Indian Journal of Agronomy **66** (2): 199–206 (June 2021)

Research Paper

Yield, yield characteristics and sequential path analysis of sesame (*Sesamum indicum*) as affected by organic fertilizers

HEBA M. NOAMAN[1], HODA. E.A. IBRAHIM[2] AND D.S. RANA[3]

Agricultural Research Station Arab EL-Awamer, Agriculture Research Center, Assiut Governorate, Giza, Egypt 12511

Received: June, 2020 Accepted: June, 2021

ABSTRACT

A field experiment was conducted 2017 and 2018 at the experimental farm of Agricultural Research station, Arab EL-Awamer, Agriculture Research Center (A.R.C.), Assiut Governorate, Egypt, to evaluate the effect of different organic sources of nutrients superimposed on inorganic fertilizers on growth and yield of in sesame (*Sesamum indicum* L.). The experiment included 14 factorial treatments, consisting of 2 sesame cultivars, viz. 'Shandaweel 3' and 'Giza 32', and 7 combinations of cattle and sheep manures fertilizers. 'Shandaweel 3' cultivar exhibited significant superiority to 'Giza 32' sesame with regard to most of studied characters except first capsule height across the 2 seasons. Among the organics manures, application of 2.5 tonnes sheep manure and 4 tonnes cattle manure resulted in the maximum values of fruit zone length, 1,000-seed weight and seed yield in the 2 seasons with significant differences compared to the control. The interaction effect between cultivars and manures application was significant for all characters in the 2 seasons except first capsule height in the first season and fruit zone length in the second season. 'Shandaweel 3' fertilized with 2.5 tonnes sheep manure gave the maximum seed yield in both the seasons. Results revealed positive and highly significant association between seed yield and its all related characters except first capsule height, which had no significant correlation coefficient with seed yield. A sequential path analysis was used to order the various variables based on their maximum direct effect and minimal collinearity.

Key words: Cattle manure, Collinearity, Seed yield, Sesame, Sheep manure, Sequential path analysis

Sesame is an important oilseed crop in the tropics and sub-tropics. In Egypt, sesame is considered as a food crop rather than an oilseed crop because most of its seed is consumed directly, without oil extraction. It is grown mainly in developing countries by small-holder farmers, who rarely apply fertilizer. This results in both low yield and poor economic returns. However, significantly higher yields have been reported with the application of organic manure across different parts of the country. Manures application improves solubility and uptake of P from sparingly soluble P compounds in soil and enhances the utilization of P from P-containing fertilizers (Zeidan, 2007). Mondal *et al*. (1992) reported that, an application of 10 tonnes farmyard manure/ha significantly increased the seed yield of sesame compared to other levels of applied organic and inorganic fertilizers. Working on the effect of spacing and fertilizer application on the growth, yield and yield components of sesame, Suddhiyam *et al.* (2009) reported that, use of 3 types organic fertilizer improves *p*H, reduces environmental pollution, minimizes production costs and improves biological, physical and chemical properties of soils.

The organic fertilization can increase the organic carbon and induce the activity of microorganisms for providing nutrients as nitrogen and phosphorus in the soil (Abdullahi *et al*., 2013). Organic manures are main source of plant nutrients, especially of nitrogen and micronutrients. Zhen *et al*. (2014) noted that, large population of microorganisms are introduced to the soil through organic manure, which promoted N fixation and P solubilization.

Studying the relationships between grain yield and yield components can be carried out by simple correlation and path analysis. Simple correlation was used to study the relationship between grain yield and yield component traits by many of researchers. Ghaderi *et al*. (2009) indicated a significant positive association between grain yield and harvest index, biological yield and the number of spikes/m^2. Simple correlation analysis is not able to provide factual cognizance between response and predictor variables. Therefore, path analysis was used in the most cases to dis-

[1]Oil Crops Department, FCRI, ARC, Giza, Egypt; [2]Central Laboratory for Design and Statistical Analysis Research, ARC, Giza, Egypt; [3]Distinguished Professor, School of Agricultural Sciences, Sharda University Greater Noida, Uttar Pradesh

cover the real associations. This method which allows studying complex relationships between traits developed by Wright (1921) as a statistical tool and used to establish the causal relationships between predictor and response variables by path diagram.

In the most path analysis studies, researchers considered all traits as the first-order variable to analyse their effects on a dependent or response variable such as grain yield. This approach leads to multi-collinearity for predictor variables, and there may be difficulties in explaining the real contribution of each variable (Hair *et al*., 1995). To prevent this mistake explanation, researchers applied a sequential path analysis to determine the relationship between yield and yield components traits in sesame. Ganasekaran *et al*. (2008) indicated that, seed yield per plant had positive and highly significant association with number of branches per plant, number of capsules per plant and number of seeds per capsule and positive and significant association with capsule length and 1,000-seed weight.

