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Estimation of yield losses in broad bean due to *Meloidogyne arenaria* in Egypt

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Abstract

Loss in yield of broad bean grown in sandy soil naturally infested with root-knot nematode *Meloidogyne arenaria* was estimated during two successive seasons. Severity of nematode infestation (damage) was assayed at harvest stage as root-gall indices (GI) based on scale of 1-6 (1= no infection and 6= 100% root galling). In the first season (2014-2015) relationship between nematode damage and yield of broad bean was negative, however no significant reduction in growth and yield (p= 0.05) was obtained at all nematode root gall indices. Correlation coefficient between nematode damage and yield was low, 0.38 in case of pod yield and 0.40 in case of dry seeds. In second season (2015-2016), both pods and dry seeds yield were significantly reduced by 10.6% and 15.2%, respectively at severe infestation (GI=6). Also correlation coefficient between nematode and yield was 0.92 in case of nematode-pod yield and 0.91 in case of nematode-seed yield. Seed contents *viz*., proteins, carbohydrates, zinc and copper decreased at severe infestation in the second season, while in the first season quality of seeds was not affected.

Keywords: Broad bean, root-knot nematodes, yield loss, *Meloidogyne* spp., Egypt.

Broad bean (*Vicia faba* L.), belongs to leguminous crops and is considered as essential food for most poor people in Africa and Asia including Egypt. This is due to the great nutritive value of its seeds which contain high level of protein, carbohydrates, vitamins and mineral elements such as iron, potassium, zinc and selenium (Pachio, 1993). Broad bean seeds are eaten as boiled or consumed after baking as “Foul” in Egypt, while immature seeds are eaten as fresh vegetable. Broad bean is also used as livestock and poultry feed, while the remaining bean straw is used as forage for domestic animals. Moreover, beans play important role in conservation farming system. The symbiotic relationship between beans and nitrogen fixing bacteria gives legume crops an economic advantage compared with crops needing nitrogen fertilizers. The amount of fixed remains in the soil with root residues after harvest which is responsible for increasing soil fertility.

Broad bean is successfully grown as a winter crop in alluvial soils of Nile Valley and sandy regions of Egypt. In the warmer climates like Egypt and other tropical and subtropical regions, plants of broad bean are infected by thermophilic root-knot nematodes *viz*., *Meloidogyne arenaria*, *M. incognita* and *M. javanica* (Ibrahim, 2011; Ali, 2012; Korayem *et al*., 2014). Economic importance of these root-knot nematode species attacking broad bean is still not accurately determined in Egypt, especially in natural infestation. A loss in yield of broad bean caused by phytonematodes was estimated at 7% in Egypt (Abd-Elgawad, 2014). This figure is not convincing because it was based on theoretical studies and not on empirical experimental ones.

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Nematode-yield relationship has been discussed by several investigators (Barker *et al*., 1985-Barker & Noe, 1987; Greco & Di Vito, 2009; Ravichandra, 2014). They reported that relationship between different nematode population densities in soil at sowing and yield of plants is a good method for predicting yield loss and estimating damage threshold. Also, the egg masses remain intact in the soil free or attached to root fragments of the host, thus majority of soil analysis methods used will not always detect egg-masses in field with low root-knot infection (Netscher & Sikora, 1990). An accurate estimation of root-knot nematode infestation in a field can be obtained at the end of vegetative period (before harvest) of an infected crop. Therefore, this research study was undertaken with the aim to estimate loss in yield of broad bean, infected naturally with *Meloidogyne arenaria* in relation to nematode damage (severity of root galling at harvest) and yield of plants.

