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Reaction of fodder beet varieties to *Meloidogyne incognita* based on quantitative and qualitative yield characteristics

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Abstract

This study was conducted to evaluate six fodder beet genotypes for their resistance to infestation under naturally infected root-knot nematode, *Meloidogyne incognita* during the 2015/2016 and 2016/2017 seasons in Nubaria region, El-Behera Governorate, Egypt. Highly significant differences among the genotypes were detected for all studied traits except for fresh foliage weight. The relative susceptibility to root-knot nematode parameters (gall index, gall size, gall area and damage index) indicated that two fodder beet genotypes Beta Rozsa and Jamon were considered as the best with high yield and resistant reaction to *M. incognita*; in contrast Starmon genotype had highly susceptible reaction while Jary, Mnro andVorosch genotypes had moderately resistant. Fodder root yield was positively and significantly correlated with root weight; meanwhile, it was negatively and significantly correlated with damage index and gall index, respectively. These findings indicate that selection for root weight and infestation involved in this study affected the variability of root yield. Stepwise multiple regression linear analysis for fodder beet yield showed that root weight per plant, gall index, number of leaves per plant and dry weight per plant were the most important contributing traits to root yield (R^2= 94.76%). Hence, the selection among these traits would be accompanied by high yielding and more effective for the improvement of fodder root yield in the same conditions.

Key words: Fodder beet, varieties, root-knot nematode, yield characteristics.

Fodder beet is one of the best fodder crops that fit the environment to afford salinity. It can be planted on some trees and crops such as beans or cultivated channels of wheat and alfalfa where they are harvested at the end of the growing season for these crops. The cultivation of fodder beet has facilitated from September to December, but the most appropriate time for planting is in the month of October and November to get the highest yield of tubers. Insects that infect fodder beet include cotton leaf worm and beet leaf fly. Nematodes also infect the crop root and show injury in the form of blisters on the roots. Plant parasitic nematodes cause severe damage to sugar beet, especially *Meloidogyne incognita* that is considered as the predominant nematode species attacking plants (El-Nagdi *et al*., 2004; Korayem, 2006). The cultivation of root crops provides fodder that could be stored and used for feed during the long summer. The root-knot nematode is a serious problem of this crop. Regulations to prevent its spread were operational in the Egyptian land. Some parameters were estimated with varied breeding methods such as Pant & Singh (1993) analyzed seven characters in two open pollinated

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populations of *Beta vulgaris*, following three cycles of selection. They observed significant inter-genotypic variability of total soluble solids (TSS%), sucrose (%), shoot and root yield. Heritability associated with high genetic advance was observed for TSS and sucrose percentage. The root weight and sugar content were found controlled by dominance-additive model, heritability values ranged from 42 to 92 % for root weight and sugar content, respectively. These results were estimated by Ogata *et al.*, (2001) through analysis in the F1 of a half dialed cross. Refay (2010), Ogata *et al*., (2001) and Pant & Singh (1993) reported that full model regression is used to determine the best predictive equation for yield. Genetic parameters and correlation analysis help to facilitate the selection of genetically diverse parents in hybridization programs. The objective of this work was to evaluate six fodder beet genotypes for their resistance to infestation under naturally infected root-knot nematode, *Meloidogyne incognita* based on quantitative and qualitative yield characteristics.

Materials and Methods

Field experiment: This study was conducted in field having clay loam soil naturally infected with root-knot nematode (*M*. *incognita*) and irrigated by overhead irrigation sprinklers, during the 2015/2016 and 2016/2017 seasons in Nubaria region, El- Behera Governorate, Egypt. Treatments included six varieties of fodder beet with four replications, and each plot was 3 m wide × 3.5 m long (= 10.5 m^2 i.e. 1/400 Fadden). Each plot consisted of six rows of plants spaced 50 cm apart. Treatments were arranged in a Randomized Complete Block Design (RCBD). Different genotypes of fodder beet *viz*., Beta Rozsa, Jamon, Jary, Mnro, Starmon and Vorosch were sown in the 1st week of October. Seeds were sown at a particular distance to provide the normal density of 40,000 plants/Fadden (2.4 Faddens = 1 ha). All genotypes were managed throughout the growing season according the recommended agricultural practices.

Response of fodder beet cultivars to *M. incognita*: Roots of fodder beet were gently freed of adhering soil and were examined for number of galls under stereomicroscopic and counted. The root gall index (GI), gall size (GS), gall area (GA) and damage index (DI) were estimated according to Sharma *et al*., (1994). The DI was calculated by dividing the sum of GI, GS and GA by 3 to determine the host susceptibility rating. The different ratings of DI were as follows: resistance (≤ 3.0) moderately resistant (≤ 5.0), susceptible (5.1-7.0) and highly susceptible (7.1-9.0).