Hence the present investigation was carried out to analyse the correlation between yield and related traits in sesame by applying the sequential path analysis and identify traits of genotypes which may prove useful in breeding higher yielding genotypes and find out the best rate of sheep manure and cattle manure with 2 sesame cultivars and the interaction between them.

MATERIALS AND METHODS

The field experiment was conducted at the Arab El-Awamer Agricultural Research Station, Giza, Egypt during the successive seasons of 2017 and 2018. Before initiation of experiment, the mechanical and chemical analysis of the experimental soil was done as per Jackson (1973). The soil was sandy, basic in reaction with *p*H 8.37 and electric conductivity 6.3 dS/m and bulk density is 1.63 Mg/m^3. Permanent wilting point, field capacity and saturation per cent of the experimental field were 4.5, 10.9 and 23.3 respectively. Plant nutrient status of the experimental field is given in table 1, which indicates that the soil is low in organic carbon and available and total nutrient status.

Cattle and sheep manures were used to provide different levels of nutrient across the treatments. These sources were analysed for its composition according to Black (1982) and composition is given in Table 2. The experiment was conducted in 3-times replicated split-plot design. In the experiment, 2 cultivars, viz. 'Shandaweel 3' and 'Giza 32', were allocated in the mainplots, while the subplots received 7 treatments of cattle and sheep manure as per detailed in Table 3, besides the recommended dose of NPK before sowing of the crop.

Table 2. The chemical composition of manures

Properties	Manure	
	Cattle	Sheep
Water content (%)	20.2	18.8
*p*H (H_2O)	6.6	6.7
Biological oxygen (%)	45.0	41.3
C, organic (%)	26.1	23.9
N, total (%)	1.05	1.01
C : N ratio	24.8	23.7
P_2O_5	0.50	0.75
K_2O	0.73	1.47

Seeds of 2 cultivars 'Shandaweel 3' and 'Giza 32' were sown on ridges, 50 cm apart and 3.5 cm high on 15 May in the first season and on 22 May in the second season. The type of irrigation used at this experiment was sprinkler irrigation. Distance between each 2 hills was 20 cm. Plants were thinned to 2 plants/hill. Each plot included 6 ridges. The plot size was 10.5 m^2 (3.5 m × 3.0 m). The recommended agricultural practices were applied for growing sesame. Recommended dose of NPK (45 kg N/fed; 32 kg P_2O_5/fed and 24 kg K_2O/fed) was applied in all the treatments through various inorganic sources. Calcium superphosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O) @ 32 kg P_2O_5)/fed and 24 kg K_2O/fed, respectively, and were added before planting. Nitrogen fertilizer @ 45 kg N/fed as ammonium nitrate (33.5% N) was applied as 1 dose.

Samples of 5 guarded plants were taken from each plot to measure plant height, (cm), first capsule height, fruit zone length, number of capsules/plant, 1,000-seed weight (g) and seed yield/plant (g). Seed yield (kg/fed.) was worked on not plot yield.

Analysis of variance was automated for each season according to Steel and Torrie (1984). Differences among the various means for different characters were compared using (CD) test at 0.05 probability level. Pearson correlation coefficients between various pairs of the characters were computed. Sequential step-wise multiple regression

Table 1. Soil organic carbon and nutrient status of the experimental site before cultivation.

Soluble cations (meq/L)				Soluble anions meq/L		Available phosphorus (ppm)	Total nitrogen (%)
Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}+ HCO_3^{-}	Cl^{-}		
1.43	1.16	0.19	0.75	1.68	1.47	8.31	0.003

Table 3. Treatment details along with nutrients as added from different sources

Treatment	Nitrogen (N kg/fed)		Phosphorus (P_2O_5 kg/fed)		Potassium (K_2O kg/fed)	
	Inorganic	Organic	Inorganic	Organic	Inorganic	Organic
Control (without fertilization)	45.0	0.0	32.0	0.0	24.0	0.0
2.0 tonnes/fed cattle manure	45.0	21.0	32.0	10.0	24.0	14.6
3.0 tonnes/fed cattle manure	45.0	31.5	32.0	15.0	24.0	21.9
4.0 tonnes/fed cattle manure	45.0	42.0	32.0	20.0	24.0	29.2
1.5 tonnes/fed sheep manure	45.0	15.2	32.0	11.3	24.0	22.05
2.0 tonnes/fed sheep manure	45.0	20.2	32.0	15.0	24.0	29.4
2.5 tonnes/fed sheep manure	45.0	25.3	32.0	18.7	24.0	26.7

was conducted to organize the predictor variables into first- and second-order on the basis of their respective contributions to the total variation of seed yield (SY) and minimal collinearity. The level of multicollinearity was measured from 2 common measures, namely, the tolerance value and the variance inflation factor (VIF) as suggested by Hair *et al*. (1995).

