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Full Length Research Paper

Anti-nutritional factors as screening criteria for some diseases resistance in sesame (*Sesamum indicum* L.) genotypes

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Since sesame genotypes differed significantly in the levels of anti-nutritional factors (phytate, trypsin inhibitor and tannins), these anti-nutritional factors were examined as screening criteria for diseases resistance. Forty eight sesame genotypes from different sources were grown in soil infested by *Fusarium oxysporum* (FOS) and *Macrophomina phaseolina* (MPH) at Experimental Farm, Faculty of Agriculture, Suez Canal University, Egypt through two seasons (2009 and 2010) and approved for the above mentioned aim. The anti-nutritional factors of the tested sesame genotypes were associated significantly with both of infection pathogens percentages and seed yield. Most tested sesame genotypes were gathered in the scale of resistance (R) by scoring 48.90% and moderate resistance (MR) by scoring 40.7% of all the tested genotypes. On the other hand, 9.90% and 0.50% of the tested sesame genotypes were gathered in the scale of moderate susceptible (MS) and susceptible(S), respectively. Sesame genotype groups (resistant, moderately resistant, moderately susceptible and susceptible) were observed differenced significantly in their contents of the anti-nutritional factors. Most of the relationships among sesame genotype groups or among the anti-nutritional factors and among themselves were showed significant correlations in both seasons (2009 and 2010) over the two fungal pathogens (FOS and MPH) together. The resistance (R) class possessed the highest values of the anti-nutritional factors, while the lowest values were related to the susceptible (S) class of sesame group. However, the other two classes, the moderately resistance and moderately susceptible possessed the medium values of phytic acid, trypsin inhibitor, and tannins over an average of the two seasons. Hence, these anti-nutritional factors could have played a clear role in the range and magnitude of resistance or susceptibility to fungal pathogens, *F. oxysporum* and *M. phaseolina* in sesame genotype groups considered in this work.

Key words: Disease resistance, *Fusarium oxysporum*, infection percentage, *Macrophomina phaseolina*, phytate, screening, seed yield, sesame, tannins, trypsin inhibitor.

INTRODUCTION

Sesame is a plant species of *Sesamum indicum* L., and herbaceous annual plant belonging to the Pedaliaceae family (Sugano et al., 1990; Sugano and Akinmoto, 1993). Sesame seed is one of the world's important and oldest oilseed crops known according to some archaeological findings (Nayar and Sastry, 1990; Elleuch et al., 2010). Its cultivation went back to 2130 B.C. (Weiss, 1983). However, its recorded history in Egypt returned to 1300 B.C. (Burkill, 1953). Despite the fact that 100% of the world's sesame area is found in the developing countries (Ashri, 1998), it is common in many countries over the world with different names according to the region of production. For example, in some areas, it is known as Sesamum (China, Mexico, South and Central America), gingelly (South India, Burma),

Abbreviations: FOS, *Fusarium oxysporum*; **MPH,** *Macrophomina phaseolina*.

benniseed (Sierra Leone, Guinea in West Africa), sim-sim (Middle East) and till (East and North Africa *via* Egypt). China, India, Sudan, Mexico and Burma are the major producers of sesame seeds in the world by contributing to approximately 60% of its total world production (Kemal and Yalçin, 2008). In Egypt, it represents about 0.37% of the total cultivated area (Anonymous, 2010), and approximately 80 to 90% of the sesame crop is used in the production of a popular food (Halawa Tahnia), while the remainder amount of about 10 to 20% is used in the production of Tehineh, the bakeries and confectionery (Serry and Satour, 1981).

However, sesame has been cultivated for centuries, particularly in Asia and Africa, for its high content of edible oil and protein (Salunkhe et al., 1991). It is an important source of food worldwide and constitutes an inexpensive source of protein, fat, minerals and vitamins in the diets of rural populations, especially children (Namiki, 1995; Shahidi et al., 2006). The chemical composition of sesame shows that the seed is an important source of oil (48 to 60%), protein (18 to 23.5%). It was also reported to have carbohydrate (13.5%), ash (5.3%) and moisture (5.2%) (Obiajunwa et al., 2005; Kahyaoglu and Kaya, 2006). Moreover, sesame oil is known as the king of oil seeds due to continuous antioxidative constituents that is, sesamolin, sesamin and sesamol contents, compared to other oil seeds (Brar and Ahuja, 1979).

On the other hand, other chemical components such as anti-nutritional factors such as phytate, trypsin, a-amylase inhibitors, lectin, and tannins are in existence in sesame seeds and can limit their utilization in food system (Moran et al., 1969; Wu and Inglett, 1974). However, these anti-nutritional factors may be related considering disease resistance and since sesame plants are susceptible to fungal diseases, they are liable to attack at least by eight economically important fungal diseases (Kolte, 1985). The most serious fungal diseases, which infect sesame plants, are Fusarium wilt disease, caused by Fusarium oxysporum f. sp. sesami (FOS) and charcoal root rot disease caused by Macrophomina phaseolina (MPH). Since sesame plants are so affective with both diseases, it differed greatly in their response and had heavy losses in the yield crop. F. oxysporum (FOS) pathogen causes vascular wilt disease and sudden death of sesame plants. Therefore, these soil-borne pathogens may cause heavy yield losses in sesame ranging from 50 to 100% and survive in soil for several years (Gaber et al., 1998; Khaleifa, 2003; El-Bramawy, 2006a, b; Bayoumi and El-Bramawy, 2007; El-Bramawy and Shaban, 2007). While, M. phaseolina (MPH) infects sesame plants at all stages and damage can result in poor seedling establishment, pre and post emergence damping off and reduced vigor and productivity of older plants. Major symptoms on infected plants are stunting, chlorosis, premature defoliation, early maturity and death (Abawi and Corrales, 1989; El-Bramawy and Abd Al-Wahid, 2007; El-Bramawy and Shaban, 2007; El-Bramawy, 2008). However, the control of the main diseases that infect sesame in Egypt is a problem and is difficult to overcome completely, because most of them are caused by ground pathogenic inhabitants, which require a special treatment for their eradication or diminution. Application of some agronomic practices and improvement of diseases resistance in current genotypes have been proposed as the most effective strategies of solving the disease problems in sesame. Therefore, the improvement of current sesame genotypes to be more diseases resistant is an alternative option to solving disease problems in sesame (Zahra, 1990; Ziedan, 1993; Zhang et al., 2001; Ragab et al., 2002; El-Fiki et al., 2004; El-Bramawy, 2006, 2008; El-Shahkess and Khaleifa, 2007).

Moreover, there is a wide diversity in agronomic traits, namely: plant height, branches number, capsules number, capsule length, length of fruiting zone, maturity date, seed index, seed yield, oil content and seed color among sesame species and genotypes within a species (Li et al., 1991). Seed chemical components such as phytate, trypsin, a-amylase inhibitors, lectin, and tannins are also assorted among sesame accessions and germoplasm within accessions (Chang et al., 2002; Kanu et al., 2009). This biodiversity in agronomic traits or/and chemical components characteristic could be a valuable tool for screening and breeding a new germplasm for higher diseases resistance. El-Bramawy et al. (2009a) found that maturity date, branches number per plant and seed color traits may successfully be used to predict the resistance of sesame genotypes to Fusarium wilt (caused by F. oxysporum) and charcoal rot (caused by M. phaseolina) diseases without conducting tedious crop experiments. In the same connect, but with other field crops, Jalali and Chand (1992) observed that most practical and cost-efficient method for management of Fusarium wilt of chickpea is the use of resistant cultivars. Also, Gupta and Sharma (2006) reported that evaluation and exploitation of wild accessions for different morphological and agronomical traits will help in tapping the unexplored variability in cultivated lentil. Introgression of related wild lens taxa into the cultivated lentil will help in the flow of useful genes into the cultivated lentil and thus including these wild species in the common gene pool (Ladizinsky, 1993).

