|---|---|---|---|---|---|
| AS0081 | 2010/2011 | 39 | 6 | 5 | 7 | 6.0 | susceptible |
| | 2011/2012 | 34 | 6 | 5 | 5 | 5.3 | susceptible |
| AS0082 | 2010/2011 | 35 | 6 | 5 | 5 | 5.3 | susceptible |
| | 2011/2012 | 30 | 5 | 5 | 5 | 5.3 | susceptible |
| HN627 | 2010/2011 | 38 | 6 | 5 | 7 | 6.0 | susceptible |
| | 2011/2012 | 34 | 6 | 5 | 5 | 5.3 | susceptible |
| Ravel | 2010/2011 | 86 | 8 | 9 | 9 | 8.7 | highly susceptible |
| | 2011/2012 | 92 | 8 | 9 | 9 | 8.7 | highly susceptible |
| SN626 | 2010/2011 | 41 | 6 | 7 | 7 | 6.7 | susceptible |
| | 2011/2012 | 40 | 6 | 7 | 5 | 6.0 | susceptible |

*2.2-Effect of two bio-control products and nematicide on sugar beet root galling:*

Results gives in Table (4) indicated that all treatments including Fornem x5® and Pacile-Bio-Nematicide® as well as Nemacur® significantly reduced ($P \leq 0.05$) the number of galls compared to check treatment (control). After 2 months of sowing, the number of galls ranged from 2- 4 galls/plant and 2-5 galls/plant at using two bio-control products, compared to 4-26 galls/plant and 4- 29 galls/plant with control in 2010/2011and 2011/2012seasons, respectively (Tables, 4 & 5). The number of gall was highly reduced at using Pacile-Bio-Nematicide® (92.3%) in Ravel variety, followed by SN626 variety with Fornem x5® and Pacile-Bio-Nematicide® (85.7 %) in season 2010/2011 (Table, 4). While, gall reduction (%) was highly recorded in SN626 variety with Fornem x5® (91.3%), followed by Ravel variety with Pacile-Bio-Nematicide® and Nemacur® (89.7%), respectively in season 2011/2012 (Table, 5). After 4 months of sowing, the number of galls was ranged of 6 -11 galls/plant and 8 -11 galls/plant with bio-control agents, compared to 9-39 galls and 14- 40 galls which recorded with untreated plots in seasons 2010/2011 and 2011/2012, respectively (Tables 4 and 5). The percentages of galls reduction were high at using Fornem x5® (84.6%) in Ravel variety followed by Nemacur® then Pacile-Bio-Nematicide in the first season (Table, 4). In second season, the Ravel variety also achieve the same highly percentages of gall reduction at using Fornem x5®, Pacile-Bio-Nematicide® and Nemacur® treatments (75.0%).

After 6 months of sowing,the number of galls was ranged of 9-20 galls/plant and 15-21 galls/plant with bio-control agents, compared to 35-86 galls and 34-92 galls with untreated plots in seasons 2010/2011 and 2011/2012, respectively (Tables, 4& 5). The Ravel variety was highly percentages of gall reduction with Pacile-

Bio-Nematicide® (89.5 and 82.6 %), followed by Nemacur® then Fornem x5® in 2010/2011 and 2011/2012 seasons, respectively.

**Table 4:** Effect of Fornem x5® and Pacile-Bio-Nematicide® on number of galls of *Meloidogyne javanica* infested five sugar beet varieties at 2, 4 and 6 months after field application the 1st season.