Evaluation of growth and technological parameters: Plant growth parameters of fodder beet plants such as foliage weight, root length, diameter and weight of roots were recorded at harvest time. The technological parameters of fodder beet roots such as sucrose percentage (S %), total soluble solids percentage (TSS %) and purity percentage were estimated. Sucrose percentage was determined according to method described by Le-Docte (1927). TSS percentage in fresh roots were determined using a refractometer, while juice purity percentage was determined as a ratio between S% and TSS% according to method described by Carruthers & Oldfield (1961).

Statistical analysis: Initially the analysis of variance was applied, after that a combined analysis of variance was computed over two seasons according to Snedecor & Cochran (1981). Before running the combined analysis, Levene (1960) test was used to satisfy the assumption of homogeneity of variances. Mean comparison was done using least significant differences test at 5% level of probability. Correlations among different maize traits and stepwise multiple linear regression procedure was used according to Draper & Smith (1966) to determine the variable accounting for the majority of total yield variability.

Results and Discussion

Response of fodder beet cultivars to *M. incognita*: Reaction of the tested six fodder beet genotypes to the root-knot nematode, *M. incognita,* in terms of number of galls, gall index (GI), gall size (GS), gall area (GA) and damage index (DI) under field conditions are shown in Table 1. After three months of sowing, the number of galls was in the range of 4 to 28 galls/plant and significant differences among beet cultivars were recorded. Beta Rozsa and Jamon varieties had the lowest gall numbers (4 and 2 galls / plant and 5 galls/ plant, respectively). Meanwhile, the Starmon variety had the highest value of galls about 28 and 34 galls/ plant in both seasons, respectively (Tables 1 & 2).

Six months after sowing, the number of galls was in the range of 6 to 77 and 4 to 80 galls / plant in the 2015/2016 and 2016/2017 seasons, respectively. Roots of Beta Rozsa variety had the lowest galls 4-6 galls/plant, while roots of Starmon variety had the highest galls about 77-80 galls/ plant, respectively. Results showed that the number of galls in roots of Vorosch, Jary, Mnro and Jamon varieties were; 29, 18, 14 and 9 galls/ plant, respectively in the 2015/2016 season (Table 1); while the number of galls were 23, 13, 10 and 10 in Vorosch, Mnro, Jary and Jamon respectively in the 2016/2017 season (Table 2).

The GI values were in the range of 3 and 8. Beta Rozsa and Jamon varieties had the lowest value of GI about 3 for each, while Starmon variety had the highest value about 8, followed by the Vorosch enger (5), Jary and Mnro (4, 4) (Tables 1&2). Concerning of GS and GA, Beta Rozsa and Jamon varieties gave the lowest value (3) for each, while Starmon variety produced the highest GS and GA values followed by the Vorosch enger, Jary and Mnro (Tables 1&2).

Table 1. Relative susceptibility of six fodder beet genotypes for *Meloidogyne incognita* under natural infection conditions in the 1st season in Al-Behira Governorate (2015/2016 season).

Genotypes of fodder beet	Nematode parameters						
	No. of galls at three months	No. of galls at 6 months					
		No. of galls	Gall index	Gall size	Gall area	Damage index	*Host susceptibility rating
Beta Rozsa	4	6	3	3	3	3.0	Resistant
Jamon	5	9	3	3	3	3.0	Resistant
Jary	9	18	4	5	5	4.7	Moderately resistant
Mnro	8	14	4	3	3	3.3	Moderately resistant
Starmon	28	77	8	9	9	8.7	Highly susceptible
Vorosch	15	29	5	5	5	5.0	Moderately resistant
$LSD_{0.05}$	**3.02**	**5.53**					

*Host susceptibility rating**:** according to Sharma *et al.*, (1994).

Table 2. Relative susceptibility of six fodder beet genotypes for *Meloidogyne incognita*, under naturally infection conditions, in the 2nd season in Al-Behira Governorate (2016/2017 season).