Numerous studies have shown positive and negative correlations between agronomic traits and disease resistance. For example, Dubin et al. (1998) found that heading date and plant height in wheat showed a negative significant correlation with area under disease progress curve (AUDPC). Duveiller et al. (1998 a, b) also found that plant height is expected to influence spot blotch severity in wheat. Through their studies for the relationship of plant height and days to maturity in homozygous wheat lines with resistance to spot blotch, Joshi et al. (2002) reported that resistance to spot blotch severity was independent of plant height and days to maturity in progenies from wheat crosses. These lines showed a significant difference for plant height and days to maturity, but not for AUDPC values of spot blotch disease. Several reports have indicated that seed colors in various crops are associated with diseases resistance. It has also been reported that polyphenolics and tannins are subsets involved in seed color expression and are often associated with plant resistance to pathogens or insects (Li et al., 1991; Pastor-Corrales et al., 1998; Islam et al., 2003). In general, more total phenols in common bean plants have been linked with greater resistance to root-rot disease (Statler, 1970). Also, tannin is beneficial in the field because its presence provides resistance to fungi. Therefore, it is important to develop an effective evaluation approach for screening disease resistant genotypes that would be reliable, quick, easy, practical and economical. Whereas, screening under natural field conditions is not feasible due to high degree of heterogeneity as well as fungal competition (Harris and Burns, 1973). Therefore, the main aim of the study was assessment the validity of the anti-nutritional factors (phytate, trypsin inhibitor, tannins) as screening criteria of 48 sesame germplasm for resistance to fungal pathogens (FOS and MPH). Sup-objective was to investigate the predictive screening parameters by judging the relationships among these anti-nutritional factors of sesame seeds in relation to the diseases resistance levels.

MATERIALS AND METHODS

Plant materials

Forty eight sesame genotypes were used as plant materials in this work. They include two mutants (these two mutants achieved by Nuclear Research Center, Atomic Energy Authority in Egypt), eight local cultivars, three introduced varieties, fifteen promising lines originated from hybridization and selections through a breeding program in the Agronomy Department, and twenty land races collected from Egypt district over Egypt Governorates. The names, origin, pedigree and sources of these sesame genotypes, which were considered in this work are listed in Table 1.

Field treatments

At the Experimental Plant Breeding Farm, Faculty of Agriculture, Suez Canal University, Egypt, field treatments were established in two growing seasons (2009 and 2010). These field treatments were screened for assessment of the resistance levels of sesame germplasm with their seed yield potential against isolate of the two fungal pathogens [*F. oxysporum* (FOS) and *M. phaseolina* (MPH)].

Soil experimental analysis and characteristics

The experimental soil was classified as a sandy soil (94.46% sand, 2.50% silt and 3.04 clay, in season 2008 and 94.66% sand, 2.54% silt and 3.24 clay in season, 2009) according to the method outlined by Kilmer and Alexander (1949). This soil possessed pH values of 7.62 and 7.56, contained 3.14 and 3.45 ppm available N, 1.81 and 1.85 ppm available P, 11.64 and 11.92 ppm available K, and 0.049 and 0.058% organic matter in the two growing seasons, respectively.

Experimental design and inoculation of soil

A randomized complete block design (RCBD) with three replicates was used in this work. Two field experiments were conducted at Experimental Farm, Faculty of Agriculture, on infected field by the two fungal pathogens [*F. oxysporum* (FOS) and *M. phaseolina* (MPH)] during 2008 and 2009 growing seasons. Each sesame entry was planted on a plot containing two ridges that were 60 cm apart and 4 m in length (4.8 m^2). The seeds were planted on the upper third of the ridges in hills with 10 cm between hills. Sowing was done in wilt-sick and charcoal rot-sick plot in soil known to have a high inoculums density of both pathogenic fungi from a long-term sesame research field that was naturally infested with FOS and MPH (El-Bramawy, 1997, 2003, 2006 and 2008; El-Bramawy and Shaban, 2007; El-Bramawy and Abd Al-Wahid, 2009; El-Shazly et al., 1999; Bayoumi and El-Bramawy, 2007; El-Bramawy et al., 2009a).

Measurements of infection percentage

The sesame genotypes were examined weekly and noted for any wilt and charcoal root rot symptoms for 10 weeks of sowing. The infected sesame plants by Fusarium wilt were characterized by the internal vesicular discoloration, appearance of wilt on plants and might die and fell down (considered wilted). However, the charcoal root rot infection was expressed as root discoloration, black stem rot and pronounced reduction in root system of the infected plants (Smith and Carvil, 1997). Re-isolation of the wilt (*F. oxysporum*) and charcoal root rot (*M. phaseolina*) pathogens from the diseased plant were then done and compared with the original isolates to assure the existence of a relation between inoculation pathogen and the development of diseases.

Scoring of resistance levels for sesame genotypes

To evaluate the resistance levels of sesame genotypes to both fungal pathogens, 1- 6 scales of Kavak and Boydak (2006) were formed based on the infection percentage of each sesame genotype by each pathogen. This Scale presented in Table 2 was based on twenty plants selected randomly per plot. The wilted and rotted sesame plants were counted and calculated as percentage of infected plants, then transformed to Arcsine values and prepared for statistical analysis.

Determination of Anti-nutritional factors

The anti-nutritional factors, that is, phytic acid, and trypsin inhibitor, and tannins were determined in Laboratory of Food Technology Department. These estimates were done on four sesame groups [Resistant (R), Moderately Resistant (MR), Moderately Susceptible (MS) and Susceptible (S)] depending on their behavior towards the fungal pathogens (FOS and MPH). Five gram seeds of the different four groups among all sesame genotypes were used as samples for determining the anti-nutritional factors as follows:

Phytic acid: Phytic acid was determined according to the method described by Latta and Eskin (1980), and later modified by Vaintraub and Lapteva (1988). One gram of dried sample was

Table 1. Serial number, names, origin and pedigree of 148 sesame genotypes used in the study.