Tolerance value is the amount of variability of the selected independent variable not explained by other independent variables ($1\text{-}Ri^2$), where Ri^2 is the coefficient of determination for the prediction of variable i by the other predictor variables. Variance inflation factor indicates the extent of effects of other independent variables towards the variance of the selected independent variable [$VIF = 1/(1\text{-}Ri^2)$] (Mohammadi *et al*., 2003). Thus, very small tolerance value (much below 0.1) or large variance inflation factor value (above 10) indicate high collinearity (Hair *et al.,* 1995). Direct effects of the yield characters were estimated by the procedure described by Williams *et al*. (1990). Partial coefficient of determination (analogues to R^2 of linear regression) was calculated from the path coefficients for seed yield and related traits. Also, sequential path analysis diagram was drawn.

RESULTS AND DISCUSSION

Yield and yield attributes

Effect of cultivar

Significant differences between the 2 cultivars for all studied traits except for plant height and number of capsules/plant in the 2 seasons and zone fruit length in the second season were recorded (Table 4). Cultivar 'Shandaweel 3' was superior to 'Giza 32' with regard to all the studied characters except first capsule height in the 2 seasons. Cultivar 'Shandaweel 3' recorded the maximum plant height, fruit zone length, capsules/plant, seed weight/plant, 1,000-seed weight and seed yield in the 2 seasons. The results may be owing to the differences in genetic background between the 2 studied cultivars. The notable performance of 'Shandweel 3' may be attributed to its superiority in seed yield/feddan and its most components**.** These results are in agreement with those obtained by Abou-Taleb (2012). El-Samanody *et al*. (2010), Fakhry (2016) and Hassaan and Bughdady (2018) reported superiority of 'Shandaweel 3' in seed yield to 'Giza 32'.

Effect of sources of manure: The effect of cattle and sheep manure treatments on growth and yield attributes of sesame in 2017 and 2018 seasons are shown in Tables 4 and 5). Results showed that, there were significant differences among cattle and sheep manure fertilizer treatments for all the studied traits except first capsule height in the 2 seasons. The first capsule height ranged between 26.6 cm for 4 tonnes cattle manure/fed and 29.5 cm for 2 tonnes cattle manure/fed in the first season while its values in the second season ranged between 25.83 cm for 3 tonnes cattle manure/ha and 36.6 cm for the null fertilizer treatment of cattle and sheep manure (control). Tallest plants were obtained with by using 2.5 tonnes sheep manure, followed by 4 tonnes cattle manure, in the 2 seasons. The smallest plants were recorded by adding 2 tonnes cattle manure.

Application of 2.5 tonnes sheep manure and 4 tonnes cattle manure also resulted in the maximum values of fruit zone length, 1,000-seed weight and seed yield in the 2 seasons with significant differences compared to control treatment of cattle and sheep manure. In the first season, application of 2.5 tonnes sheep manure to the soil recorded 152.5 cm of fruit zone length, 5.99 g of 1,000-seed weight and 715.2 kg/fed of seed yield, while their corresponding values when applying 4 tonnes cattle manure were 147.5 cm, 5.50 g and 757.8 kg/fed for the above 3 mentioned traits respectively. In the second season, the soil fertilized with 2.5 tonnes sheep manure recorded 160.8 cm fruit zone length, 6.58 g 1,000-seed weight and 1,094.3 kg/fed seed yield, while their corresponding values with 4 tonnes cattle manure were 169.1 cm, 5.88 g and 926.1 kg/fed. These results indicate the importance of the organic manure in increasing seed yield and its attributes in sesame crop. These results confirm the findings of Kumar *et al*. (2009) and Ziedan *et al.* (2011).

The maximum number of capsules/plant were obtained

by applying 4 tonnes cattle manure, 1.5 and 2 tonnes sheep manure in terms of application of 4.0 tonnes cattle manure, 1.5, 2.0 and 2.5 tonnes of sheep manure in the first season (Table 5). When the soil was fertilized by 2 and 2.5 tonnes sheep manure, the sesame plants produced the highest number of capsules/plant in the second season. Considering the seed yield/plant, the application of 2 and 4 tonnes cattle manure resulted in the highest seed yield/plant in the first season, while application of 2 and 2.5 tonnes sheep manure recorded the highest seed yield/plant in the second season (Table 5).

