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Bio and Organic Fertilizers as an Alternative to Conventional Mineral Source on Sesame (*Sesamum indicum* L.) Production and Oil Quality in Egypt

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POSSIBILITIES of partial or complete substitution of mineral fertilizer via bio and organic fertilizers were evaluated for improving the characteristics of sesame seed yield and oil yield, also contributing to decrease environmental pollution. The two experiments were implemented in the two summer seasons of 2015 and 2016 at the Agricultural Experimental and Research Station, Faculty of Agriculture, Cairo University. The experimental design was a randomized complete block design with seven treatments. Sesame was tested under three types of fertilizers i.e., 33, 50, and 100% mineral, compost, and 100% bioformulations. Results revealed that the treatment of 100% compost attained the highest values of number of plants ha^{-1} (119.80 thousands ha^{-1}), seed yield $plant^{-1}$ (15.37g), biological yield (5721.00kg ha^{-1}), also gave the highest significant values of seed yield (1544.00kg ha^{-1}) and oil yield (865.60kg ha^{-1}); however, the treatment of 100% bioformulations in combination with 50% mineral recorded maximum values of plant height (135.33cm), fruiting zone length (81.06cm), number of seeds $plant^{-1}$ (3880.68), seed index (4.61g) and produced a maximum significant value of number of capsules $plant^{-1}$ (77.06) in both seasons. While, the treatment of 100% bioformulations mixed with 50% compost attained the highest value of seed oil percentage (59.03%), whereas all treatments did not significant effect on the fatty acids composition when compared with the control treatment (100% mineral) in both seasons. It can be concluded that the mineral fertilizer was completely replaced via 100% compost and partially replaced by 100% bioformulations with 50% mineral recorded the best results in both seasons.

Keywords: Sesame, Bio-fertilizers, Compost, NPK, Fatty acids, Seed yield, Oil yield.

Introduction

Sesame plant is an important oilseed crop and it is belonging to the family *Pedaliaceae* (Anilakumar et al., 2010; Noorka et al., 2011; Boghdady et al., 2012 and Shaban et al., 2012). Its oil has a stable chemical construction and rarely exposed to oxidation process under the hot climate conditions (Anilakumar et al., 2010). It has ability to tolerate drought (Jan et al., 2014 and Hamza & Abd El-Salam, 2015) and it has not capability to tolerate higher water levels than its needs, which may cause root infections. It has a high proportion of both edible oil (42-54%) and protein (22-25%) (Ali & Jan, 2014). Its seeds contain 80% of unsaturated fatty acids in the oil (Mahrous et al., 2015), as well as some of vitamins and minerals like a high content of vitamin E (Shasmitha, 2015), calcium, phosphorus, (Patel et al., 2014), and potassium (Mahrous et al., 2015).

Nitrogen is the main nutrient (Noorka et al., 2011 and Motaka et al., 2016 b) for many vital processes such as proteins, nucleic acids (Ohyama, 2010), protoplasm and (chlorophyll is playing a vital role in both phases of vegetative and reproductive of the crop growth) (Blal et al., 2012, 2013 and Ahmed et al., 2015). Phosphorus can increase the density and proliferation of the root for getting water and nutrients that results in an increase in the growth and yield of the traits, hence ensuring further seed yield (Mahrous et al., 2015). Potassium is the main nutrient for many biochemical and physiological processes, which can impact on the growth and

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metabolism of the plant (Wang et al., 2013). Abdel-Galil & Abdel-Ghany (2014) found that increasing N-levels from 107.1 to 178.5kg of ammonium nitrate ha^{-1} on Shandaweel-3 cv. significantly increased plant height, number of capsules plant^{-1}, seed index, seed yield plant^{-1}, and seed yield ha^{-1}. Additionally, Deepthi et al. (2018) noticed that the addition of 50kg N: 25kg P: 25kg K ha^{-1} produced the highest values of number of capsules plant^{-1}, number of seeds capsule^{-1}, test weight (1000 seed weight), and attained the highest significant value of seed yield ha^{-1} in a sandy loam soil.