| Sugar beet varieties (V) | Months (M) | Fornem x5® | | Pacile-Bio-Nematicide® | | Nemacur® | | Control (untreated) |
|---|---|---|---|---|---|---|---|---|
| | | No. of galls | % Reduction | No. of galls | % Reduction | No. of galls | % Reduction | |
| AS0081 | 2 | 3 | 25.0 | 3 | 35.0 | 4 | 0.0 | 4 |
| | 4 | 8 | 11.1 | 9 | 0.0 | 8 | 11.0 | 9 |
| | 6 | 13 | 66.7 | 14 | 64.1 | 10 | 74.4 | 39 |
| Mean | | 8 | | 9 | | 7 | | 17 |
| AS0082 | 2 | 3 | 62.5 | 2 | 75.0 | 4 | 50.0 | 8 |
| | 4 | 11 | 47.6 | 9 | 57.1 | 8 | 61.9 | 21 |
| | 6 | 20 | 42.9 | 12 | 65.7 | 13 | 62.9 | 35 |
| Mean | | 11 | | 8 | | 8 | | 21 |
| HN627 | 2 | 2 | 77.8 | 3 | 66.7 | 2 | 77.8 | 9 |
| | 4 | 8 | 42.9 | 7 | 50.0 | 5 | 64.3 | 14 |
| | 6 | 15 | 60.5 | 11 | 71.1 | 14 | 63.2 | 38 |
| Mean | | 8 | | 7 | | 7 | | 20 |
| Ravel | 2 | 4 | 84.6 | 2 | 92.3 | 3 | 88.5 | 26 |
| | 4 | 9 | 76.9 | 6 | 84.6 | 8 | 79.5 | 39 |
| | 6 | 20 | 76.7 | 9 | 89.5 | 20 | 76.7 | 86 |
| Mean | | 11 | | 6 | | 10 | | 50 |
| SN626 | 2 | 3 | 85.7 | 3 | 85.7 | 4 | 80.9 | 21 |
| | 4 | 7 | 76.7 | 8 | 73.3 | 7 | 76.7 | 30 |
| | 6 | 12 | 70.7 | 13 | 68.3 | 10 | 75.6 | 41 |
| Mean | | 7 | | 8 | | 7 | | 31 |
| L SD at 0.05% | | | | | | | | |
| Month (M) | | = 1.14 | | MV | | =2.51 | | |
| Treatment (T) | | =1.30 | | TV | | =2,90 | | |
| Variety (V) | | =1.45 | | MTV | | =5.03 | | |
| MT | | =2.25 | | | | | | |

**Table 5:** Effect of Fornem x5® andPacile-Bio-Nematicide® on number of galls of *Meloidogyne javanica* infested five sugar beet varieties at 2, 4 and 6 months after field application in the 2nd season.

| Sugar beet varieties (V) | Months (M) | Fornem x5® | | Pacile-Bio-Nematicide® | | Nemacur® | | Control (untreated) |
|---|---|---|---|---|---|---|---|---|
| | | No. of galls | % Reduction | No. of galls | % Reduction | No. of galls | % Reduction | |
| AS0081 | 2 | 2 | 50.0 | 3 | 25.0 | 3 | 25.0 | 4 |
| | 4 | 8 | 42.9 | 10 | 28.6 | 10 | 28.6 | 14 |
| | 6 | 18 | 47.1 | 18 | 47.1 | 19 | 44.1 | 34 |
| Mean | | 9 | | 10 | | 11 | | 17 |
| AS0082 | 2 | 2 | 80.0 | 2 | 80.0 | 3 | 70.0 | 10 |
| | 4 | 9 | 52.6 | 9 | 52.6 | 9 | 52.6 | 19 |
| | 6 | 17 | 43.3 | 17 | 43.3 | 17 | 43.3 | 30 |
| Mean | | 9 | | 9 | | 10 | | 20 |
| HN627 | 2 | 2 | 81.8 | 3 | 72.7 | 3 | 72.7 | 11 |
| | 4 | 11 | 42.1 | 8 | 57.9 | 8 | 57.9 | 19 |
| | 6 | 17 | 50.0 | 15 | 55.9 | 18 | 47.1 | 34 |
| Mean | | 10 | | 9 | | 10 | | 21 |
| Ravel | 2 | 5 | 82.8 | 3 | 89.7 | 3 | 89.7 | 29 |
| | 4 | 10 | 75.0 | 10 | 75.0 | 10 | 75.0 | 40 |
| | 6 | 21 | 77.2 | 16 | 82.6 | 20 | 78.3 | 92 |
| Mean | | 12 | | 10 | | 11 | | 53 |
| SN626 | 2 | 2 | 91.3 | 4 | 82.6 | 4 | 82.6 | 23 |
| | 4 | 10 | 68.8 | 11 | 65.6 | 10 | 68.8 | 32 |
| | 6 | 18 | 55.0 | 16 | 60.0 | 18 | 55.0 | 40 |
| Mean | | 10 | | 10 | | 11 | | 32 |
| LSD at 0.05 | | | | | | | | |
| Month (M) | | =2.04 | | MV | | =4.55 | | |
| Treatment (T) | | =2.35 | | TV | | =5.25 | | |
| Variety (V) | | =2.63 | | MTV | | =9.10 | | |
| MT | | =4.07 | | | | | | |