Genotypes of fodder beet	Nematode parameters						
	No. of galls at three months	No. of galls at 6 months					
		No. of galls	Gall index	Gall size	Gall area	Damage index	*Host susceptibility rating
Beta Rozsa	2	4	3	3	3	2.7	Resistant
Jamon	5	10	3	3	3	3.0	Resistant
Jary	6	10	3	5	5	4.3	Moderately resistant
Mnro	10	13	4	3	3	3.3	Moderately resistant
Starmon	34	80	8	9	9	8.7	Highly susceptible
Vorosch	17	23	5	5	5	5.0	Moderately resistant
$LSD_{0.05}$	**4.30**	**4.82**					

*Host susceptibility rating according to Sharma *et al*., (1994)

The DI values were in the range of (3.0 to 8.7) and (2.7-8.7) in the 2015/2016 and 2016/2017 seasons, respectively (Tables 1&2). Beta Rozsa variety gave the lowest value (3.0- 2.7), while Starmon variety had the highest value about 8.7 in the two seasons.

Results of host susceptibility rating revealed that Jary, Mnro and Vorosch varieties showed moderately resistant reaction to *M. incognita* and Beta Rozsa and Jamon varieties had resistant while Starmon variety exhibited highly susceptible reaction to the root-knot nematode (Tables 1&2).

Results revealed that field of El-Behera Governorate were heavily infected with the root-knot nematodes, *Meloidogyne incognita*, thus it was chosen for field experiment. According to nematode parameters, viz., root gall index (GI), gall size (GS), gall area (GA) and damage index (DI), the relative susceptibility results indicated that fodder beet variety of Starmon were considered as highly susceptible to infection with *M. incognita*, and other three varieties of fodder beet i.e., Jary, Mnro and Vorosch were scored as moderately resistant, while Beta Rozsa and Jamon varieties had resistance under natural infection conditions (Sharma *et al*., 1994). These results are in conformity with those obtained by El-Nagdi *et al*., (2004). These results are in agreement with those recorded by Maareg *et al*., (2005); Saleh *et al*., (2009); Abd-El-Khair *et al*., (2013). They classified sugar beet varieties into four groups; resistant, susceptible, moderately susceptible and highly susceptible to infection with *M. incognita* and *M. javanica*, respectively.

Evaluation of growth and biochemical parameters: Data of Table (3) revealed that the studied genotypes differed significantly for all the traits in each season. The homogeneity of error across the two seasons was checked by Levene (1960) test, and then combined across the two seasons. Results showed the effect of genotypes on the studied vegetative growth and technological traits of sugar beet across two seasons. Highly significant differences among the genotypes were detected for all studied traits except for fresh weight of foliage. The differences between genotypes may be due to their genetic makeup (El-Sheikh, 2007; Ghareeb *et al*., 2013).

Table 3. Differences among six sugar beet genotypes under *Meloidogyne incognita* infestation for root growth, quality and yield traits at harvest (Combined data over 2015/2016 and 2016/2017 seasons).

Fodder beet genotypes	Plant height (cm)	No. of Leaves	Root diameter (cm)	Root length (cm)	Foliage fresh wt (g)	Foliage dry wt (g)	Root yield ton/fed.	TSS %	Sucrose %	Purity %
Beta Rozsa	52.67	32.00	10.00	24.67	610.00	252.58	29.77	15.83	8.85	55.96
Jamon	48.33	41.67	10.83	31.17	775.17	290.62	51.83	16.33	9.97	58.87
Jary	48.33	34.67	10.83	29.00	683.50	255.23	47.50	17.17	9.30	54.20
Mnro	48.17	29.17	10.00	38.50	434.33	237.53	40.39	15.00	7.61	62.89
Starmon	53.17	38.67	10.00	24.67	488.83	228.82	42.23	19.00	11.27	59.58
Voroschnger	44.33	44.67	9.50	29.33	581.67	219.93	31.61	16.50	9.27	56.28
$LSD_{0.05}$	**3.27**	**4.66**	**1.47**	**8.38**	**N.S.**	**38.31**	**11.10**	**1.04**	**4.62**	**6.73**
Y1 mean	49.16	37.61	10.83	30.40	607.00	275.41	42.77	16.70	13.90	58.50
Y2 mean	49.16	36.00	10.00	28.72	594.00	219.49	38.20	16.11	9.70	57.45
$LSD_{0.05}$	**N.S.**	**N.S.**	**0.05**	**N.S.**	**N.S.**	**27.10**	**N.S.**	**N.S.**	**N.S.**	**N.S.**
Grand mean	**49.17**	**36.81**	**10.19**	**29.56**	**595.58**	**247.45**	**40.56**	**16.64**	**9.38**	**57.96**

Vegetative growth traits: Data showed that Jamon and Jary genotypes had the highest values for root yield, root diameter, weight of fresh and dry foliage (51.83-47.5 ton/fed, 10.83-10.83cm, 755.17 - 683.50g and 290.62 - 255.23g, respectively). Meanwhile, Beta Rozsa, Jamon and Jary genotypes had the highest values for plant height, Jamon and Vorosch enger for number of leaves and Jamon and Mnro for root length across the two seasons. Similar results were reported by El-Sheikh (2007), Saker *et al.*, (2011), Aly *et al*., (2012), Abdel Elnaby *et al.*, (2014) and Rammah *et al.*, (1984).