Bio and organic fertilizers are inexpensive nutrients source, which can be used as an alternative to mineral fertilizer and enhance the crop productivity; also, the organic fertilization can increase the organic carbon and induce the microorganism's activity for providing nutrients as nitrogen and phosphorus in the soil (Abdullahi et al., 2013). Aghili et al. (2015) pointed out that the addition of 10ton compost ha^{-1} resulted in an improve in plant height and harvest index in a silt loam soil. While, Debnath et al. (2007) found that the inoculation by *Azotobacter* attained the highest significant value of 1000-seed weight. Moreover, Sabannavar & Lakshman (2008 and 2011) noticed that the interaction of the two varieties *viz.,* DS 1 and E 8 × the inoculation of *Glomus fasciculatum* (*Thax. sensu Gerd.*) *Gerd*. (Gf), *Azotobacter chroococcum* (Ac) and *Pseudomonas fluorescens* (Pf) or the interaction of TSES 1 variety × the inoculation of Gf, Ac and Pf or the interaction of TSES 4 variety × the inoculation of *Acaulospora laevis*, Ac and Pf significantly increased number of capsules plant^{-1} in a sandy loam soil.

Whereas, Eifediyi et al. (2017) found that the combination of 100 or 200kg NPK ha^{-1} + the addition of 3 or 4ton neem seed cake ha^{-1} attained maximum values of number of capsules plant^{-1}, seed yield plant^{-1} and seed yield ha^{-1}. However, Shakeri et al. (2016) noticed that the interaction of the PGPR inoculation *viz*., *Azotobacter chroococcum*, *Azotobacter agillis*, *Azospirillum brasilense*, and *Azospirillum lipoferum* × 25kg of urea ha^{-1} produced more seed yield ha^{-1} than the addition of 50kg of urea ha^{-1} individually, also the combination of PGPR and two N-rates i.e., 25 and 50kg urea ha^{-1} resulted in an increase in oil yield and significantly increased unsaturated fatty acids *viz*., oleic and linoleic acids in a sandy clay loam soil. While, Jahan et al. (2012 and 2013 b) stated that the combination of the inoculation by *Azotobacter* sp., *Azospirillum* sp., *Bacillus* sp., *Pseudomonas* sp. and *Thiobacillus* spp. + the two cover crops *viz*., *Lathyrus* sp. and *Trifolium resopinatum* significantly influenced number of seeds plant^{-1}, seed weight plant^{-1}, harvest index, biological yield and seed yield. Whereas, Babajide (2014) indicated that the inoculation of *Azospirillum lipoferum* in combination with 75% green *Tithonia diversifolia* and 25% urea significantly increased plant height, number of capsules plant^{-1}, weight of 1000 seeds, seed oil content (63.80%) and total seed yield in a sandy loam soil.

Mineral fertilizers are expensive, not easily available and increasing its doses about plant needs lead to environmental pollution. In Egypt, the production of the local edible oil is inadequate (Hamza, 2010) and it represent 10% of the consumption (Noorka et al., 2011). Therefore, the objectives of this study were for improving the characteristics of sesame seed yield and oil yield, also contributing to decrease environmental pollution by evaluating the possibilities of partial or complete substitution of mineral fertilizer via bio and organic fertilizers.

Materials and Methods

Experimental site

The two experiments were implemented in the two summer seasons of 2015 and 2016 at the Agricultural Experimental and Research Station, Faculty of Agriculture, Cairo University, Egypt. The Egyptian cultivar Shandweel-3 was used. Physical and chemical properties of compost are shown in Table 1. While, physical and chemical properties of soil before the planting day are shown in Table 2.

Physical and chemical analysis methods of soil and compost

Moisture content

Organic material samples were oven dried at 70ºC, but soil samples were oven dried at 105ºC to a constant weight. The difference between the fresh and corresponding dry weight equals the moisture content, which was calculated as a percentage for each material according to APHA (1989).

The pH value

It was directly measured in the (1: 5) soil: water suspensions and in (1: 10) compost: water mixture using a pH glass electrode of Orion Expandable ion analyzer EA 920.

TABLE 1. Average values of physical and chemical properties of compost in 2015 and 2016 seasons.