Materials and Methods

Two experiments were conducted in experimental plots having sandy soil with root-knot nematode infection during 2014-2015 and 2015-2016 seasons at National Research Centre Experimental Station in Noubaria district Northwest Egypt. In the first experiment seeds of broad bean cv. Noubaria-1 were planted on 10-10-2014, while in the second experiment seeds of same broad bean cultivar were planted on 15-11-2015. Area of each experiment was more than one acre, prepared before planting in rows of 50 cm width, and seeds were planted in hills at rate of 2-3 seeds per hill. After seed germination, area of each experiment was provided with mixture of ammonium nitrate (33.5% N) @ 200kg, superphosphate (15.5% P2O5) @ 200kg and potassium sulphate (48.5% K2O) @ 100 kg, in two equal portions applied before first irrigation and at beginning of flowering. Average temperature (maximum and minimum) of both seasons was also incorporated (Table 1).

Nematode damage assay: At harvest (30-3-2015 for first experiment and in 6-5-2016 for second one), more than one hundred plants were randomly selected from each experiment for assaying nematode damage (severity of root galling).

Root-gall index was assayed according to Barker (1985) as follows: 1= no galls, 2= 1-20% root galling, 3= 21-40%, 4= 41-60%, 5= 61-80% and 6= 81-100% root-galling. Protein, carbohydrates and mineral elements determination: Total protein in dry seeds was determined according to A.O.A.C. (1990), total carbohydrates were calculated by the method of Dubois *et al*., (1956), mineral elements, N, P, K, Cu, Zn and Fe content were estimated as given by Cottenie *et al*., (1982).

Statistical analysis: Weights of fresh shoots, pods, dry seeds per plant were recorded then averages were calculated and analyzed according to Tukey test (Neler *et al*., 1985) for detection significant differences between averages. Relationship between nematode damage (GI) and broad bean yield was also depicted as regression lines to calculate regression equations, as well as type and degree of the correlation between them.

Results

For the first season (2014-2015), data presented in Table (2) indicated that fresh shoot weight, pods and dry seeds as well number of pods per plant were not influenced by nematode infection. Non-significant reduction (P= 0.05) was observed in the growth parameters and yield at all root gall indices compared with those of healthy plants (not infected). Relation between nematode damage and both yield of pods and dry seeds was negative, however correlation coefficient (r) between them was low, and as it was 0.38 in case of pods yield (Fig.1) and 0.4 in case of yield of seeds (Fig. 2). For second season (2015-2016), data presented in Table (3) indicated that fresh shoot weight and number of pods per plant showed non- significant reduction (P=0.05) at all root gall indices compared with

Table 1. Average temperature (maximum and minimum) recorded during growing both seasons (2014-2015 and 2015-2016).

Dates	Temperature (°C)		
	Maximum	Minimum	Average
October, 2014	26.17	18.47	21.92
November, 2014	22.01	15.65	18.44
December, 2014	19.74	11.91	15.34
January, 2015	17.17	9.14	12.78
February, 2015	18.20	9.11	13.32
March, 2015	21.49	11.17	15.93
April, 2015	23.22	12.18	17.24
November, 2015	22.90	16.63	19.41
December, 2015	18.75	11.75	14.96
January, 2016	16.80	9.41	12.72
February, 2016	20.39	11.03	15.28
March, 2016	22.09	12.04	16.57
April, 2016	26.48	15.01	20.74
May, 2016	27.65	16.86	21.71

Table 2. Effect of *Meloidogyne arenaria* infection on yield of broad bean grown in 2014-2015 seasons.

Root gall index	Fresh shoot wt (g) /plant	Red%	No. of pods/ plant	Red%	Pod yield (g) /plant	Red%	Dry seed (g) /plant	Red %
1.	120(n=16)	-	15.5	-	220	-	49.5	-
2.	121(n=17)	-	16.0	-	221	-	50.5	-
3.	120(n=17)	-	16.1	-	225	-	52.0	-
4.	118(n=18)	1.7	17.0	-	223	-	49.6	-
5.	119(n=16)	0.8	14.9	3.9	220	-	50	-
6.	119(n=18)	0.8	15.4	0.6	217	1.4	48.5	2.0
	ns		ns		ns		ns	

n= Number of replicates
ns= non significant (P=0.05) according to Turkey test.