*2.3-Effect on plant growth:*

Plant growth components, viz. foliage weight (g), root length (cm), root diameter (cm), root weight (g) and root yield (Ton/Fadden), significantly increased in treated plots compared to untreated plots (Tables, 6-10).

**Table 6:** Effect of Fornem x5® and Pacile-Bio-Nematicide® on foliage weight (g/plant) of five sugar beet varieties infested with *Meloidogyne javanica* throughout 2010/2011 & 2011/2012 seasons.

| Sugar beet varieties (V) | Season 2010/2011 | | | | Mean |
|---|---|---|---|---|---|
| | Fornem x 5 | Pacile-Bio-Nematicide | Nemacur® | Control (untreated) | |
| AS0081 | 407.3 | 473.3 | 533.0 | 449.3 | 465.7 |
| AS0082 | 343.3 | 420.3 | 348.2 | 409.7 | 380.4 |
| HN627 | 277.3 | 420.7 | 353.0 | 302.3 | 338.3 |
| Ravel | 399.7 | 515.7 | 424.7 | 403.3 | 435.8 |
| SN626 | 397.7 | 407.7 | 361.3 | 515.0 | 420.4 |
| Mean | 365.1 | 447.5 | 404.0 | 415.9 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | 107.1 |
| Treatment (T) | | | | | N.S. |
| V x T | | | | | N.S. |

| | Season 2011/2012 | | | | |
|---|---|---|---|---|---|
| AS0081 | 600.7 | 562.7 | 431.3 | 431.7 | 506.6 |
| AS0082 | 431.0 | 380.0 | 461.3 | 320.3 | 398.2 |
| HN627 | 411.3 | 444.3 | 410.3 | 334.0 | 400.0 |
| Ravel | 527.0 | 534.3 | 511.7 | 333.7 | 476.7 |
| SN626 | 501.0 | 456.0 | 406.3 | 322.0 | 421.3 |
| Mean | 494.2 | 475.5 | 444.2 | 348.3 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | 80.78 |
| Treatment (T) | | | | | 82.82 |
| V x T | | | | | N.S. |

**Table 7:** Effect of Fornem x5® and Pacile-Bio-Nematicide® on root length (cm/plant) of five sugar beet varieties infested with *Meloidogyne javanica* throughout 2010/2011 & 2011/2012 seasons.

| Sugar beet varieties (V) | Season 2010/2011 | | | | Mean |
|---|---|---|---|---|---|
| | Fornem x 5 | Pacile-Bio-Nematicide | Nemacur® | Control (untreated) | |
| AS0081 | 30.7 | 30.7 | 30.7 | 30.7 | 30.7 |
| AS0082 | 27.7 | 30.0 | 28.6 | 30.7 | 29.2 |
| HN627 | 28.0 | 31.0 | 29.3 | 28.3 | 29.2 |
| Ravel | 28.5 | 31.1 | 31.7 | 29.7 | 30.3 |
| SN626 | 28.0 | 32.0 | 30.7 | 31.3 | 30.5 |
| Mean | 28.5 | 31.1 | 30.2 | 30.1 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | N.S. |
| Treatment (T) | | | | | 2.33 |
| V x T | | | | | N.S. |

| | Season 2011/2012 | | | | |
|---|---|---|---|---|---|
| AS0081 | 32.0 | 31.7 | 33.0 | 28.0 | 31.2 |
| AS0082 | 28.7 | 32.3 | 30.7 | 31.0 | 30.7 |
| HN627 | 30.7 | 31.3 | 31.7 | 25.3 | 29.8 |
| Ravel | 32.7 | 30.7 | 32.3 | 27.7 | 30.8 |
| SN626 | 30.0 | 32.0 | 32.7 | 28.3 | 30.8 |
| Mean | 30.8 | 31.6 | 32.1 | 28.1 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | N.S. |
| Treatment (T) | | | | | 2.09 |
| V x T | | | | | 3.19 |