Parameter	Value
Bulk density (kg m^{-3})	538
Moisture content (%)	33
pH	7.44
Electrical conductivity EC (dS m^{-1})	4.44
Total nitrogen (%)	1.19
Ammoniacal nitrogen - NH_4^+ (ppm)	383
Nitrate nitrogen - NO_3^-	Nil
Organic matter (%)	39.65
Organic carbon (%)	22.99
Ash (%)	60.35
C: N ratio	1:19.32
Total phosphorus (P_2O_5) (%)	1.09
Total potassium (%)	0.53
Weed seeds	Nil
Nematodes	Nil

Electrical conductivity measurements

Run in a suspension of (1: 5) soil: water or (1: 10) compost: water determined by Richards (1954) using EC meter, ICM model 71150.

Organic matter content of compost and soil

Compost was determined by glowing the dried samples at 550ºC to a constant weight as recommended in APHA (1989). From the values of organic matter, the quantity of organic carbon percentage was calculated by multiplying by 0.58. While, soil was determined by the determination of total carbon (C%) according to the method of Hesse (1971) and multiplying the result by 1.724.

Total nitrogen

In dry compost or soil samples were determined by micro-Kjeldahl method as recommended by Jackson (1973 a).

Total phosphorus

Acid solutions of the digested soil or compost materials were used for determination of total phosphorus contents as described by APHA (1989).

Total potassium

Digested solutions of soil or compost materials were used for the determination of total potassium using flame-photometric method according to APHA (1989).

Available nitrogen (ammoniacal and nitrate-N)

Nitrogen forms in compost materials were determined according to the methods outline by Page et al. (1982) as follows: Soluble nitrogen forms *viz*., ammonia and nitrate were extracted from the soil or compost samples in KCl solutions and distilled in the presence of MgO for extracting NH_4, meanwhile NO_3 were extracted by running the distillation process another time in the presence of MgO and Devarda alloy. In both steps, the evolved ammonia was collected in 4% H_3BO_3 using a mixed indicator of methyl red and bromocresol green and titrated against 0.05N H_2SO_4 solution.

TABLE 2. Average values of physical and chemical properties of soil sample before the planting day in 2015 and 2016 seasons.

Physical properties			Chemical properties	
Particle size distribution	Coarse sand (%)	6.48	pH	7.85
	Fine sand (%)	12.01	Electrical conductivity EC (dS m^{-1})	1.34
	Silt (%)	39.00	Total nitrogen (%)	0.05
	Clay (%)	42.51	Total phosphorus (%)	0.32
Textural class		Clay	Total potassium (%)	0.18
Bulk density (g cm^{-3})		1.42	Available nitrogen (mg kg^{-1})	80.50
Total porosity (%)		46.41	Available phosphorus (mg kg^{-1})	26.80
Hydraulic conductivity (cm h^{-1})		0.80	Available potassium (mg kg^{-1})	169.0
Field capacity (%)		27.12	Available iron (mg kg^{-1})	13.27
Wilting point (%)		13.04	Available manganese (mg kg^{-1})	8.39
Available water (%)		14.08	Available zinc (mg kg^{-1})	7.58
			Available copper (mg kg^{-1})	3.15
			Organic matter content (%)	1.32

Available phosphorus

Soil available P was obtained by the method introduced by Olsen et al. (1954). About 10g of soil samples or 5g of compost were extracted with 100ml 0.5M $NaHCO_3$ (pH 8.5) and 5ml aliquot of the extract was analyzed for soluble phosphorus. The concentration of phosphorus in compost materials or soil was determined colourimetrically according to Troug & Mayer (1949) at a wave length of 660nm and calculated as ppm.

Available potassium

Compost materials or soil were extracted with a normal solution of ammonium acetate (pH 7) in ratio of 1: 2.5 (soil/solution, W/V) and determined by Chapman & Pratt (1961). Soluble potassium concentration in the filtrate was estimated using a flame photometer (Corning 410).

Available iron (mg kg^{-1}), available manganese (mg kg^{-1}), available zinc (mg kg^{-1}) and available copper (mg kg^{-1}) in soil were determined according to Jackson (1973 b).

Physical analysis methods of soil

Particle size distribution was determined by the method of Day (1965). Bulk density (g cm^{-3}) was determined by using paraffin wax method according to Dewis & Freitas (1970). Total porosity (%) was determined by Vomocil (1965) method. Hydraulic conductivity (cm hr^{-1}) was carried out according to Klute (1965). Field capacity (%), wilting point (%) and available water (%) were determined by Peters (1965).