Kerenhap *et al*. (2007) reported that, organic manure has an important role as N-fixing organism and the availability of P and K. Manure application also have favourable effect on soil structure, activities of microorganisms and availability of nutrients, which contribute for improvement in yield. Duhboon *et al*. (2004) reported that, the excessive usage of NPK fertilizers may increase soil pollution, decrease soil productivity and leads to nutrient imbalance.

Our results are in conformity with the reports of Abdullahi *et al*. (2013), Anguria *et al*. (2017), Hassaan and Bughdady (2018) and Heba *et al*. (2019).

Interaction effect between cultivars and cattle and sheep manure

Results presented in Table 6 indicated that, the interaction effect between sesame cultivars and organic manures and their sources was significant for all the studied traits except fruit zone length in the first season and first capsule

Table 4. Effect of cultivars and organic fertility levels from different sources on growth attributes of sesame crop during 2017 and 2018

Treatments	Plant height (cm)		First capsule height (cm)		Fruit zone length(cm)	
	2017	2018	2017	2018	2017	2018
Cultivar						
'Shandaweel 3'	155.9	178.5	26.9	28.1	135.4	150.4
'Giza 32'	146.2	170.2	30.00	33.3	119.5	136.9
SEm±	2.33	5.78	0.44	0.47	2.71	6.19
CD (P=0.05)	NS	NS	2.2	2.34	14.09	NS
Organic manure from different sources						
Control (without manure)	125.0	160.0	29.5	30.8	115.0	129.1
2.0 tonnes/fed cattle manure	140.8	172.5	31.6	36.7	114.1	135.8
3.0 tonnes/fed cattle manure	150.0	170.8	27.1	25.8	121.6	145.0
4.0 tonnes/fed cattle manure	173.3	195.0	26.7	27.5	147.5	169.1
1.5 tonnes/fed sheep manure	147.5	164.2	27.9	30.0	121.6	134.1
2.0 tonnes/fed sheep manure	146.6	161.7	28.3	30.0	120.0	131.6
2.5 tonnes/fed sheep manure	174.3	196.7	27.9	34.2	152.5	160.8
SEm±	3.46	6.23	1.70	2.31	4.01	6.08
CD (P=0.05)	10.24	18.44	NS	NS	11.96	17.99

Table 5. Effect of cultivars and organic fertility levels from different sources on yield and yield attributes of sesame crop during 2017 and 2018

Treatments	Capsules/plant		Seed yield/plant (g)		1,000-seed weight (g)		Seed yield (kg/fed)	
	2017	2018	2017	2018	2017	2018	2017	2018
Cultivar								
'Shandaweel 3'	194.5	211.6	33.5	41.8	5.3	5.8	723.3	913.4
'Giza 32'	186.9	215.7	25.1	33.2	4.8	5.2	509.4	679.7
SEm±	1.59	7.01	0.71	0.96	0.032	0.082	7.76	27.6
CD (P=0.05)	NS	NS	3.69	4.99	0.17	0.42	40.3	143.5
Organic manure from different sources								
Control (without fertilization)	111.4	149.5	26.6	32.1	4.38	4.67	417.1	515.6
2.0 tonnes/fed cattle manure	128.7	148.1	30.9	35.4	4.68	5.42	574.3	647.6
3.0 tonnes/fed cattle manure	134.3	132.0	29.6	36.9	4.99	5.71	631.6	799.8
4.0 tonnes/fed cattle manure	246.7	264.2	31.4	38.9	5.50	5.88	757.8	926.1
1.5 tonnes/fed sheep manure	246.7	227.5	28.5	37.1	4.93	5.20	576.9	750.7
2.0 tonnes/fed sheep manure	258.2	280.9	29.9	39.2	5.18	5.26	641.7	841.9
2.5 tonnes/fed sheep manure	238.3	293.6	28.4	43.3	5.99	6.58	715.2	1094.4
SEm±	3.72	7.77	0.67	1.62	0.13	0.21	15.3	39.5
CD (P=0.05)	11.01	22.79	1.98	4.79	0.38	0.62	45.28	116.9

height in the second season. Crop fertilized with 2.5 tonnes sheep manure and 4 tonnes cattle manure interacted significantly with 2 cultivars ('Shandaweel 3' and 'Giza 32') and thus recorded the highest values of plant height and fruit zone length in the two seasons. With respect to first capsule height in the 1st season, the maximum values of cultivar 'Shandaweel 3' was obtained by 2 tonnes cattle manure and 2 tonnes sheep manure, while their corresponding values for cultivar 'Giza 32' were obtained by the control fertilizer treatment. No significant interaction effect was observed in the second season.