S/N	Genotype name	Origin	Sources	S/N	Genotype name	Origin	Sources
1	Mutants 48	Egypt	Giza 24 D 20 M 3 R-10	25	S 2	Egypt	Selection from local lines under breeding program
2	Mutants 8	Egypt	Giza 24 D 20 M 6 R -12	26	S 3	Egypt	Selection from local lines under breeding program
3	Toshka 1	Egypt	M2 A1 B11 (CAN 114 x Type 29) x NA413	27	S 4	Egypt	Selection from local lines under breeding program
4	Toshka 2	Egypt	M2 A2 B11 (CAN 114 x Type 29) x NA413	28	S 5	Egypt	Selection from local lines under breeding program
5	Toshka 3	Egypt	M2 A3 B11 (CAN 114 x Type 29) x NA413	29	L.R1	Egypt	Land race collected from Ismailia Governorate
6	Taka 1	Egypt	Not available	30	L.R2	Egypt	Land race collected from El-Sharkia Governorate
7	Taka 2	Egypt	Not available	31	L.R3	Egypt	Land race collected from El-Mina Governorate
8	Taka 3	Egypt	Not available	32	L.R4	Egypt	Land race collected from El-Mina Governorate
9	Giza 25	Egypt	Giza white x Type 9	33	L.R56	Egypt	Land race collected from Assuite Governorate
10	Giza 32	Egypt	B 32 (CAN 114 x Type29)	34	L.R6	Egypt	Land race collected from Assuite Governorate
11	U N. A 130	U.S.A	Unknown	35	L.R7	Egypt	Land race collected from Sohag Governorate
12	G N. A 574	Greece	Unknown	36	L.R8	Egypt	Land race collected from Ismailia Governorate
13	K N. A 592	Korea	Unknown	37	L.R9	Egypt	Land race collected from El-Fayum Governorate
14	H 1	Egypt	Ismailia line 10 x Neu H.B	38	L.R10	Egypt	Land race collected from El-Sharkia Governorate
15	H 2	Egypt	Oro x Local line 274	39	L.R11	Egypt	Land race collected from El-Sharkia Governorate
16	H 3	Egypt	U C. R 10 x Giza 32	40	L.R12	Egypt	Land race collected from Ismailia Governorate
17	H 4	Egypt	U C. R 11 x Giza 25	41	L.R13	Egypt	Land race collected from El-Fayum Governorate
18	H 5	Egypt	Ismailia line 8 x Ismailia line 20	42	L.R14	Egypt	Land race collected from El-Fayum Governorate
19	H 6	Egypt	A cross between two local lines	43	L.R15	Egypt	Land race collected from Ismailia Governorate
20	H 7	Egypt	A cross between two local lines	44	L.R16	Egypt	Land race collected from Bani sueif Governorate
21	H 8	Egypt	A cross between two local lines	45	L.R17	Egypt	Land race collected from Bani sueif Governorate
22	H 9	Egypt	A cross between two local lines	46	L.R18	Egypt	Land race collected from Wady El-Gaded Govenorate
23	H 10	Egypt	A cross between two local lines	47	L.R19	Egypt	Land race collected from Wady El-Gaded Govenorate
24	S 1	Egypt	Selection from local lines under breeding program	48	L.R20	Egypt	Land race collected from El-Sharkia Governorate

Table 2. The scale used in this investigation.

Scale number	Infection percentage (%)	Category
1	0.00	Immune (I)
2	0.1 – 20	Resistant (R)
3	20.1 – 40	Moderately resistant (MR)
4	40.1 – 60	Moderately susceptible (MS)
5	60.1 – 80	Susceptible (S)
6	80.1 – 100	Highly susceptible (HS)

extracted with 50 mL of 2.4% HCl for 1 h at an ambient temperature and centrifuged (3000 xg/30 min). The clear supernatant was used for the phytate estimation. One milliliter of Wade reagent (0.03% solution of FeC13.6H2O containing 0.3% sulfosalicylic acid in water) was added to 3mL of the sample solution and the mixture was centrifuged. The absorbance at 500nm was measured using spectrophotometer. The phytate concentration was calculated from the difference between the absorbance of the control (3 mL of water+1 mL Wade reagent) and that of assayed sample. The concentration of phytate was calculated using phytic acid standard curve and results were expressed as phytic acids in g per 100 g dry weight.

Trypsin inhibitor: Trypsin inhibitor activities were determined using the procedure of Kakade et al. (1974). One gram of defatted seed flour was mixed with 100 ml of 0.009 HCl. The mixture was shaken at an ambient temperature for 2 h and centrifuged (10000xg/ 20 min) and the supernatant was used for inhibitor estimation. The diluted extract (1ml) was incubated with 1 ml of trypsin solution at 37°C for 10 min. A 2.5 ml of prewarmed substrate (BAPNA) was added and after exactly 10 min at 37°C the reaction was stopped with 0.5 ml of acetic acid (30%, v/v). The absorbance was measured at 410 nm against a blank using a spectrophotometer.

Tannins: Total tannins were determined as described in the A.O.A.C. (1990).

Statistical analysis

Data obtained were subjected to statistical analysis using analysis of variance for randomized complete block design, with sesame genotypes as a whole plot and replicates as blocks. Statistical analysis was done for sesame genotypes with their pathogens as well as anti-nutritional factors were estimated using CoStat Version 6.311 (CoHort software, Berkeley, CA 94701). Treatments' means were compared using Duncan's Multiple Range Test (Steel and Torrie, 1980). Probability levels lower than 0.05 or 0.01 were held to be significant.

The relationships between the four sesame crop [resistant (R), moderately resistant (MR), moderately susceptible (MS) and susceptible (S)] due to the interaction with two fungal pathogens (*F. oxysporum* and *M. phaseolina*) and the anti-nutritional factors (phytic acid, a-amylase inhibitor and trypsin inhibitor, and tannins were analyzed by regressions. The best equations to fit the relations were chosen by regression procedures with selection of forward, backward and stepwise methods. The relationships were analyzed comparing the slops of the linear regressions using a covariance analysis (Antunez et al., 2001).

RESULTS

The infection percentage and seed yield (kg/ha) of sesame genotypes infected with both fungal pathogens *F. oxysporum* (FOS) and *M. phaseolina* (MHP) in the two growing seasons (2009 and 2010) are presented in Tables 3 and 4, respectively. Highly significant variations were observed among the evaluated sesame genotypes based on the infection percentages and seed yield at infection by *F. oxysporum* (Tables 3) and *M. phaseolina* (Table 4). The infection percentages recorded for both pathogens varied among sesame genotypes from 1.7% (S_2) with rank of resistance (R) to 61.6% (H_4) with rank of susceptible (S) for FOS (Table 3) and from 2.2% (H_9) with rank of resistance (R) to 54.2% (LR_{17}) with rank of moderately susceptibility (MS) for MPH (Table 4) in the first season (2009). In the second season (2010) however, it ranged from 1.4% (H_1) as resistance to 54.2% as a moderately susceptibility (FOS, Table 3) and from 3.7% (Toshka 2) as resistance to 55.1% as moderately susceptibility (MPH, Table 3). The seed yield (kg/ha) ranged from 416.8 to 886.4 kg ha^{-1} (Table 3) and 443.2 to 917.5 kg ha^{-1} (Table 4), in 2009 under infection of *F. oxysporum* (FOS) and *M. phaseolina* (MHP), respectively, while in 2010, the values obtained ranged from 374.4 to 873.1 kg ha^{-1} for FOS and 409.5 to 884.8 kg ha^{-1} for MHP in Tables 3 and 4, respectively.

The most evaluated sesame genotypes were gathered in the scale of resistance (R) and moderate resistance (MR), while neither immune (I) genotypes nor highly susceptibility (HS) genotypes among all tested sesame genotypes were observed for both fungal pathogens *(F. oxysporum* and *M. phaseolina*) in the two seasons (2009 and 2010). On averaged over the two seasons, 49.0 and 38% at the infection of *F. oxysporum* (FOS) and 49.0 and 44% at the infection of *M. phaseolina* (MPH) were gathered in the scale of resistance (R) and moderate resistance (MR), respectively. However, only 13 and 7% of the tested sesame genotypes (averaged over the two seasons) at infection with *F. oxysporum* and *M. phaseolina,* respectively were grouped in the scale of moderately susceptible (MS) and susceptible (S). Among all tested sesame genotypes only one genotype tagged no.17 (U C. R 11 x Giza 25) possessed the rank of susceptible (S) with infection rate (61.00) by *F. oxysporum* only in the first season (2009), while this changed to the rank of moderately susceptible (MS) by infection rate of 44.00 in the second season (2010). On the other hand, the same genotype (U C. R 11 x Giza 25) under *M. phaseolina* infection, possessed the rank of moderately susceptible (MS) with infection rate of 32.50 and 21.40 in seasons 2009 and 2010, respectively (Table 4). It was noted also that the sesame genotypes such as Toshka 2, U N. A 130, H1, H 8, H9, S1, S 2 and S5 had the resistance (R) rank under infection by *F. oxysporum* or/and *M. phaseolina* through both seasons (2009 and 2010).