*2.3.1. Foliage weight/ plant:*

Results given in Table (6) pointed out that foliage weight of sugar beet plants significantly affected ($P \leq 0.05$) by the examined varieties, and their values ranged from 338.3 g/plant to 465.7 g/plant in the first season and from 398.2 to 506.6 g/plant in the second season, where the AS0081 variety attained highly foliage weight in the two seasons (Table, 6). These results may be due to variance in gene make-up of the tested varieties. Concerning bio-nematicide treatments and its influence on foliage weight, it is obviously notice that there was a significant difference between bio-nematicide treatments in the 2nd season only. The maximum value of foliage weight was achieved at using Pacile-Bio-Nematicide® on Ravel variety (515.7 g/plant) and AS0081 variety at using Fornem x5® product (600.7g/plant) in two seasons 2010/2011 and 2011/2012, respectively.

*2.3.2. Root length:*

Data obtained in Table (7) showed that the root length of sugar beet plants insignificantly affected under the studied sugar beet varieties. The average of root length of sugar beet varieties ranged from 29.2 to 30.7 cm and 29.8 to 31.2 during 2010/2011 and 2011/2012 seasons, respectively. It could be noted that also, despite of the significant effect of bio-nematicide treatments on root length in the two growing seasons, the interactions between the studied factors i.e varieties and bio-nematicide treatments was insignificantly,. The maximum value of root length was achieved at using SN626 variety with Pacile -Bio-Nematicide®(32cm) and Ravel variety with Fornem x5® (30.7 cm) during 2010/2011 and 2011/2012 seasons, respectively.

**Table 8:** Effect of Fornem x5® and Pacile-Bio-Nematicide®on root diameter of five sugar beet varieties infested with *Meloidogyne javanica* throughout 2010/2011 & 2011/2012 seasons.

| Sugar beet varieties (V) | Season 2010/2011 | | | | Mean |
|---|---|---|---|---|---|
| | Fornem x 5 | Pacile-Bio-Nematicide | Nemacur ® | Control (untreated) | |
| AS0081 | 7.67 | 9.67 | 10.33 | 10.00 | 9.42 |
| AS0082 | 8.33 | 9.00 | 9.11 | 9.33 | 8.94 |
| HN627 | 8.33 | 9.33 | 9.00 | 7.33 | 8.50 |
| Ravel | 8.00 | 9.67 | 10.33 | 9.67 | 9.42 |
| SN626 | 8.67 | 9.33 | 9.33 | 9.67 | 9.25 |
| Mean | 8.20 | 9.40 | 9.62 | 9.20 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | N.S. |
| Treatment (T) | | | | | 1.06 |
| V x T | | | | | N.S. |
| | Season 2011/2012 | | | | |
| AS0081 | 9.00 | 10.33 | 10.67 | 7.67 | 9.42 |
| AS0082 | 10.67 | 10.33 | 11.33 | 8.00 | 10.08 |
| HN627 | 9.00 | 10.00 | 8.67 | 7.33 | 8.75 |
| Ravel | 9.33 | 10.33 | 10.33 | 7.67 | 9.42 |
| SN626 | 10.33 | 10.67 | 9.67 | 8.67 | 9.83 |
| Mean | 9.67 | 10.33 | 10.13 | 7.87 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | 1.10 |
| Treatment (T) | | | | | 1.13 |
| V x T | | | | | N.S. |

**Table 9:** Effect of Fornem x5 ® and Pacile-Bio-Nematicide®on root weight (g/plant) of five sugar beet varieties infested with *Meloidogyne javanica* throughout 2010/2011 & 2011/2012 seasons.