Results showed that, the application of 2.5 tonnes sheep manure and 4 tonnes cattle manure produced the profuse number of capsules/plant for cultivar 'Shandaweel 3' while the maximum number of capsules/plant for cultivar 'Giza 32' was recorded by 4 tonnes cattle manure and 2 tonnes sheep manure only in the first season. In the second season, adding 2 or 2.5 tonnes sheep manure fertilizer gave the highest number of capsules/plant for the used 2 cultivars.

In case of seed yield/plant, 'Shandaweel 3' gave the highest seed yield/plant when fertilized by 4 tonnes cattle manure and 2 tonnes sheep manure in the first season, while the highest seed yield/plant in the second season was attained by adding 2 and 2.5 tonnes sheep manure fertilizer to the soil. Cultivar 'Giza 32', gave the maximum seed yield/plant when fertilized by 4 tonnes cattle manure in both the seasons (Table 5).

Table 6. The interaction effect between sesame cultivars and organic manure sources on growth and yield and yield attributes during 2017 and 2018 seasons.

Cultivars	Organic manure sources and levels	Plant height (cm)	First capsule height (cm)	Fruit zone length (cm)	No. of capsules / plants (no)	Seed yield/plant (g)	1,000-Seed weight(g)	Seed yield (kg/fed)
				Season 2017				
	T_1	140.0	22.5	125.0	142.2	25.8	4.37	430.7
	T_2	110.0	30.8	115.0	149.2	34.1	4.55	697.8
	T_3	156.7	28.3	125.0	154.4	34.5	4.97	735.3
'Shandaweel 3'	T_4	183.3	24.2	158.3	223.1	35.3	5.90	852.5
	T_5	158.3	26.7	133.3	211.7	33.0	5.31	689.0
	T_6	163.3	29.2	133.3	219.3	35.6	5.51	765.1
	T_7	180.0	26.7	158.3	262.1	34.6	6.47	892.7
	T_1	141.7	40.8	103.3	80.5	25.3	4.38	403.6
	T_2	140.0	28.3	115.0	108.2	25.9	4.81	450.7
	T_3	143.3	25.8	118.3	114.1	24.6	5.01	527.8
'Giza 32,	T_4	163.3	29.2	136.7	270.3	27.5	5.10	663.1
	T_5	136.7	29.2	110.0	223.6	23.9	4.56	464.8
	T_6	130.0	27.5	106.7	297.2	24.3	4.84	518.3
	T_7	168.7	29.2	146.0	214.4	22.3	5.50	537.6
SEm±		5.10	2.27	5.91	5.12	0.88	0.18	21.4
CD (P=0.05)		17.6	7.85	NS	17.7	3.04	0.62	74.04
				Season 2018				
'Shandaweel 3'	T_1	178.3	30.0	148.3	212.8	37.1	4.83	611.5
	T_2	151.7	30.0	121.7	172.3	40.1	5.59	745.3
	T_3	166.7	25.0	141.7	139.1	38.3	5.78	842.0
	T_4	213.3	23.3	190.0	237.8	41.4	5.98	987.1
	T_5	168.3	28.3	140.0	221.1	38.8	5.66	813.7
	T_6	171.7	28.3	143.3	241.6	45.5	6.00	1007.1
	T_7	200.0	31.7	168.3	256.6	51.8	6.86	1387.1
'Giza 32'	T_1	166.7	43.3	123.3	86.2	27.1	4.52	419.6
	T_2	168.3	31.7	136.7	123.8	30.7	5.25	549.8
	T_3	175.0	26.7	148.3	124.9	35.6	5.63	757.6
	T_4	180.0	31.7	148.3	290.6	36.3	5.77	865.1
	T_5	160.0	31.7	128.3	233.9	35.5	4.74	687.8
	T_6	151.7	31.7	120.0	320.3	32.9	4.51	676.7
	T_7	190.0	36.7	153.3	330.6	34.8	6.30	801.7
SEm±		9.99	3.06	10.18	12.35	2.32	0.301	58.7
CD (P=0.05)		34.5	NS	35.22	42.73	8.03	1.04	203.1

It is obvious that the plants fertilized by 2.5 tonnes sheep manure and 4 tonnes cattle manure of cultivar 'Giza 32' gave the highest 1,000-seed weight and seed yield/fed in the 2 seasons. Meanwhile, the 2 treatments of 2.5 tonnes sheep manure and 4 tonnes cattle manure gave the maximum values of 1000-seed weight and seed yield/fed for 'Shandaweel 3' in the first season, while in the second season, the highest values were obtained by 2 tonnes sheep manure and 2.5 tonnes sheep manure. These results are in parallel line with those obtained by Hassaan and Bughdady (2018) and Heba *et al*. (2019).