Biochemical composition: Starmon and Jary genotypes had the highest values for total soluble solids percentage, and Jamon and Starmon for purity percentage across seasons. Meanwhile, Jamon and Starmon genotypes had the highest values for sucrose percentage (Saker *et al*., 2011; Abdel Elnaby *et al*., 2014; Rammah *et al*., 1984).

In general, results showed that genotype x season interaction were insignificant for all studied traits except for root diameter and weight of dry foliage. All traits in both seasons revealed significant differences among the studied genotypes. This indicates the presence of sufficient variability. This result was in conformity with the results reported by many authors (Saker *et al*., 2011; Abdel Elnaby *et al*., 2014; Rammah *et al*., 1984; El-Sarag, 2013). It could be noticed that Jamon genotype showed better performance for vegetative growth traits. Meanwhile, Starmon genotype had the highest values for technological traits.

Simple correlation coefficients between pairs of studied characters, in both seasons, are presented in Table (4). The results showed that root yield was positively and significantly correlated with root weight 0.956**, indicating to increase root yield by increasing root weight. But, fodder yield was negatively significant and significantly correlated with damage index-0.378* and gall index-0.440**, respectively. However, damage index was positively and highly significantly correlated with gall index 0.963**.However, damage index and gall index were positively correlated with number of leaves 0.527** and 0.416*, respectively. Conversely, its significantly negative association with plant height was -0.434** and -0.434***, respectively. The infestation with *Meloidogyne incognita* decreased the fodder beet root yield and plant height. These results are in line with those confirmed by El-Nagdi *et al.*, (2004) and Maareg *et al.*, (2018).

Stepwise multiple regression analysis showed that 94.76% of total variation in fodder beetroot yield per plant could be explained by the variation in root weight per plant, gall index, number of leaves per plant and fresh dry weight per plant (Table 5). From these results it could be concluded that the root weight per plant, gall index, number of leaves per plant and fresh dry weight per plant were the most suitable inputs to the model of prediction equation for root yield/plant (Ŷ) which formulated as follows:

Yield = 8.638 + 0.0303^{**} root weight/plant + 0.770^{**}gall index - 0.182^{*} number of leaves/plant -0.023^{*} fresh dry weight/plant.

Hence, it could be concluded that selection based on the root weight per plant, gall index, number of leaves per plant and fresh dry weight per plant is more appropriate under *Meloidogyne incognita* infestation. These findings are in accordance with the results obtained by El-Nagdi *et al.*, (2004) and Maareg *et al.*, (2018) who reported that these traits were useful for the determination of an increase in root yield.

Table 4. Matrix of simple correlation coefficients (r) for the estimated variables of under *Meloidogyne incognita* infestation for fodder beet root growth.

Trait	Ph	Leaves	RL	RD	FW	DW	RW	GI	DI
Leaves	-0.230								
RL	-0.313	-0.238							
RD	0.091	0.015	-0.053						
FW	0.115	0.336*	-0.073	0.335*					
DW	0.196	0.079	-0.085	0.276	0.574**				
RW	-0.053	0.194	0.029	0.186	0.267	0.333*			
GI	-0.434**	0.416*	-0.133	-0.245	0.046	-0.240	-0.325		
DI	-0.455**	0.527**	-0.102	-0.222	0.099	-0.156	-0.239	0.963**	
RY	0.034	0.071	0.022	0.196	0.201	0.230	0.956**	-0.440**	-0.378*

*, ** and ns indicates significant at the 0.05 and 0.01 level of probability and insignificant, respectively.
Ph: plant height, Leaves: Leaves number, RL: root length (cm), RD: root diameter (cm), FW: Fresh weight, DW: Dry weight, Rw: Root weight (g), GI: Gall index, DI: Damage index; Ry: Root yield (ton/fed).

Table 5. Regression method of relative proportion of root yield components in fodder beet.

Independent variable	intercept	Regression coefficient				Accumulative partial R-Square	Adjusted R-Square
		b1	b2	b3	b4		
Root weight	2.722	0.0280**				91.46	91.21
Gall index	- 2.530	0.0289**	0.900*			92.99	92.56
Leave no.	4.165	0.0294**	0.780*	-0.184*		93.95	93.38
Dry weight	8.638	0.0303**	0.770*	-0.182*	-0.023*	94.76	94.08

** Significant at 1% of probability levels

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