Treatments

The treatments were T_1= 100% of mineral (control treatment) (M), T_2= 100% of compost (C), T_3= 100% of bioformulations (B), T_4= 50% of mineral in interaction with 50% of compost, T_5= 100% of bioformulations in combination with 50% of mineral, T_6= 100% of bioformulations mixed with 50% of compost and T_7= 100% of bioformulations combined with 33% of compost and 33% of mineral.

Agricultural practices

Sesame seeds were obtained from Oil Crops Research Department, Field Crops Research Institute (FCRI), Agricultural Research Center (ARC) and sown in hills by hand on the 17th July in both seasons. The distance between each hill was 20cm. Approximately 164.7g of the seeds were soaked with bioformulations i.e., 200ml of biofertile bioformulation *viz*., *Azospirillum brasilense*, *Azotobacter chroococcum*, *Bacillus polymyxa*, *Enterobacter agglomerans* and *Pseudomonas putida* in combination with 200ml of biocontrol bioformulation *viz*., *Bacillus polymyxa*, *Bacillus macerans*, *Bacillus circulans*, and *Enterobacter agglomerans* provided from Environmental Studies and Research Unit (ESRU), Department of Agricultural Microbiology, Faculty of Agriculture, Cairo University, Egypt for an hour before the planting. While, compost rates of green manure source i.e., 3.17, 4.8, and 9.6ton ha^{-1} were obtained from Beni Suef compost company and added on the same day of the planting. Sesame seedlings were also sprayed with 1L of biofertile bioformulation: 7L of the irrigation water and 1L of biocontrol bioformulation: 7L of the irrigation water as a foliar treatment at 8 to 10 AM on the 22th day of the planting. In the early bloom phase after 34 days of the planting day the mineral fertilizers *viz*., ammonium nitrate (33.5% NH_4 NO_3) i.e., 94.56: 143.28: 286.56kg ha^{-1}, single superphosphate (15.5% P_2O_5) i.e., 153.29: 232.27: 464.52kg ha^{-1}, and potassium sulfate (48% K_2O) i.e., 79.2: 120: 240kg ha^{-1} were applied on the seedlings, as well as the seedlings were thinned to two seedlings per hill to avoid the competition between the plants directly after the mineral fertilization on the same day. The two experiments were irrigated by flooding irrigation after 17, 34, 50 and 83 days of the planting day. Weeds were controlled by hand and hoeing after 13, 32, and 43 days of the planting day. Finally, the crop was harvested after 112 days of the planting day when 80 to 90% of the leaves and capsules turned to yellow.

Studied traits

Three plants were randomly taken from the two central ridges of each plot at the harvest to measure the following traits:

Yield components

Number of plants ha^{-1}, plant height (cm), fruiting zone length (cm), number of fruiting nodes $plant^{-1}$, number of capsules $plant^{-1}$, number of seeds $capsule^{-1}$, number of seeds $plant^{-1}$, seed yield $plant^{-1}$ (g) and seed index (g).

Yields

Biological yield (kg ha^{-1}), seed yield (kg ha^{-1}), oil yield (kg ha^{-1}), and harvest index (%).

Oil quality

Seed oil percentage was determined according to A.O.A.C. (2012). Furthermore, fatty acids composition were analyzed on two phases *viz*., the oil extraction of sesame seeds according to A.O.A.C. (2012) and gas chromatography analysis of fatty acids according to ISO 12966-2 (2011).

Experimental design

A randomized complete block design (RCBD) with three replications was used. The experiment consisted of 21 plots for each season. Each plot consisted of 4 ridges, 0.60 meters apart, and 3 meters long (7.2m^2).

Statistical analysis

Test of normality distribution was carried out according to Shapiro & Wilk (1965) method, by using SPSS v. 17.0 (2008) software package. Additionally, data were tested for validation of assumptions underlying the combined analysis of variance by separately analyzing of each season and then combined analysis across the two seasons was performed if homogeneity (Bartlet test) was insignificant. Estimates of LSD 5% were calculated to test the significance of differences among means according to Snedecor & Cochran (1994).