| Sugar beet varieties (V) | Season 2010/2011 | | | | Mean |
|---|---|---|---|---|---|
| | Fornem x 5 | Pacile-Bio-Nematicide | Nemacur ® | Control (untreated) | |
| AS0081 | 887.3 | 885.3 | 884.3 | 795.3 | 863.1 |
| AS0082 | 846.3 | 902.7 | 924.4 | 703.0 | 844.1 |
| HN627 | 777.0 | 806.0 | 834.0 | 553.7 | 742.7 |
| Ravel | 828.3 | 846.3 | 911.7 | 727.7 | 828.5 |
| SN626 | 783.3 | 917.3 | 899.7 | 899.3 | 874.9 |
| Mean | 824.5 | 871.5 | 890.8 | 735.8 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | 101.9 |
| Treatment (T) | | | | | 104.5 |
| V x T | | | | | N.S. |
| | Season 2011/2012 | | | | |
| AS0081 | 927.3 | 829.3 | 988.3 | 826.3 | 892.8 |
| AS0082 | 867.3 | 946.3 | 947.3 | 808.7 | 892.4 |
| HN627 | 796.3 | 887.0 | 823.3 | 435.3 | 735.5 |
| Ravel | 954.7 | 882.3 | 834.7 | 695.3 | 841.8 |
| SN626 | 901.3 | 917.7 | 984.7 | 931.0 | 908.7 |
| Mean | 889.4 | 892.5 | 915.7 | 719.3 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | 98.51 |
| Treatment (T) | | | | | 101.0 |
| V x T | | | | | 154.6 |

*2.3.3. Root diameter:*

Data collected in Table (8) revealed that the root diameter of sugar beet varieties was significantly effected on in the 2nd season only. The average value of root diameter of sugar beet varieties ranged from 8.50 to 9.42 cm and from 8.75 to 10.08 during 2010/2011 and 2011/2012 seasons, respectively. As for the influence of the tested bio-nematicide treatments on root diameter, there was a significant increase ($P \leq 0.05$) in root diameter due to bio-nematicide treatments application in the two seasons. Nemacur® treatment was achieved the highest root

diameter in the 1st season, however, Pacile-Bio-Nematicide® treatment surpassed the other compound in its effect on root diameter. The AS0081 and Ravel varieties were achieved the maximum values of root diameter with Nemacur® (10.33cm) in 2010/2011 season and AS0081, SN626 and AS0082 varieties were recorded the highest values at using Nemacur® (11.33 cm), Pacile-Bio-Nematicide®(10.67cm) and Fornem x5® (10.67cm) in 2011/2012 season.

*2.3.4. Root weight/plant:*

All the tested treatments were significantly increased (P≤ 0.05) root weight of sugar beet varieties as compared to control in the two seasons (Table 9). Concerning bio-nematicide treatments and their influence on root weight/plant, the results in Table (9) demonstrated that Nemacur® surpassed the various bio-nematicide treatments and achieved the highest value. However, it could be noted that the differences between bio-nematicide treatments were insignificantly. The AS0082 variety was achieve the maximum root weight at using Nemacur® (924.4 g), followed by SN626 variety with Pacile-Bio-Nematicide® (917.3 g) in 2010/2011 season. In the second season AS0081 and SN626 varieties were achieve the maximum root weight with Nemacur® (988.3 and 984.7 g), followed by Ravel variety with Fornem x5® (954.7g).

*2.3.5. Root yield/fed:*

Results given in Table (10) cleared that there was a significant differences (P≤ 0.05) between the studied varieties with respect to their influence on root yield (tons/fed.).These findings were fairly true in the 2nd season and did not reach the level of significance in the 1st season. The average of root yield of sugar beet varieties were ranged from 24.76 to 29.16 ton/fed. and from 24.52 to 30.29 ton/fed. during 2010/2011 and 2011/2012 seasons, respectively (Table, 10). Sugar beet variety AS0082 was recorded the highest root yield with Nemacur® (30.81 tons/fed.) followed by SN626 variety with Pacile-Bio-Nematicide® (30.58 tons/fed.) in 2010/2011 season. The AS0081 variety was recorded highly root yield with Nemacur® (32.94 tons/fed.) followed by SN626 variety (32.82 tons/fed.) and then Ravel variety with Fornem x5® (31.82 tons/fed.) in 2011/2012 season.