Correlation matrix

Correlation coefficients computed between different pairs of studied characters revealed positive and highly significant associations between seed yield/fed and its related characters except first capsule height which had no significant and negative correlation with seed yield/fed (Table 7). The highest correlation coefficient was obtained between seed yield/fed and seed yield per plant (0.90**) and 1,000-seed weight (0.83**) indicating that the 2 traits are the main determinant of seed yield in sesame crop. Plant height showed positive and highly significant associations towards most seed yield components indicating that the tall plant is preferred in sesame breeding programme to get high-yielding cultivar. Fortunately, there were positive and highly significant associations among the 4 seed yield components, being fruit zone length, capsules/plant, seed yield/plant and 1,000-seed weight. Our results are in agreement with the findings of Aydin *et al.* (2010) and Engine *et al. (*2010), who reported positive correlation of seed yield/unit area with plant height, number of branches, number of capsules/plant and 1,000-seed in different crops including sesame.

Conventional path analysis

Estimation of direct effects, tolerance and variance inflation factor (VIF) computed by conventional path analysis are presented in Table 8. Using conventional path analysis, all the yield-related characters were considered as the predictor variables towards seed yield per feddan as the response variable. Analysis of multi-collinearity showed that, there was high degree of multi-collinearity (VIF>10 and tolerance <0.1) for some characters such as zone fruit length (VIF=14.43) and plant height (VIF=13.43) indicating weakness of fit. Accordingly, the conventional path analysis model was statistically rejected, as the model lost the assumption of the independence among the predictor variables.

Table 8. Direct effects of predictor variables toward seed yield and measures of collinearity parameters (tolerance and variance inflation factor).

Predictor variables	Direct effect	Tolerance	VIF
Plant height	–0.183	0.074	13.42
First capsule height	0.031	0.437	2.28
Fruit zone length	0.247	0.069	14.42
Capsule/plants	0.151	0.827	1.21
Seed yield/plant	0.600	0.445	2.25
1,000-seed weight	0.324	0.394	2.53

Sequential path analysis

Sequential path analysis provided a better understanding of the interrelationships among various variables and their relative contribution to seed yield/feddan (Table 9). Seed yield/plant, 1,000-seed weight and capsules/plant were considered first-order variables, which accounted for nearly 92% of the variation in seed yield (Table 9, and Fig. 1). The highest and positive direct effects toward seed yield was recorded by seed yield/plant (0.63) followed by 1,000-seed weight (0.34) and capsules/plant (0.16).

The path analysis of second-order variables towards the first-order variables showed that, 53% of the total variation for seed yield/plant was explained by 5 characters, viz. plant height, first capsule height, fruit zone length, capsules/plant and 1,000-seed weight, while 40% of the total

Table 7. Correlation coefficients computed between seed yield/fed and growth and yield attributes of crop

Traits	Plant height (cm)	First capsule height (cm)	Fruit zone length (cm)	Capsules/ plant (No)	Seed yield/ plant (g)	1,000-seed weight (g)	Seed yield (kg/fed)
Plant height (cm)	1						
First capsule height (cm)	0.07	1					
Fruit zone length (cm)	0.92**	-0.20	1				
Capsules/plant	0.33**	-0.04	0.34**	1			
Seed yield/plant (g)	0.49**	0.13	0.51**	0.27*	1		
1,000-seed weight (g)	0.60**	-012	0.62**	0.39**	0.67**	1	
Seed yield (kg/fed)	0.58**	-0.003	0.63**	0.46**	0.90**	0.83**	1

*P=.05; **P=0.01

Table 9. Adjusted coefficient of determination (R^2), direct effects, tolerance, and variance inflation factor (VIF) values for the predictor variables toward seed yield.

Response variable	Predictor variables	Adjusted R^2	Direct effect	Tolerance	VIF
Seed yield/fed	SY/P	0.92	0.63	0.55	1.98
	NC/P		0.16	0.85	1.18
	1,000 SW		0.34	0.50	1.82
Seed yield/plant	PH	0.53	0.19	0.76	1.31
	FCH		–0.12	0.98	1.02
	FZL		0.23	0.74	1.35
	NC/P		0.24	0.93	1.08
	1000 SW		0.40	0.55	1.82
1,000-seed weight	PH	0.40	0.06	0.62	1.59
	FCH		–0.04	0.92	1.09
	FZL		0.10	0.60	1.66
	NC/P		0.16	0.84	1.18
Capsules/plants	PH	0.09	0.03	0.62	1.62
	FCH		–0.03	0.91	1.09
	FZL		0.08	0.69	1.69

Ph, Plant height; FCH, first capsule height; ZL, zone fruit length; NCP, number of capsules/plant; SY/p, seed yield/plant, 1,000SW, 1,000-seed weight; SY/fed, seed yield/feddan

variation for 1,000-seed weight was explained by plant height, first capsule height, fruit zone length and capsules/plant. In the same order path, the characters of plant height, first capsule height, fruit zone length accounted for 9% of the capsules/plant variation. In the second order path analysis, it is obvious that all characters had positive direct effect except first capsule height which had negative direct effects on seed yield/plant, 1,000-seed weight and capsules/plant (Table 9 and Fig. 1).