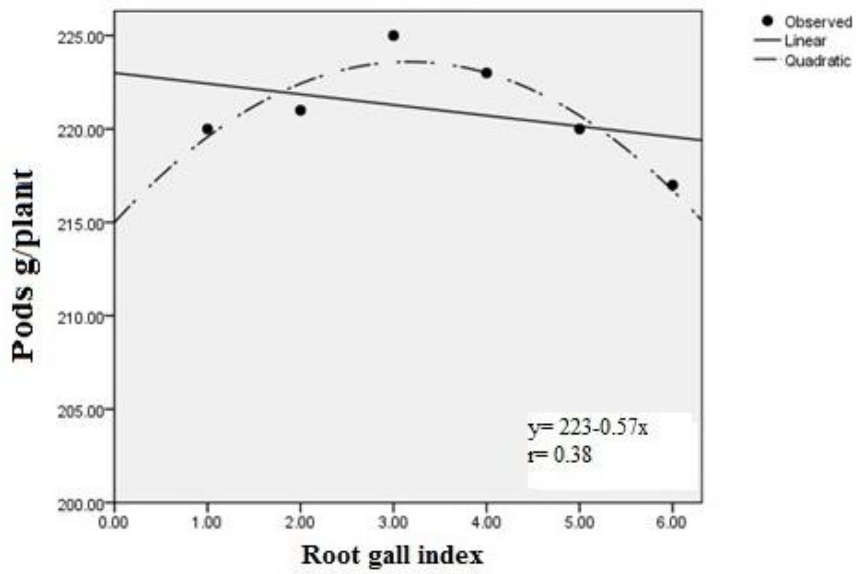

Fig. 1. Relationship between nematode root-gall index and weights of pods of broad bean grown in 2014-2015 season.

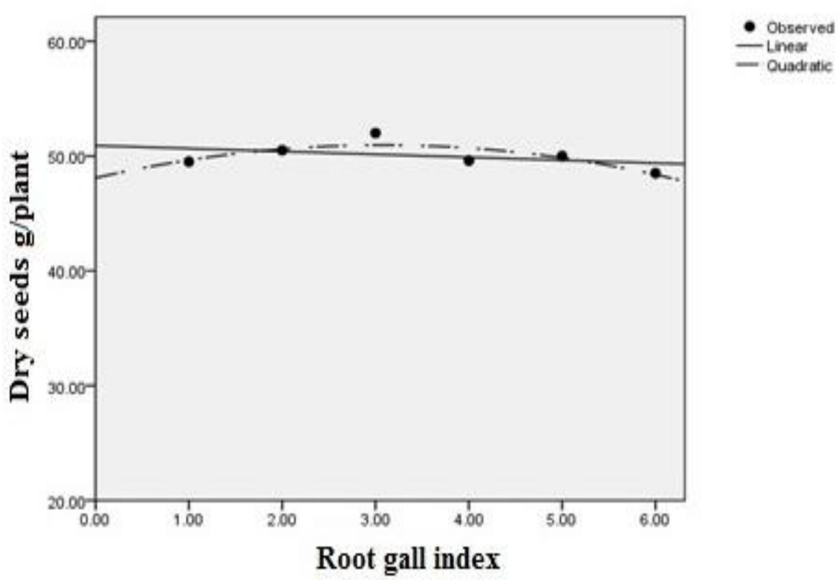

Fig. 2. Relationship between nematode root-gall index and dry seeds of broad bean grown in 2014-2015 season.

Table 3. Effect of *Meloidogyne arenaria* infection on yield of broad bean.grown in 2015-2016 season.