**Table 10:** Effect of Fornem x5® and Pacile-Bio-Nematicide®on root yield (tons/fed.) of five sugar beet varieties infested with *Meloidogyne javanica* throughout 2010/2011 & 2011/2012 seasons.

| Sugar beet varieties (V) | Season 2010/2011 | | | | Mean |
|---|---|---|---|---|---|
| | Fornem x 5 | Pacile-Bio-Nematicide | Nemacur ® | untreated | |
| AS0081 | 29.58 | 29.51 | 29.48 | 26.51 | 28.77 |
| AS0082 | 28.21 | 30.09 | 30.81 | 23.44 | 28.14 |
| HN627 | 25.90 | 26.87 | 27.80 | 18.46 | 24.76 |
| Ravel | 27.61 | 28.21 | 30.39 | 24.26 | 27.62 |
| SN626 | 26.11 | 30.58 | 29.99 | 29.98 | 29.16 |
| Mean | 27.48 | 29.05 | 29.69 | 24.53 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | 3.40 |
| Treatment (T) | | | | | 3.50 |
| V x T | | | | | N.S. |
| | Season 2011/2012 | | | | |
| AS0081 | 30.91 | 27.65 | 32.94 | 27.54 | 29.76 |
| AS0082 | 28.91 | 31.55 | 31.58 | 26.96 | 29.75 |
| HN627 | 26.55 | 29.57 | 27.45 | 14.51 | 24.52 |
| Ravel | 31.82 | 29.41 | 27.82 | 23.18 | 28.06 |
| SN626 | 30.05 | 30.59 | 32.82 | 27.70 | 30.29 |
| Mean | 29.65 | 29.75 | 30.52 | 23.98 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | 3.28 |
| Treatment (T) | | | | | 3.37 |
| V x T | | | | | 5.15 |

*2.4- The technological parameters:*

The technological parameters revealed that data the tested of sugar beet varieties in terms of sucrose % and purity % are shown in Tables (11&12).

*2.4.1. Sucrose %:*

Values in Table (11) revealed that there was insignificant effect on sucrose percentage within the studied varieties in both seasons. The value of sucrose % significantly affected by nematicide compound in the 1st

season only. As for, the interactions influence between the studied factors, the results obtained revealed that HN627 variety recorded the highest value of sucrose % at using Nemacur® compound.

**Table 11:** Effect of Fornem x5® and Pacile-Bio-Nematicide®on sucrose (%) of five sugar beet varieties infested with *Meloidogyne javanica* throughout 2010/2011 & 2011/2012 seasons.

| Sugar beet varieties (V) | Season 2010/2011 | | | | Mean |
|---|---|---|---|---|---|
| | Fornem x 5 | Pacile-Bio-Nematicide | Nemacur ® | Control (untreated) | |
| AS0081 | 15.73 | 14.24 | 15.78 | 15.29 | 15.26 |
| AS0082 | 15.03 | 13.65 | 15.15 | 16.36 | 15.05 |
| HN627 | 15.56 | 13.54 | 15.67 | 15.83 | 15.15 |
| Ravel | 14.75 | 14.55 | 15.04 | 15.71 | 15.01 |
| SN626 | 14.93 | 15.01 | 15.05 | 14.52 | 14.88 |
| Mean | 15.20 | 14.20 | 15.34 | 15.54 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | N.S. |
| Treatment (T) | | | | | 1.06 |
| V x T | | | | | N.S. |
| | Season 2011/2012 | | | | |
| AS0081 | 15.85 | 14.27 | 16.09 | 15.19 | 15.35 |
| AS0082 | 14.82 | 13.31 | 16.05 | 14.79 | 14.74 |
| HN627 | 13.67 | 14.87 | 16.59 | 14.93 | 15.02 |
| Ravel | 15.64 | 15.09 | 14.45 | 15.63 | 15.20 |
| SN626 | 15.72 | 16.41 | 14.75 | 15.06 | 15.49 |
| Mean | 15.14 | 14.79 | 15.59 | 15.12 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | N.S. |
| Treatment (T) | | | | | N.S. |
| V x T | | | | | 1.55 |