Results and Discussion

Analysis of variance

Results in Table 3 indicate that significant difference existed in seed index (g) and highly significant difference for the rest of studied traits, except number of seeds plant^{-1} and harvest index (%). Mean squares due to the treatments × seasons interaction showed significant difference in biological yield (kg ha^{-1}) and highly significant difference for the rest of studied traits, except fruiting zone length (cm), number of seeds plant^{-1}, seed index (g), harvest index (%) and seed oil percentage.

Yield components

All treatments did significant effect on yield components and yields, also the treatment of 100% of compost and the treatment of 100% of bioformulations in combination with 50% of mineral were the best treatments, whereas the treatment of 100% of bioformulations was the worst treatment in both seasons.

TABLE 3. Mean squares from combined analysis of variance of randomized complete block design for some traits of sesame plant under the effect of bio, organic, and mineral fertilizers on yield components, yields and oil quality in 2015 and 2016 seasons.

S. O. V.	Number of plants (thousands ha^{-1})	Plant height (cm)	Fruiting zone length (cm)	Number of fruiting node plant^{-1}	Number of capsules plant^{-1}	Number of seeds capsule^{-1}	Number of seeds plant^{-1}
Season (S)	82.32	91.02	22.18	108.13	1055.01**	100.60	585020.37
Error	22.89	70.34	97.18	31.74	32.79	38.24	1060814.97
Treatment (A)	2281.33**	470.91**	209.08**	81.19**	496.28**	184.04**	1439582.80
SA	926.29**	179.22**	61.43	123.18**	698.27**	108.62**	756859.18
Error	45.05	40.82	39.06	20.08	44.66	21.00	1009174.99
S. O. V.	**Seed yield plant^{-1} (g)**	**Seed index (g)**	**Biological yield (kg ha^{-1})**	**Seed yield (kg ha^{-1})**	**Oil yield (kg ha^{-1})**	**Harvest index (%)**	**Seed oil percentage**
Season (S)	1.29	0.03	1359858.99	365378.49*	88091.72	29.33	4.38
Error	6.01	0.04	2315857.34	149371.14	47809.25	15.04	4.25
Treatment (A)	38.36**	0.17*	5814627.35**	360780.29**	103912.17**	14.27	37.55**
SA	32.02**	0.07	1722008.46*	190119.67**	59607.45**	21.80	5.81
Error	6.68	0.07	521768.01	39651.74	12405.40	9.49	3.36

*and ** indicate significant at 0.05 and 0.01 levels of probability, respectively.

Number of plants ha^{-1} and seed yield plant^{-1}(g)

Results in Table 4 show that the treatment of 100% of compost gave maximum values of number of plants ha^{-1} (119.80 thousands ha^{-1}) and seed yield plant^{-1} (15.37g), but the treatment of 100% of bioformulations gave minimum values of number of plants ha^{-1} (67.33 thousands ha^{-1}) and seed yield plant^{-1} (8.61g) with significant difference between them in both seasons. It could be due to the high content of ammoniacal nitrogen - $NH4^{+}$ (383ppm), organic matter (39.65%) and organic carbon (22.99%) in compost. This result is in accordance with those obtained by Ndor et al. (2015) who noticed that the rates of 0, 5, and 10ton sawdust biochar ha^{-1}, as well as 0, 5, and 10ton rice husk biochar ha^{-1} significantly impacted seed weight plant^{-1} in a sandy loam soil. Moreover, Eifediyi et al. (2017) found that the addition of 3ton neem seed cake ha^{-1} attained a maximum value of seed yield plant^{-1}. On the other hand, Jadhav et al. (2015) found that the inoculation via 600g *Azotobacter chroococcum* and *Pseudomonas striata* 3kg^{-1} of seeds gave the highest value of seed yield plant^{-1} in a clay soil. Furthermore, Subash & Rafath (2016) noticed that the bacterial inoculum of *Azospirillum* gave a maximum value of seed yield plant^{-1} followed by the bacterial inoculum of *Azotobacter*.