For this instance, it is very interesting to report that, some sesame genotypes such as Toshka 2, H1, H9 and L.R15 kept their resistance characteristic over the two fungal pathogens. Other genotypes possessed the resistance (HR) or moderately resistance rank (MR) to one or two diseases/ fungal pathogens and changed their behavior to moderately susceptible (MS) or susceptible (S) with the other pathogen such as H 4 and H 10 for *F. oxysporum* (FOS) and L.R7 for *M. phaseolina* (MPH). However, it should be taken into account that by contrast, some genotypes lost their susceptible (S) or moderately susceptible (MS) rank with pathogen to be more resistance (R) or, moderately resistance (MR) to other fungal pathogen.

By viewing to the data obtained, it can conclude that fascinatingly, 68, 57 and 44% in season 2009 and 78, 73

Table 3. Infection percentage and seed yield (kg/ha) of 48 sesame genotypes studied for the fungal pathogens (*F. oxysporum*) in 2009 and 2010.

S/N	***Fusarium oxysporum* f. sp. *sesami*, FOS**						S/N	***Fusarium oxysporum* f. sp. *sesami*, FOS**					
	Season, 2009			**Season, 2010**				**Season, 2009**			**Season, 2010**		
	Infection (%)	**Rank**	**Yield (kg /ha)**	**Infection (%)**	**Rank**	**Yield (kg /ha)**		**Infection (%)**	**Rank**	**Yield (kg /ha)**	**Infection (%)**	**Rank**	**Yield (kg/ha)**
1	25.40	MR	665.3	9.60	R	817.6	25	1.70	R	873.1	2.70	R	896.7
2	16.00	R	763.8	12.90	R	817.1	26	16.70	R	802.2	20.50	MR	710.9
3	21.70	MR	717.7	16.20	R	756.5	27	20.00	R	717.9	22.70	MR	694.3
4	19.20	R	606.8	20.00	R	814.1	28	6.90	R	865.3	10.10	R	815.3
5	17.10	R	737.1	23.30	MR	680.0	29	15.10	R	749.5	21.10	MR	801.0
6	12.10	R	787.4	13.80	R	861.8	30	25.50	MR	690.5	33.50	MR	737.3
7	3.40	R	886.4	3.20	R	575.6	31	30.30	MR	679.1	32.30	MR	679.1
8	58.90	MS	598.3	47.70	MS	661.8	32	30.20	MR	678.8	42.20	MS	636.7
9	27.10	MR	635.1	14.20	R	784.4	33	19.00	R	749.5	21.00	MR	702.7
10	42.70	MS	512.9	19.80	R	727.5	34	20.20	MR	751.6	26.20	MR	845.2
11	31.10	MR	619.4	28.00	MR	678.4	35	50.20	MS	433.1	54.20	MS	456.5
12	13.10	R	812.9	6.80	R	875.6	36	45.60	MS	515.3	38.90	MR	506.4
13	18.50	R	709.7	9.30	R	530.5	37	22.90	MR	678.8	16.90	R	721.0
14	9.20	R	820.2	1.40	R	608.4	38	38.20	MR	644.0	30.20	MR	620.6
15	20.6	MR	774.3	14.90	R	797.7	39	40.70	MS	492.1	48.70	MS	450.0
16	15.80	R	773.1	14.90	R	783.9	40	15.80	R	854.3	23.80	MR	821.6
17	61.60	S	416.8	44.00	MS	519.5	41	16.00	R	751.8	20.00	R	798.6
18	27.70	MR	696.4	12.80	R	774.1	42	30.10	MR	655.7	24.10	MR	697.8
19	1.80	R	855.0	2.30	R	880.1	43	15.10	R	819.7	11.10	R	838.4
20	23.40	MR	683.3	10.80	R	822.5	44	21.20	MR	797.0	17.20	R	801.7
21	18.80	R	775.2	6.70	R	561.6	45	20.10	MR	702.2	20.10	MR	800.5
22	3.90	R	831.4	7.90	R	810.8	46	25.10	MR	609.6	31.10	MR	647.0
23	41.50	MS	599.0	23.60	MR	374.4	47	22.20	MR	702.7	18.20	R	707.4
24	7.50	R	869.3	9.40	R	886.6	48	45.30	MS	643.7	37.30	MR	671.8
LSD (0.05)	___	_____	_____	_____	_____	_____		2.7	_____	59.90	2.6	_____	31.82

R = Resistance, MR= moderately resistance, MS = moderately susceptibility, S =susceptible and HS = highly susceptibility.

and 65% in season 2010 of resistance genotypes for FOS and 68, 78 and 61% in 2009 and 70, 76 and 56% in 2010 of resistance genotypes for MPH had a high of anti-nutritional factors, and are medium anti-nutritional factors and having low anti-nutritional factors, respectively. However, 22, 17 and 11% in 2009 and 14, 10 and 8% in 2010 of resistance genotypes to FOS and 25, 13 and 8 % in 2009 and 17, 14 and 5% in 2010 of resistance genotypes to MPH had high seed yield kg/ha, medium seed yield kg/ha and low seed yield kg/ha, respectively.

Analysis of variance was performed for the anti-nutritional factors (phytic acid, trypsin inhibitor and tannins) among the four sesame groups (resistant,

Table 4. Infection percentage and seed yield (kg/ha) of 48 sesame genotypes studied for the fungal pathogens (*M. phaseolina*) in 2009 and 2010.

S/N	***Macrophomina phaseolina,* MPH**						S/N	***Macrophomina phaseolina,* MPH**					
	Season, 2009			**Season, 2010**				**Season, 2009**			**Season, 2010**		
	Infection (%)	**Rank**	**Yield (kg/ha)**	**Infection (%)**	**Rank**	**Yield (kg /ha)**		**Infection (%)**	**Rank**	**Yield (kg /ha)**	**Infection (%)**	**Rank**	**Yield (kg /ha)**
1	20.40	MR	691.2	14.40	R	837.0	25	4.10	R	887.3	3.80	R	853.2
2	26.20	MR	686.8	16.50	R	762.4	26	2.60	R	917.5	4.20	R	893.4
3	24.20	MR	692.4	16.30	R	803.3	27	16.20	R	770.6	21.80	MR	702.0
4	18.00	R	747.2	3.70	R	890.4	28	10.30	R	830.2	10.00	R	832.6
5	15.30	R	738.7	3.70	R	892.5	29	16.10	R	749.0	22.10	MR	795.8
6	15.60	R	761.2	16.10	R	781.1	30	16.10	R	702.2	13.80	R	744.4
7	9.00	R	824.6	7.90	R	444.6	31	11.00	R	795.8	17.00	R	884.8
8	26.10	MR	777.8	20.10	MR	825.6	32	20.10	MR	714.2	20.10	MR	686.1
9	30.10	MR	463.6	11.60	R	848.7	33	20.10	MR	772.9	30.10	MR	730.8
10	23.50	MR	758.6	20.10	MR	698.7	34	20.30	MR	796.1	22.30	MR	772.7
11	14.20	R	631.1	14.20	R	814.8	35	45.10	MS	562.1	55.10	MS	604.2
12	33.40	MR	524.2	25.60	MR	662.9	36	20.30	MR	669.0	22.30	MR	734.5
13	31.90	MR	565.1	13.90	R	670.9	37	25.10	MR	690.8	31.10	MR	714.2
14	10.80	R	794.0	7.10	R	526.5	38	23.30	MR	702.2	19.30	R	833.3
15	30.40	MR	649.4	17.60	R	790.0	39	32.20	MR	749.5	30.20	MR	702.7
16	13.20	R	819.2	21.70	MR	698.0	40	32.10	MR	778.3	26.10	MR	764.2
17	32.50	MR	648.4	21.40	MR	727.0	41	25.30	MR	690.5	29.30	MR	704.6
18	33.10	MR	624.8	17.90	R	764.7	42	16.50	R	808.5	20.50	MR	827.2
19	36.80	MR	502.2	23.70	MR	636.2	43	25.20	MR	714.2	33.20	MR	681.4
20	19.30	R	711.6	9.80	R	819.9	44	18.10	R	807.5	20.10	MR	830.9
21	19.20	R	724.5	9.80	R	518.8	45	19.20	R	750.2	19.20	R	754.9
22	2.20	R	892.9	5.80	R	834.2	46	17.00	R	797.7	21.00	MR	839.8
23	52.20	MS	443.2	42.30	MS	409.5	47	23.40	MR	807.8	19.40	R	784.4
24	20.00	R	703.2	6.10	R	856.7	48	40.20	MS	632.3	48.20	MS	672.0
LSD (0.05)	_____	_____	_____	_____	_____	_____	___	2.1	_____	41.42	2.3	_____	28.08