**Table 12:** Effect of Fornem x5® and Pacile-Bio-Nematicide®on purity (%) of five sugar beet varieties infested with *Meloidogyne javanica* throughout 2010/2011 & 2011/2012 seasons.

| Sugar beet varieties (V) | Season 2010/2011 | | | | Mean |
|---|---|---|---|---|---|
| | Fornem x 5 | Pacile-Bio-Nematicide | Nemacur ® | Control (untreated) | |
| AS0081 | 82.81 | 76.64 | 84.81 | 79.11 | 80.84 |
| AS0082 | 80.81 | 73.20 | 78.44 | 79.49 | 77.98 |
| HN627 | 80.35 | 75.46 | 81.16 | 79.11 | 79.02 |
| Ravel | 79.36 | 76.70 | 75.47 | 77.36 | 77.22 |
| SN626 | 78.73 | 81.77 | 79.46 | 77.81 | 79.44 |
| Mean | 80.41 | 76.75 | 79.87 | 78.58 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | N.S. |
| Treatment (T) | | | | | N.S. |
| V x T | | | | | N.S. |
| | Season 2011/2012 | | | | |
| AS0081 | 84.88 | 82.31 | 80.73 | 76.13 | 81.01 |
| AS0082 | 79.29 | 72.70 | 83.14 | 72.82 | 76.99 |
| HN627 | 77.44 | 79.88 | 81.60 | 77.21 | 79.03 |
| Ravel | 82.33 | 78.11 | 73.52 | 82.22 | 79.04 |
| SN626 | 82.80 | 86.39 | 76.23 | 79.62 | 81.26 |
| Mean | 81.35 | 79.88 | 79.04 | 77.60 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | N.S. |
| Treatment (T) | | | | | N.S. |
| V x T | | | | | N.S. |

*2.4.2. Purity %:*

Results given in Table (12) cleared that neither the examined varieties nor under the tested treatments had significant effect on the values of purity percentage in both seasons. However, the percentages of purity in sugar beet varieties ranged from 77.22 to 80.84% and from 76.99 to 81.26 %in the two seasons, respectively. Treating sugar beet AS0081 variety with Nemacur® gave highly purity (84.81%) and treating SN626 variety with Pacile-Bio-Nematicide® gave highly purity (86.39%) during 2010/2011 and 2011/2012seasons, respectively (Table, 12).

*2.4.3. Sugar yield:*

Data in Table (13) showed that the studied varieties significantly affected ($P \leq 0.05$) on the values of sugar yield, meanwhile, the lowest sugar yield was recorded with sugar beet variety HN627 in both seasons, however, the highest sugar yield was recorded with AS0082 variety (4.67 tons/fed.) in the1st season and AS0081 variety (5.30 tons/fed.) in the 2nd season.

**Table 13:** Effect of Fornem x5® andPacile-Bio-Nematicide®on sugar yield (ton/fed.) of five sugar beet varieties infested with *Meloidogyne javanica* throughout 2010/2011 & 2011/2012 seasons.