Plant height (cm), fruiting zone length (cm), number of capsules plant^{-1} and number of seeds plant^{-1}

Results in Table 4 clear that the treatment of 100% of bioformulations in combination with 50% of mineral recorded the highest values of plant height (135.33cm), fruiting zone length (81.06cm), number of seeds plant^{-1} (3880.68), and recorded the highest significant value of number of capsules plant^{-1} (77.06), but the treatment of 100% of bioformulations recorded the least values of plant height (111.00cm), fruiting zone length (63.39cm), number of seeds plant^{-1} (2284.77) and number of capsules plant^{-1} (48.83) with significant difference between them in both seasons. This result is in parallel with those obtained by Boghdady et al. (2012) who found that the interaction of 50, 100 and 200kg ammonium sulfate with 50, 100 and 200kg calcium superphosphate fed^{-1} × the inoculation of 10g *Azotobacter* sp., *Azospirillum* sp. and *Bacillus megaterium var. phosphaticum* kg^{-1} seeds resulted in an improve in number of seeds plant^{-1} in a clay loam soil. Additionally, Hafiz & El-Bramawy (2012) and Aziz et al. (2016) observed that the combination of the inoculated seeds by *Bacillus megatherium var. phosphaticum* + 76kg calcium superphosphate ha^{-1} significantly increased plant height, fruiting zone length, and number of capsules plant^{-1} in a sandy soil. Moreover, Wayase et al. (2014) observed that the interaction of 30kg urea: 60kg DAP ha^{-1} × the inoculation of *Azotobacter* and PSB produced a maximum value of number of seeds plant^{-1} in a loam soil. Furthermore, Omer & Abd-Elnaby (2017) found that the combination of the inoculated seeds via *Alcaligenes faecalis* and *Pseudomonas geniculate* + the different concentration of 1 and 2% KCl significantly increased plant height and number of capsules plant^{-1} in a clay soil under saline conditions. On the other hand, Subash & Rafath (2016) noticed that the bacterial inoculum of *Azospirillum* gave a maximum value of plant height and number of capsules plant^{-1} followed by the bacterial inoculum of *Azotobacter*. Additionally, Asl (2017) observed that the combination of 108 *Azospirillum* with *Azotobacter* ml^{-1} bacterial inoculums + phosphate solubilizing bacteria, *Pseudomonas putida* and *Bacillus lentus* bacterial inoculums significantly impacted plant height and number of capsules plant^{-1} in a loam soil.

Number of fruiting nodes plant^{-1}

Results in Table 4 indicate that the treatment of 100% of bioformulations combined with 33% of compost and 33% of mineral attained a maximum value (38.72), but the treatment of 100% of bioformulations mixed with 50% of compost attained a minimum value (28.58) with significant difference between them in both seasons.

Number of seeds capsule^{-1}

Results in Table 4 show that the treatment of 50% of mineral in interaction with 50% of compost produced the highest value (59.06), but the treatment of 100% of bioformulations in combination with 50% of mineral produced the least value (44.35) with significant difference between them in both seasons. This result is in harmony with that obtained by Shankar et al. (2015) who pointed out that the two foliar treatments of seaweed extract i.e., 5, 7.5, 10 and 15% of *Kappaphycus* with *Gracilaria* in combination with 80kg urea: 40kg single superphosphate: 40kg muriate of potash ha^{-1} resulted in an improve in number of seeds capsule^{-1}. On the other hand, Boghdady et al. (2012) found that the interaction of 50, 100, and 200kg ammonium sulfate with 50, 100 and 200kg calcium superphosphate fed^{-1} × the inoculation of 10g *Azotobacter* sp., *Azospirillum* sp. and *Bacillus megaterium var. phosphaticum* kg^{-1} seeds resulted in an improve in number of seeds $capsule^{-1}$ in a clay loam soil. Moreover, Wayase et al. (2014) observed that the interaction of 30kg urea: 60kg DAP ha^{-1} × the inoculation of *Azotobacter* and PSB produced a maximum value of number of seeds $capsule^{-1}$ in a loam soil.

Seed index (g)

Results in Table 4 clear that the treatment of 100% of bioformulations in combination with 50% of mineral gave a maximum value (4.61g), but the treatment of 100% of bioformulations mixed with 50% of compost gave a minimum value (4.14g) with significant difference between them in both seasons. This result is in accordance with those obtained by Boghdady et al. (2012) who found that the interaction of 50, 100 and 200kg ammonium sulfate with 50, 100 and 200kg calcium superphosphate fed^{-1} × the inoculation of 10g *Azotobacter* sp., *Azospirillum* sp. and *Bacillus megaterium var. phosphaticum* kg^{-1} seeds resulted in an improve in weight of 1000 seeds of Shandaweel-3 cultivar under clay loam soil conditions. Furthermore, Mahrous et al. (2015) found that the addition of 60kg ammonium sulfate: 30kg single superphosphate: 50kg potassium sulfate fed^{-1} combined with *Bacillus polymyxa*, *Bacillus megaterium*, *Bacillus circulans* and *Pseudomonas fluorescens* produced a maximum value of 1000-seed weight in the first season under clay loam soil conditions.