R = Resistance, MR= moderately resistance, MS = moderately susceptibility, S =susceptible and HS = Highly susceptibility.

moderately resistant, moderately susceptible and susceptible). According to the results, highly significant differences were noted among the sesame groups for phytic acid, a-amylase inhibitor and trypsin inhibitor, lectin, and tannins (Table 5), indicating high variability among genotypes.

Mean values of phytic acid, trypsin inhibitor, and tannins in the four sesame genotype groups are presented in Table 6. Significant differences were observed among the resistant, moderately resistant, moderately susceptible and susceptible sesame genotype groups for their anti-nutritional factors. Moreover, the phytic acid, trypsin inhibitor and tannins as a anti-nutritional there were a significant variations among them within each of

Table 5. Mean squares of phytic acid, trypsin inhibitor and tannins in four sesame genotype groups through average of the two seasons (2009/2010).

S.O.V.	Degree of freedom	Anti-nutritional factors		
		Phytic acid	Trypsin inhibitor	Tannins
Replication	2	n.s	n.s	n.s
Sesame genotype groups	3	6.18 **	19.78**	491.01**
Error	9	1.69	4.01	25.98

*Significant at *P<0.05*, **Significant at *P<0.01*, NS= Non-significant.

Table 6. Mean values of phytic acid, and trypsin inhibitor and tannins in four sesame genotype groups through average of the two seasons (2009/2010).

Sesame genotype groups	Anti-nutritional factors		
	Phytic acid (%)	Trypsin inhibitor (TIU/ ml)	Tannins (mg/100 g)
Resistant (R)	6.07	12.79	413.67
Moderately Resistant (MR)	5.02	9.13	381
Moderately Susceptible (MS)	3.14	5.27	334
Susceptible (S)	2.94	4.40	218.67
L.S.D., 0.05	1.11	3.09	30.67

sesame group, whereas the phytic acid content was differed significantly among the all sesame groups with high value (6.07) in seed of the resistance (R) sesame crop, but decreased to score latest one (2.94) in seed of susceptible (S) group.

Trypsin inhibitor showed significant differences through all sesame groups, where the two sesame groups (resistant and moderately resistant) differed significantly among themselves as well as with the other two groups (moderately susceptible and susceptible). However, these two sesame groups moderately susceptible (MS) and susceptible (S) did not differ significantly from each other. These four sesame groups possessed 12.79, 9.13, 5.27, and 4.40 as trypsin inhibitor values, respectively (Table 6).

Tannins content in resistant sesame group (R) was the highest (413.67) and differed significantly from those of moderately resistant (381), moderately susceptible (334), and susceptible (218.67) groups. However, both sesame groups (moderately resistant and moderately susceptible) did not show any significant difference from each other, but differed significantly from the susceptible group. Therefore, it was apparent that the resistant (R) class possessed the highest values of the anti-nutritional factors, while the lowest values were related to the susceptible (S) class of sesame group. On the other hand, the two classes of the moderately resistant and moderately susceptible sesame genotypes possessed the medium values of phytic acid, trypsin inhibitor and tannins over average of the two seasons (Table 6).

In order to evaluate and select the predictive and reliable chemical or physiological traits that can be used as screening criteria for resistance to Fusarium wilt (*F. oxysporum*) and charcoal root rot (*M. phaseolina*) diseases among the sesame genotype groups, an objective measure based on the relationship among phytic acid, trypsin inhibitor and tannins as well as the four groups of sesame genotypes (resistant, moderately resistant, moderately susceptible and susceptible) and seed yield were adopted. These relationships were explored according to the class resistance or susceptibility of sesame genotypes containing anti-nutritional factors and their seed yield through 2009 and 2010 seasons (Table 7). If the coefficient of determination (R^2) is significant, these traits may reflect the degree of genotypic variation of sesame genotype groups. The significant value of the determination coefficient (R^2) may indicate to be a useful criteria for evaluation and assessment the content of phytic acid, trypsin inhibitor, tannins in sesame seeds genotypes with their relationship of the resistance or susceptible rank to the Fusarium wilt (*F. oxysporum*) disease and charcoal root rot disease (*M. phaseolina*). A quadratic regression equation based on stepwise analysis best fit the relationship. In general, most of these relationships showed significant correlations in both seasons (2009 and 2010) for the two fungal pathogens (FOS and MPH) together (Table 7).

A linear regression, through a covariance analysis, of sesame groups under both fungal pathogens together was used in studying the relationship between the anti-nutritional factors and the four sesame groups infected by both pathogens (FOS and MPH). Also, seed yield was considered in this relationship studied. Anti-nutritional factors were considered as the dependent variables (Y), with the four sesame genotype groups as independent variables (X).

Table 7. Regression equations and correlation coefficients between phytic acid, trypsin inhibitor and tannins sesame genotypes group through the seasons 2009 and 2010.

Sesame genotypes group	Anti-nutritional factors	
	2009	2010
	Regression equation (R^2)	Regression equation (R^2)
	Phytic acid	
Resistant (R)	0.62**	0.57**
Moderately resistant (MR)	0.11^{ns}	0.04^{ns}
Moderately susceptible (MS)	0.31**	0.29**
Susceptible (MS)	0.19*	0.12*
	Trypsin inhibitor	
Resistant (R)	0.22*	0.20*
Moderately resistant (MR)	0.21*	0.01^{ns}
Moderately susceptible (MS)	0.45**	0.39**
Susceptible (MS)	0.14*	0.16*
	Tannins	
Resistant (R)	0.52**	0.60**
Moderately resistant (MR)	0.25 *	0.21*
Moderately susceptible (MS)	0.61**	0.55**
Susceptible (MS)	0.42**	0.34**

For sesame groups, all sesame genotypes (independent variables) were classified into four groups *via* resistant, moderately resistant, moderately susceptible and susceptible according their interaction with FOS and MPH, while the anti-nutritional factors (dependent variables) *via* phytic acid, trypsin inhibitor, and tannins. These two variables (independent and dependent), represented by 24 equivalent equations and fitted as they followed:

Phytic acid, (Equations 1 - 8)