| Sugar beet varieties (V) | Season 2010/2011 | | | | Mean |
|---|---|---|---|---|---|
| | Fornem x 5 | Pacile-Bio-Nematicide | Nemacur® | Control (untreated) | |
| AS0081 | 4.65 | 4.20 | 4.65 | 4.05 | 4.39 |
| AS0082 | 4.25 | 4.11 | 4.67 | 3.83 | 4.21 |
| HN627 | 4.05 | 3.65 | 4.37 | 2.92 | 3.75 |
| Ravel | 4.07 | 4.10 | 4.57 | 3.80 | 4.14 |
| SN626 | 3.90 | 4.58 | 4.52 | 4.34 | 4.34 |
| Mean | 4.19 | 4.13 | 4.56 | 3.79 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | 0.60 |
| Treatment (T) | | | | | 0.60 |
| V x T | | | | | N.S. |
| | Season 2011/2012 | | | | |
| AS0081 | 4.90 | 3.94 | 5.30 | 4.21 | 4.59 |
| AS0082 | 4.28 | 4.20 | 5.07 | 3.99 | 4.39 |
| HN627 | 3.62 | 4.43 | 4.56 | 2.17 | 3.70 |
| Ravel | 4.97 | 4.43 | 4.02 | 3.62 | 4.26 |
| SN626 | 4.72 | 5.02 | 4.84 | 4.17 | 4.69 |
| Mean | 4.50 | 4.40 | 4.76 | 3.63 | -- |
| L.S.D at 0.05 % | | | | | |
| Variety (V) | | | | | 0.66 |
| Treatment (T) | | | | | 0.59 |
| V x T | | | | | 0.90 |

The interaction between the studied varieties and the examined nematicide was significantly in the 2nd seasons only. The highest sugar yield was recorded with the combinations between AS0081 variety with Nemacur® compound.

*Discussion:*

The results revealed that the root-knot nematode, *Meloidogyne javanica* cause remarkable damage to sugar beet plants in new reclaimed land located in Nubariya region, Egypt. These findings are agreement with those reported by Maareg *et al.* (2005) and Saleh *et al.* (2009). They reported that *M. javanica* was widespread in the rhizosphere of sugar beet in sandy-clay soil caused damage to the roots of plants. The relative susceptibility results indicated that sugar beet variety Ravel rated as highly susceptible,while other four sugar beet varieties viz. AS0081, AS0082, HN627and SN626 varieties were categorized as susceptible to the infection with *M. javanica*. Based upon the registered data and varietal reactions it could be deduced that the multigerm variety i.e. Ravel may be more sensitive to nematodes susceptibility. These results may be due to variance in gene make-up of the tested varieties. These results are agreement with those recorded by (Sharma *et al.,* 1994, El-Nagdi *et al*., 2004, Maareg *et al.*, 2005 and Saleh *et al.*, 2009).

Our study on the tested commercial bio-control products viz. Fornem x5® and Pacile-Bio-Nematicide® in addition to Nemacur®, showed suppressive effects against *M. javanica* in vitro test., when applied these treatments under field conditions, they attained significant reduction in galls number, improving growth, yield and technical characteristics of sugar beet. It is suggested that the antagonistic effects of the bio-control products may have been favored by other soil factors. This findings agree with Siddiqui & Mahmood (1996) who reported that *Paecilomyces lilacinus* attacks mainly infective stages of root knot and cyst nematodes and considered as the most promising and practicable biological control agent for the management of plant parasitic nematodes. Haque *et al*. (1996) controlled the root- knot disease complex on okra plants by using *P. lilacinus*. Also, Khan & Saxena (1997) and Morsy *et al*. (2009) reported that *Aspergillus niger*, *Bacillus subtilis*, *P. lilacinus* and *Trichoderma viride* could suppress the damage caused by *M. javanica* on tomato plants *in vitro* and in the field. Moreover, El-Nagdi *et al.* (2011) tested the effect of several commercial products containing the fungi *Paecilomyces lilacinus, P. fumosoroseus, Trichoderma album* and the bacteria *Bacillus subtilis* and *B. Megaterium* against *Meloidogyne incognita* and *Fusarium solani* on sugar beet, comparing with the nematicides i.e. fenamiphos and cadusaphos, under *in vitro*, greenhouse and field conditions. They stated that all treatments greatly reduced the population densities of second-stage juveniles in soil, and the numbers of galls, females and egg masses of *M. incognita* in the roots.

Therefore, our results suggest that the tested nematicide i.e. Nemacur® can be replaced by Fornem x5®, Pacile-Bio-Nematicide® as bio-nematicides in controlling nematodes as an alternative means of environment friendly materials to decrease pollution resulted from using chemicals.

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