Root gall index	Fresh shoot g/plant	Red%	No. pods per plant	Red. %	Pod yield g/plant	Red. %	Dry seed g/plant	Red. %
1	125(n=17)*a	-	18.0a	-	244a	-	50.0a	-
2	126(n=15)a	-	18.1a	-	245a	-	57.0a	-
3	124(n=17)a	0.8	17.8a	1.1	240a	1.6	55.0a	1.8
4	124(n=19)a	0.8	18.0a	-	235a	3.7	54.6a	2.5
5	123(n=17)a	1.6	17.7a	1.7	233a	4.5	50.0b	10.7
6	123(n=18)a	1.6	17.6a	2.2	218b	10.6	49.9b	12.5

those of healthy plants, while weight of pods per plant was significantly reduced by 10.6% at 6-GI, at other nematode damage 2, 3, 4 and 5 it was not significantly influenced. Dry seed weight also significantly reduced by 10.7% and 12.5% at 5 and 6 root galling, respectively, compared with that of healthy plants. No significant reduction in dry seed yield was obtained at 2, 3 and 4 nematode damage (GI). Depicting relation between nematode damage (root galling) and both weight of pods and dry seeds as linear regression showed that relation between them was negative and correlation coefficient was high, 0.92 in case of pod weight (Fig.3) and 0.91 in case of dry seeds (Fig.4). As to effect of nematode infection on chemical components of seeds, it was observed that content of seeds for protein, carbohydrates, macro-and micro elements was not influenced by nematodes when broad bean was grown in 2014-2015 season (Table 4). There is non-significant difference at two different time intervals when broad bean was grown in 2015-2016 season, quality of seeds was influenced by nematode infestation. The amount of protein, carbohydrates, zinc and copper reduced by 13.1%, 13.4%, 6.0% and 23.3%, respectively in infected plant seeds (Table 4).

Table 4. Chemical composition of broad bean seeds infected by *Meloidogyne arenaria.*

Chemical component of seeds	2014-2015 season			2015-2016 season		
	Non-infected	Infected	Red %	Non-infected	Infected	Red %
Crude protein (%)	24.0	23.9	0.4	29.8	25.9	13.1
Carbohydrates (%)	50.1	49.6	0.9	53.0	45.9	13.4
Phosphorus (%)	0.3	0.32	-	0.21	0.21	-
Potassium (%)	1.14	1.2	-	1.30	1.37	-
Iron (ppm)	252.0	253.0	-	262.2	283.5	-
Zinc (ppm)	64.8	63.2	2.5	59.8	56.2	6.0
Manganese (ppm)	20.1	21.0	-	22.0	22.2	-
Copper (ppm)	6.6	6.4	3.0	8.6	6.6	23.3

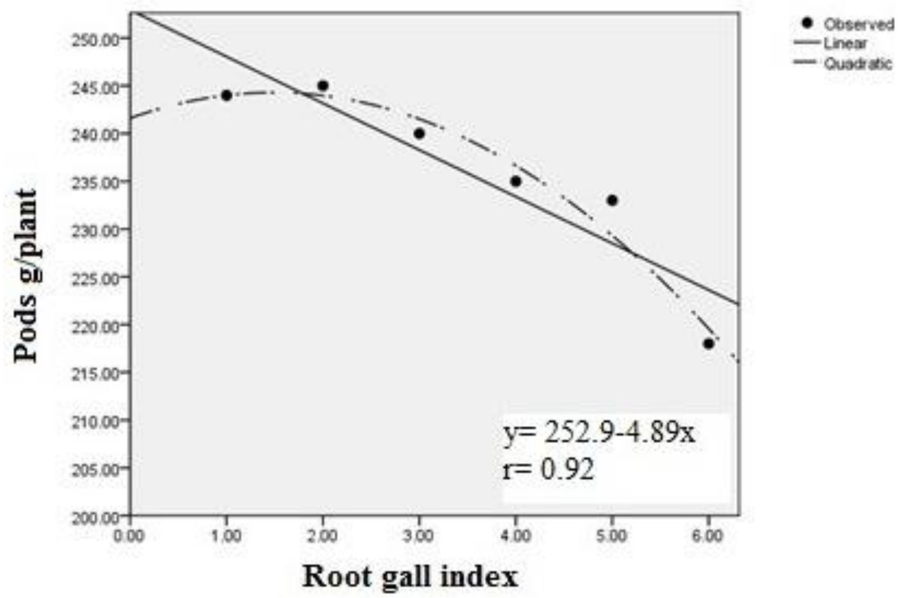

Fig. 3. Relationship between nematode root-gall index and pods weight of broad bean grown in 2015-2016 season.