Results of the equations (Equations 1, 2, 3, 4, 5, 6, 7 and 8), indicated that the relationship between sesame groups (resistant, moderately resistant, moderately susceptible and susceptible) and the phytic acid, which were analyzed simultaneously, showed significant correlation in all groups, except moderately resistant group (Table 7). However, the sesame genotypes that had high phytic acid were the only covariate which is significantly correlated with the resistance (R) rank at low infection by FOS and MPH as well as high potential seed yield (kg/ha) in both seasons (Equations 1 and 2), while low phytic acid showed correlation with the susceptible group and seed yield (Equations 7 and 8). The moderately resistant (Equations 3 and 4) and moderately susceptible (Equations 5 and 6) sesame groups were medium in their correlations with phytic acid. The results in the first season (2009) showed similar trend with the results in the second season (2010).

$$Y = 34.6 - \underset{(t=-1.91)^{0.05}}{11.32X_1} + \underset{(t=-0.72)^{0.54}}{3.29X_2} \quad (2009) \quad (1)$$

$$Y = 31.16 - \underset{(t=-1.93)^{0.05}}{10.33X_1} - \underset{(t=-0.52)^{0.54}}{2.91X_2} \quad (2010) \quad (2)$$

Where; Y, X_1 and X_2 are, the phytic acid, the resistant (R) sesame group and seed yield (kg/ha), respectively.

$$Y = 21.6 - \underset{(t=-1.73)^{0.05}}{10.25X_1} - \underset{(t=-0.52)^{0.54}}{1.99X_2} \quad (2009) \quad (3)$$

$$Y = 19.16 - \underset{(t=-1.90)^{0.25}}{9.13X_1} - \underset{(t=-0.62)^{0.50}}{1.79X_2} \quad (2010) \quad (4)$$

Where; Y, X_1 and X_2 are, phytic acid, the moderately resistant (MR) sesame group seed yield (kg/ha), respectively.

$$Y = 23.12 - \underset{(t=-0.21)^{0.84}}{0.94X_1} + \underset{(t=0.52)^{0.61}}{3.04X_2} \quad (2009) \quad (5)$$

$$Y = 22.71 - \underset{(t=-1.7)^{0.10}}{1.32X_1} - \underset{(t=0.41)^{0.69}}{2.11X_2} \quad (2010)\ (6)$$

Where; Y, X_1 and X_2 are, the phytic acid, the moderately susceptible (MS) sesame group and seed yield (kg/ha), respectively.

$$Y = 18.55 - \underset{(t=-1.03)^{0.05}}{10.20X_1} - \underset{(t=-0.72)^{0.51}}{1.91X_2} \quad (2009)\ (7)$$

$$Y = 15.63 - \underset{(t=-1.03)^{0.04}}{8.39X_1} - \underset{(t=-0.22)^{0.14}}{1.82X_2} \quad (2010)\ (8)$$

Where; Y, X_1 and X_2 are, the phytic acid, the susceptible (S) sesame group and seed yield (kg/ha), respectively.

Trypsin inhibitor, (Equations 9 - 16)

In respect of trypsin inhibitor, R^2 ranged from highly significant to significant values in all cases in both seasons, except moderately resistant (MR) group only in the second season (Table 7). However, Equations from 17 to 24, inferred that the values of dependent variable (trypsin) increase by increasing that of in dependent variables gradually from susceptible (S) sesame group through resistance (R) sesame group to seed yield (kg/ha).

$$Y = 31.36 - \underset{(t=-1.93)^{0.05}}{11.23X_1} - \underset{(t=-0.62)^{0.54}}{3.92X_2} \quad (2009)\ (9)$$

$$Y = 28.62 - \underset{(t=-1.93)^{0.05}}{12.12X_1} - \underset{(t=-0.62)^{0.54}}{2.19X_2} \quad (2010)\ (10)$$

Where; Y, X_1 and X_2 are, trypsin inhibitor, the resistant (R) sesame group, and seed yield (kg/ha), respectively.

$$Y = 14.23 - \underset{(t=-1.13)^{0.02}}{1.98X_1} - \underset{(t=-0.32)^{0.14}}{3.44X_2} \quad (2009)\ (11)$$

$$Y = 11.26 - \underset{(t=-1.73)^{0.15}}{1.34X_1} - \underset{(t=-0.64)^{0.44}}{2.49X_2} \quad (2010)\ (12)$$

Where; Y, X_1 and X_2 are, trypsin inhibitor, the moderately resistant (MR) sesame group and seed yield (kg/ha), respectively.

$$Y = 13.16 - \underset{(t=-1.43)^{0.45}}{4.13X_1} - \underset{(t=-0.12)^{0.64}}{1.49X_2} \quad (2009)\ (13)$$

$$Y = 12.11 - \underset{(t=-1.90)^{0.15}}{3.34X_1} - \underset{(t=-0.22)^{0.14}}{1.19X_2} \quad (2010)\ (14)$$

Where; Y, $X1$ and X_2 are, trypsin inhibitor, the moderately susceptible (MS) sesame group, and seed yield (kg/ha), respectively.

$$Y = 11.66 - \underset{(t=-2.03)^{0.25}}{10.30X_1} - \underset{(t=-0.64)^{0.94}}{0.91X_2} \quad (2009)\ (15)$$

$$Y = 10.46 - \underset{(t=-2.93)^{0.04}}{9.13X_1} - \underset{(t=-0.42)^{0.14}}{0.79X_2} \quad (2010)\ (16)$$

Where; Y, X_1 and X_2 are, trypsin inhibitor, the susceptible (S) sesame group and seed yield (kg/ha), in respectively.

Tannins, (Equations 17 - 24)

Significant to highly significant values of R^2 were shown in each of the seasons (2009 and 2010) among the four sesame groups for tannins (Table 7). The dependent variable tannins (Y) increased gradually in the sesame group from susceptible class to resistant class, including the moderately susceptible class as well as moderately resistant class (Equations 33 to 40). This increase indicates that high level of tannins was related to resistance of sesame group, while the low level of tannins was related to susceptible class. The seed yield (kg/ha) also increased gradually from low tannins containing sesame group to high tannin containing one.

$$Y = 9.96 - \underset{(t=-2.93)^{0.04}}{10.11X_1} + \underset{(t=-0.42)^{0.50}}{3.41X_2} \quad (2009)\ (17)$$

$$Y = 9.66 - \underset{(t=-0.13)^{0.05}}{10.01X_1} - \underset{(t=-0.62)^{0.14}}{3.01X_2} \quad (2010)\ (18)$$

Where; Y, X_1 and X_2 are, tannins, the resistant (R) sesame group, and seed yield (kg/ha), respectively.

$$Y = 8.01 - \underset{(t=-1.03)^{0.25}}{6.63X_1} - \underset{(t=-0.22)^{0.24}}{1.94X_2} \quad (2009) \tag{19}$$

$$Y = 7.52 - \underset{(t=-1.53)^{0.55}}{2.93X_1} - \underset{(t=-0.52)^{0.54}}{0.98X_2} \quad (2010) \tag{20}$$

Where; Y, X_1 and X_2 are, tannins, the moderately resistant (MR) sesame group, and seed yield (kg/ha), respectively.

$$Y = 10.16 - \underset{(t=-3.13)^{0.15}}{2.63X_1} - \underset{(t=-1.02)^{0.04}}{1.19X_2} \quad (2009) \tag{21}$$

$$Y = 8.77 - \underset{(t=-1.13)^{0.05}}{2.43X_1} - \underset{(t=-1.02)^{0.50}}{2.01X_2} \quad (2010) \tag{22}$$

Where; Y, X_1 and X_2 are, tannins, the moderately susceptible (MS) sesame group, and seed yield (kg/ha), respectively.

$$Y = 7.76 - \underset{(t=-1.90)^{0.05}}{2.93X_1} - \underset{(t=-0.62)^{0.54}}{1.32X_2} \quad (2009) \tag{23}$$

$$Y = 6.66 - \underset{(t=-3.13)^{0.15}}{2.39X_1} - \underset{(t=-1.62)^{0.04}}{1.9X_2} \quad (2010) \tag{24}$$

Where; Y, X_1 and X_2 are, tannins, the susceptible (S) sesame group, and seed yield (kg/ha), respectively.