With respect to multi-collinearity, it was observed that there was worthless degree of multi-collinearity (VIF<10 and tolerance >0.1)) for all characters in the first-and second-sequential path analysis indicating goodness of fit. Therefore, the sequential path analysis model was statistically considered a good remedial tool to overcome the data problem of multi-collinearity.

Path analysis in the earlier studies on sesame considered the different yield components as first-order variables towards seed yield as the response variable and did not take into account the multi-collinearity problem. This means the efficiency of sequential path analysis for detecting cause and effect connections. The characters often highlighted in this regard were seed yield/plant, 1,000-seed weight, fruit zone length and capsules/plant. The current results confirmed the results reported by Biabani *et al.* (2008).

It was concluded that cultivar 'Shandaweel 3, proved superior to 'Giza 32'. Application of 2.5 tonnes sheep manure or 4 tonnes of cattle manure recorded maximum seed yield/fed across 2 seasons with significant differences compared to null fertilizer treatment (control). Positive and

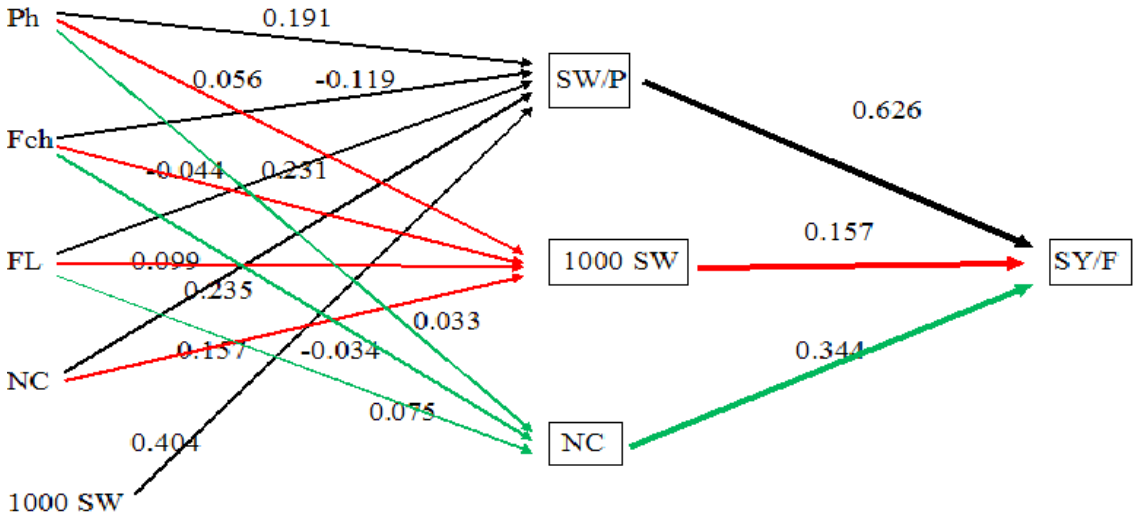

Fig. 1. Sequential path model indicating the interrelationships among seed yield with related characters.

highly significant associations between seed yield and growth and yield attributes was noted. Based on sequential path analysis, seed yield/plant and 1,000-seed weight may be used as selection criterion for improving seed yield per feddan in sesame breeding programme.

REFERENCES

Abdullahi, R., Sheriff, H.H. and Lihan, S.2013. Combine effect of bio-fertilizer and poultry manure on growth, nutrients uptake and microbial population associated with sesame (*Sesamum indicum* L.) in North-Eastern Nigeria. *Journal of Environmental Science Toxicology and Food Technology* **5**(5): 60–65.

Abou-Taleb, S.M. 2012. Response of sesame crop to the bio-fertilizer cerealine with or without mineral nitrogen fertilization. *Research Journal Agriculture and Biological Sciences* **8**(1): 45–54.

Anguria, P.G N., Chemining, W.A., Onwonga, R.N. and Ugen, M.A. 2017. Effect of organic manures on nutrient uptake and seed quality of sesame. *Journal of Agricultural Science*s **9** (7): 135–144.

Black, C.A. 1982. Methods of Soil Analysis. American Society of Agronomy. Inc., Madison, Wisconsin, USA, pp. 1–178.