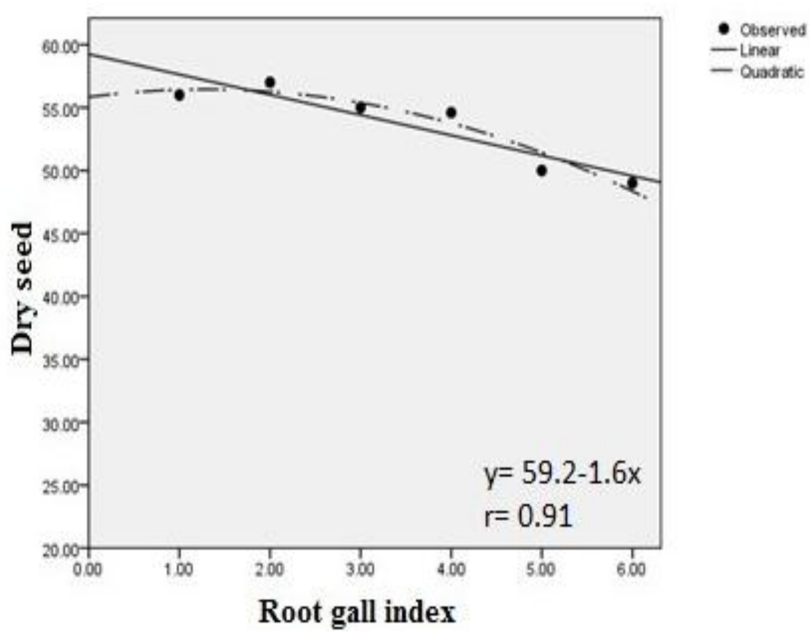

Fig 4. Relationship between nematode root-gall index and dry seeds of broad bean grown in 2015-2016 season.

Discussion

The results suggested that broad bean is infected by *Meloidogyne arenaria*. Damage and loss in its yield caused by nematodes were influenced by the growing season and climatic condition. In the first season (2014-2015), `growth and yield of plants were not significantly influenced by nematode infection. This may be attributed to low temperature observed during vegetative period of plants. At low temperatures, all biological activities of thermophilic nematodes (*Meloidogyne arenaria*) as embryonic development of eggs, ability of juveniles to escape from eggshell, survival, growth and reproduction are suppressed (de Guiran & Ritter, 1979; Van Gundy, 1985; Evans & Perry; 2009).

Thus the nematode life cycle be prolonged and production of egg-masses may be complete after more than three months (de Guiran & Ritter, 1979; Korayem & Romascu, 1983), hence broad bean reach maturity stage before emergence of first nematode generation which may have otherwise caused a significant damage to plants.
In second season (2015-2016), broad bean yield was significantly influenced by nematode infection especially at severe infestation. This may be due to delay of planting time (15-11-2015), thus maturity and harvest of plants were delayed (6-May-2016). As at beginning of spring temperatures begin to increase (Table 1), then activity of penetrated nematodes and development may have been accelerated, and their consumption from plant sap may have been increased, finally nematodes reaching maturity (egg laying stage) quickly leading to emergence of second stage juveniles (first generation), which may contribute to increase the nematode damage.

In general, our study suggests that broad bean is subject to infection by the root-knot nematode *Meloidogyne arenaria*. At severe nematode infestation, broad bean yield may significantly decrease according to date of planting and the climate condition during growing season.

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