DISCUSSION

Various diseases cause considerable damage to crop plants and reduce their yield. Successful breeding for disease resistance has occurred in many different crop types, including vegetables, fruits, field crops and ornamentals. Because field crops are considered as low value crops compared with fruits and vegetables, control costs must be minimized and it is in these crops that host plant resistance breeding has had the most attention and success. Therefore, success of improving the disease resistance of genotypes requires an effective and reliable screening attitude of characters in breeding programs. However, since field study of plant reaction to the fungal pathogens is difficult, laborious and time consuming, breeders often search for easily and rapidly evaluated characters that are correlated with resistance to diseases. The highly significant values, which were observed among sesame genotypes or sesame groups in resistance to fungal diseases (FOS and MPH) and seed yield, indicated the presence of sufficient variability for all investigated sesame genotypes, which could be valuable in a further breeding program for wilt and charcoal root rot diseases management with high seed yield. Also, the significant differences in the anti-nutritional factors (phytic acid, trypsin inhibitor and tannins) of the sesame genotypes / sesame groups in both seasons (2009/2010), confirmed the presence of fair amount of genetic variability considered adequate for further bio-anti-nutritional factors assessment in sesame genotypes considered in this work. These findings are more or less in agreement with those reported by several investigators (El-Shakhess, 1998; Chattopadhyay and Kalpana, 2000; Dinakaran and Mohammed, 2001; Philip et al., 2007; Nzikou et al., 2009; El-Bramawy et al., 2009 a, b; Akande et al., 2010) who worked with different sesame populations under various conditions.

The characterization of the four sesame genotypes groups (resistant, moderately resistant, moderately susceptible and susceptible), possessed differences significant, base on presence or absence of anti-nutritional factors in their seeds. Anti-nutritional factors (phytic acid, trypsin inhibitor and tannins) seeds estimated were highly variable in sesame seeds. Similarity coefficients among these four sesame genotype groups, showed a wide variability range, where the relationships among these (Anti-nutritional factors) can be observed clearly (Tables 5 and 6). This indicates that, there is a great adjustment to the sesame genotypes used (four sesame group) in the similarity behavior, based on the high value of the phytate, trypsin, a-amylase inhibitors, lectin and tannins in sesame seeds.

According to these findings presented in Table 5, there is a very close relationship among sesame group and anti-nutritional factors, with incidence of Fusarium wilt (caused by *F. oxysporum*) and charcoal root rot (caused by *M. phaseolina*) fungal pathogens on sesame. Susceptible sesame group showed the lowest values for phytate, trypsin, a-amylase inhibitors, lectin and tannins (Table 6). Laurentin et al. (2003) found similar results when they evaluated the same six genotypes during two years in Turén, Venezuela. Bergvinson et al. (1997) indicated that, the behavior of some diseases and insects can be influenced by the nutritional quality of plants on which they infect or feed.

The resistance (R) and moderately resistance (MR) to both fungal pathogens (FOS and MPH) are the famous cases among all classes, indicating the high ability of sesame genotypes for resistance to the pathogens and keeping a good, fairly high seed yield potential. This also explains the absence of highly susceptible (HS) genotypes among all tested sesame genotypes through the two seasons (2009 and 2010). These results are in harmony with those reported by Gaber et al. (1998), Khaleifa (2003), El-Bramawy (2006a, b), Bayoumi and El-Bramawy (2007), and El-Bramawy and Shaban (2008). Also, the nonexistence of immune (I) sesame genotypes was reported before by Li et al. (1991), El-Bramawy, (2003) and El-Bramawy et al. (2009a, b).

Sesame genotypes, which kept their resistant (R) characteristic over the two fungal pathogens such as Toshka 2, H1, H9 and L.R15, exhibited their stability level to both pathogens. While, the genotypes, which possessed the high resistance (HR) or moderately resistance rank (MR) to one or two diseases/ fungal pathogens and changed their behavior to be moderately susceptible (MS) or susceptible (S) to the other pathogen such as H 4 and H 10 for *F. oxysporum* (FOS) and L.R7 for *M. phaseolina* (MPH), indicated non stability or variable stability according to conditions of their interaction with the pathogens. The stability and non-stability of sesame genotypes with fungal pathogens were detected before (El-Shakhess, 1998; El-Bramawy, 1997, 2003 and 2006; Bayoumi and El-Bramawy, 2007; El-Bramawy and Shaban, 2008; El-Bramawy et al., 2009a, b). However, the genotypes, which lost their susceptible (S) or moderately susceptible (MS) rank to pathogen to be more resistance (R) or, moderately resistance (MR) fungal pathogens indicated improvement in their resistant characteristics to diseases causing fungal pathogens.

Plant resistance to diseases has reportedly been associated with fungal pathogens, mainly *F. oxysporum* and *M. phaseolina* density in field crops (Ragab et al., 2002; Baydar, 2005; Sarwar and Haq, 2006; El-Bramawy et al., 2009a, b; El-Bramawy, 2010). However, very few papers have reported biochemical compounds of plants conferring resistance to *F. oxysporum* (FOS) and *M. phaseolinan* (MPH). Highly significant differences were detected among the sesame groups for phytic acid, a-amylase inhibitor and trypsin inhibitor, lectin, and tannins (Table 5), indicating high variability among sesame genotypes groups, which varied in their content of the anti-nutritional factors, hence varied in their reaction with fungal pathogens (FOS and MPH). These variations could be confirmed with the selection for the high content of phytic acid, trypsin inhibitor and tannins, which could also confer more resistance on sesame genotypes against each of *F. oxysporum* (FOS) and *M. phaseolina* (MPH). However, the significant differences, which were observed among the resistant, moderately resistant, moderately susceptible and susceptible sesame genotype groups for their content of the anti-nutritional factors (Table 6), confirmed the enhancement in the feasibility of selection for the high levels of phytic acid, trypsin inhibitor and tannins, which were more related to the resistant characters. While, the moderate to low values of these anti-nutritional factors were so related to the moderate to low susceptible characters respectively.

These findings are in harmony with the results reported by Li et al. (1991) and El-Bramawy et al. (2009 b). Due to the presence of the significant relationship, which noted between the anti-nutritional factors as dependent variables (phytic acid, trypsin inhibitor and tannins) and sesame groups (resistant, moderately resistant, moderately resistant and susceptible) as independent variables, it is possible to put our hands on the positive relationship between the level of resistance in sesame genotype seeds with the pathogenic fungi (FOS and MPH) and their contents of phytic acid, or trypsin inhibitor or tannins as a typical chemical in the sesame seeds. hese results were more or less agreements with the results reported by Hatano et al. (1989), Tazawa et al. (2000), Oliveira et al. (2002), Leandro et al. (2008), El-Bramawy et al. (2009a) through their working on some field crops.