Duhoon, S.S., Jyotishi, A., Deshmukh, M.R. and Singh, N.B. 2004. Optimization of sesame (*Sesamum indicum* L.) production through bio/natural inputs. http://www.cropscience.au/res.

El-Samanody, M.K.M.; El-Marsafawy, Samia M. and Rehab, H.K.A. 2010. Impact of deficit irrigation at different growth stages on some sesame cultivars in Upper Egypt. *Journal Plant Production, Mansoura University* **7**: 857–871.

Fakhry, S.M.K. 2016 Effect of mineral fertilization and some biological treatments on sesame. Ph. D. Thesis, Faculty of Agriculture, Cairo University, Cairo.

Ghaderi, M.G., Zeialikhanghah, H., Hosseinzade, A.H., Taleei, A.R. and Naghavi, M.R. 2009. Evaluation of relationships between grain yield, yield components and the other characteristics associated with grain yield in bread wheat using multivariate statistical analysis. *Iranian Journal of Crop Research* **7**(2): 573–582.

Gnanasekaran, M., Jebaraj, S. and Muthuramu, S. 2008. Correlation and path co-efficient analysis in sesame (*Sesamum indicum* L.). *Plant Archives* **8**(1): 167–169.

Hair, J.R., Anderson, R.E., Tatham, R.L. and Black, W.C. 1995. Multivariate Data Analysis with Readings. Prentice Hall, Englewood Cliff, N.J.

Hassaan, M.A. and Bughdady, A.M. 2018. Response of some sesame cultivars (*Sesamum indicum* L.) to bio and organic fertilizers under Toshka conditions. *Journal of Plant Production, Mansoura University* **9**(11): 931–938.

Heba, L., Hamza, A.M., Abbas, M.S. and Fayed, S.A. 2019. Bio and organic fertilizers as an alternative to conventional mineral source on sesame. Production and oil quality in Egypt. *Egypt Journal of Agronomy* **41**(2): 133–147.

Jackson, M.L. 1973. *Soil Chemical Analysis,* Prentice Hall, New Delhi, India.

Kumar, S., Pandey, P. and Maheshwari, D.K. 2009. Reduction in dose of chemical fertilizers and growth enhancement of sesame (*Sesamum indicum* L.) with application of rhizospheric competent *Pseudomonas aerugionsa*. *European Journal of Soil Biology* **45**: 334–340.

Mohammadi, S.A., Prassana, B.M. and Singh, N.N. 2003. Sequential path model for determining interrelationships among grain yield and related characters in maize. *Crop Science* **43**: 1,690–1,697.

Mondal, S.S., Verma, D. and Kuila, S. 1992. Effect of organic and inorganic sources of nutrients on growth and seed yield of sesame (*Sesamum indicum* L). *Indian Journal of Agronomy* **37**(4): 258–262.

Muhamman, M.A., Gungula, D.T. and Sajo, A.A. 2009. Phenological and yield characteristics of sesame (*Sesamum indicum* L.) as affected by nitrogen and phosphorus rates in Mubi, Northern Guinea savanna Ecological zone of Nigeria. *Emirate Journal of Food and Agriculture* **21**: 1–9.

Samonte, S.B., T.L. Wilson and R.E. Tabien 2006. Maximum node production rate and main culm node number contributions to yield and yield-related traits in rice. *Field Crops Research* **96**: 313–319.

Steel, R.G.D. and Torrie, J.H. 1984. Principles and Procedures of Statistics (edn 2). Pp. 172–177. Mc Graw-Hill Book Co, Singhapore.

Suddhiyam, P., Suwannaketnikom, S., Dumkhum, W. and Duandao, N. 2009. Fertilizers for organic sesame. *Asian Journal of Food and Agro-Industry* (Special Issue), S197-S204. Available online at www.ajofai.info.

Williams, W.A., Jones, M.B. and Demment, M.W. 1990. A concise table for path analysis statistics. *Agronomy Journal* **82**: 1,022–1,024.

Wright, S. 1921. Correlation and causation. *Journal of Agriculture Research* **20**: 557–585.

Zeidan M.S. 2007. Effect of organic manure and phosphorus fertilizers on growth, yield and quality of lentil plants in sandy soil. *Research Journal of Agriculture and Biological Sciences* **3**:748–752.

Zhen, Z., Liu, H., Wang, N., Guo, L., Meng, J., Ding, N., Wu, G. and Jiang, G. 2014. Effects of manure compost application on soil microbial community diversity and soil microenvironments in a temperate cropland in China. *Plos One* **9**(10): e108555

Ziedan, E.H., Elewa, I.S., Mostafa, M.H. and Sahab, A.F. 2011. Application of mycorrhizae for controlling root diseases of sesame. *Plant Protection Research Journal* **51**(4): 355–367.