Since sesame genotypes differed in their response to the fungal pathogen (FOS and MPH) as well as in their chemical components in seeds, the anti-nutritional factors could be adopted as screening criteria in building a breeding program for resistance to *F. oxysporum* and *M. phaseolina*, which cause Fusarium wilt and charcoal root rot diseases, respectively. Similar findings were reported by several authors (El-Fiki et al., 2004; El-Bramawy, 2006 and 2008; El-Bramawy and Shaban, 2007; El-Bramawy and Abd Al-Wahid, 2009; El-Shakhess and Khalifa, 2007 Bayoumi and El-Bramawy, 2007; El-Bramawy et al., 2009 a, b).

Wu et al. (2000) reported that, the selection for chemical characters may be significant in the development of Amaranthus for resistance to root rot disease. Furthermore, Lee and Choi (1986) reported that the germplasm resources of sesame could be classified based on level of chemical components and these traits are controlled by one gene (nb) (Brar and Ahuja, 1979). These indicate that the trait of chemical components (anti-nutritional factors) in seeds may be possibly used as screening criteria, if it was associated with the infection percentage caused by the fungal pathogens (FOS and MPH). However, the results found also showed that all sesame genotypes were significantly correlated with the infection percentage by FOS and also with the infection percentage by MPH (Table 5). This result may be due to the fungus of the Fusarium wilt penetrating sesame plant roots and spreading up into the stem through the water conducting vessels which causes plants to wilt from the top down or rot from down (roots) and exhibits plant vessels that are plugged and damaged.

The concentrations of phytic acid, or a-amylase inhibitor or trypsin inhibitor or lectin, or tannins phenols and tannins in sesame seeds were considered an average of its group (data not shown). The findings of this study were in agreement with those reported by Islam et al. (2003), who found that Polyphenolics, of which tannins are a subset, are involved in seed character expression and are often associated with plant resistance to pathogens or insects. Statler (1970) also reported that the more total tannins and phenols in common bean plants causing the greater resistance to root-rot disease. Harris and Burns (1973) mentioned that, tannin is beneficial in the field due to the fact that its presence provide resistance to fungi and seed vivipary. El-Fiki et al. (2004) observed that the amounts of total tannins with phenols were obviously higher in the sesame entries that were classified as highly resistant and resistant than did those classified as susceptible and high susceptible sesame entries. Li et al. (1991) found in 2992 accessions of sesame depending on seed color, that the most resistance of sesame genotypes to MPH had white seed colors, while black or grey seeded genotypes tended to be susceptible, and yellow or brown seeded ones intermediate. El-Bramawy et al. (2009a) used the phenotypical traits (tannins and phenols contents) in forty-eight sesame accessions as selection criteria for Fusarium wilt and charcoal root rot diseases resistance for a breeding program. The detected desirable phenological trait could be transfer to high-yielding cultivars by using conventional hybridization, biotechnological and bridge techniques for the introgression of both diseases resistance genes. Therefore, it indicate that the sesame seed content of phytic acid, trypsin inhibitor and tannins could successfully be used to predict the resistance of sesame genotypes to Fusarium wilt (FOS) and charcoal root rot (MPH) diseases without conducting tedious field crop experiments. In addition, we suggest that this desirable phenological trait could be transfer to high-yielding cultivars by using conventional hybridization, biotechnological and bridge techniques for the introgression of wilt and charcoal rot diseases resistance genes.

For sesame groups, all sesame genotypes (independent variables) were classified to four groups via resistant (R), moderately resistant (MR), moderately susceptible (MS) and susceptible (S) according their interaction with FOS and MPH, while the anti-nutritional factors and infection percentage by *Fusarium oxysporum* f. sp. *sesami* (FOS) and/or *Macrophomina phaseolina* (MPH), might be a suitable attitudes for direct selection among the sesame genotypes for resistance to the Fusarium wilt (FOS) and/or charcoal root rot (MPH) diseases. Therefore, it can be concluded that the resistance (R) class possessed the highest values of the anti-nutritional factors, while the lowest values were related to the susceptible (S) class of sesame group. On the other hand, the two class of the moderately resistance and moderately susceptible possessed the medium values of phytic acid, trypsin inhibitor and tannins over average of the two seasons. Hence, these anti-nutritional factors could play a clear role and magnitude in the range of resistance or susceptible to fungal pathogens, *F. oxysporum* and *M. phaseolina* in sesame genotypes groups considering this work.

According to the regression equations and correlation coefficients between contents of phytic acid, or a-amylase inhibitor or trypsin inhibitor or lectin, or tannins, sesame genotype groups through the seasons 2009 and 2010 were listed in equations 1 to 40 and collected together in Table 7. Our results found that the sesame genotypes had medium or low phytic acid, a-amylase inhibitor and trypsin inhibitor and therefore had higher infection by FOS and MHP than did genotypes that had high contents of the above (phytic acid, trypsin inhibitor and tannins). The high rate of the phytic acid and trypsin inhibitor contents in the resistant sesame seeds genotypes may increase the levels of resistance to both of FOS and MPH, while low contents of them increase the susceptibility to infection by these fungal pathogens (Equations 1 to 16).

Because of a high contents of phytic acid, a-amylase inhibitor and trypsin inhibitor in sesame seeds, it can become a good favorable conditions for spreading the fungal pathogens, hence it cause the disease. Furthermore, as infection spreads, the water feeding system becomes blocked, therefore the water uptake has not been commensurate with the water transpiration so that the plants becomes more susceptible to fungi infection and increases symptom expression.

The results of our study found that the Fusarium wilt (FOS) or charcoal root rot (MPH) incidence were not correlated with some cases of resistance range (R and MR) or susceptible rank (MS and S) as noted in Table 7 in relation to their contents of phytic acid, a-amylase inhibitor and trypsin inhibitor. It means that the selection criteria by this way may be not suitable approach for direct selection among the sesame genotypes for resistance to Fusarium wilt and charcoal root rot diseases. These finding could be due to the fact that sesame plants can gets the infestation by the both pathogens at any stage of sesame crop development. In this regard, Songa et al. (1997) found that the sesame lines did not seem to influence or affect the susceptibility or resistance to MPH, which cause the charcoal root rot diseases of the various bean accessions.

Our results also found that the sesame genotypes having high level of tannins was generally more resistance to Fusarium wilt (FOS) and charcoal root rot (MPH) diseases than genotypes having low or moderate level (Table 7). These results are confirmed from the linear regression, through a covariance analysis between the infection percentages by FOS and MPH, and the four groups of sesame seed contents (Equations 17, 18, 19, 20, 21, 22, 23 and 24). The increase in resistance of genotypes to both fungal pathogens may be due to the increase in concentrations of total phenols and tannins in their seeds. Therefore, this increase indicates that high level of tannins was related to resistance in sesame groups, while the low level of tannins was related to susceptible class. The seed yield (kg/ha) was also increased gradually from low tannins contents to high tannins contents. These findings were in harmony with the results published before by El-Bramawy et al. (2009a, b).

Conclusion

The anti-nutritional factors in sesame seed genotypes were used as screening criteria for diseases resistance. Significant differences were obtained among sesame genotype groups (resistant, moderately resistant, moderately susceptible and susceptible) for their contents of the anti-nutritional factors. Resistant (R) class possessed the highest values of the anti-nutritional factors, while the lowest values were related to the susceptible (S) class of sesame group. While the moderately resistant and moderately susceptible classes were associated with the medium values of phytic acid, trypsin inhibitor, and tannins over the two seasons of assessment. Hence, these anti-nutritional factors could have played a clear role in the magnitude and range of resistance or susceptibility to fungal pathogens, FOS and MPH in sesame genotype groups considered in this work.

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