Yields

Biological yield (kg ha^{-1}), seed yield (kg ha^{-1}), and oil yield (kg ha^{-1})

Results in Table 5 indicate that the treatment of 100% of compost recorded the highest value of biological yield (5721.00kg ha^{-1}), also recorded the highest significant values of seed yield (1544.00kg ha^{-1}) and oil yield (865.60kg ha^{-1}), but the treatment of 100% of bioformulations recorded the least values of biological yield (2723.00kg ha^{-1}), seed yield (763.30kg ha^{-1}), and oil yield (432.40kg ha^{-1}) with significant difference between them in both seasons. It could be due to the high content of ammoniacal nitrogen - $NH4^{+}$ (383ppm), organic matter (39.65%) and organic carbon (22.99%) in compost. This result is in parallel with those obtained by Abdel-Sabour & Abo El-Seoud (1996) who observed that the combination of the two organic wastes of compost *viz*., biosolids + water hyacinth significantly increased oil yield in a sandy soil. Additionally, Atia et al. (2014) mentioned that the interaction of 10ton compost fed^{-1} and 1.5g humic acid L^{-1} produced a maximum value of oil yield in a loamy sand soil. Moreover, Teame et al. (2017) found that the addition of 10ton Sudan grass ha^{-1} achieved a maximum value of seed yield ha^{-1} in a clay soil. Furthermore, Parewa et al. (2018) concluded that the combination of 10ton FYM and 2ton green leaves of neem plant significantly increased seed yield ha^{-1}. On the other hand, Hasanpour et al. (2012) pointed out that the inoculation of PGPR *viz*., *Azospirillum* spp., *Pseudomonas fluorescens*, and *Bacillus subtilis* significantly increased 10% of oil yield. Additionally, Maheshwari et al. (2012) mentioned that the inoculated seeds via *Azotobacter chroococcum* (TRA2) significantly increased seed yield ha^{-1} and oil yield ha^{-1} in a sandy loam soil. Moreover, Jahan et al. (2013 a) concluded that the inoculation of *Azotobacter* sp., *Azospirillum* sp., *Bacillus* sp. and *Pseudomonas* sp. gave a maximum value of biological yield ha^{-1} in a sandy clay loam soil. Furthermore, Ahmed et al. (2015) found that the inoculation of 350kg bio-NP fertilizer *viz*., *B. polymyxa*, *Azotobacter* spp., 3g/100kg boron active, 200g/100kg P_2O_5, 4000g/100kg calcium and bio-stimulator fed^{-1} significantly increased biological yield fed^{-1}. Additionally, Jadhav et al. (2015) found that the inoculation via 600g *Azotobacter chroococcum* and *Pseudomonas striata* $3kg^{-1}$ of seeds gave the highest value of seed yield ha^{-1} in a clay soil.

Harvest Index (%)

Results in Table 5 show that the treatment of 100% of bioformulations attained a maximum value (27.64%), but the treatment of 50% of mineral in interaction with 50% of compost attained a minimum value (23.56%) with significant difference between them in both seasons. This result is in harmony with those obtained by Jahan et al. (2013 a) who concluded that the inoculation via *Thiobacillus* spp., *Bacillus* sp. and *Pseudomonas* sp. recorded a maximum value of harvest index in a sandy clay loam soil. Moreover, Jadhav et al. (2015) found that the inoculation via 600g *Azotobacter chroococcum* and *Pseudomonas striata* $3kg^{-1}$ of seeds gave the highest value of harvest index in a clay soil. On the other hand, Motaka et al. (2016 a) observed that the interaction of 50% RDN via urea × 50% RDN via vermicompost significantly increased harvest index. Furthermore, Teshome (2016) concluded that the addition of 5ton FYM ha^{-1}, 60kg urea ha^{-1} and 30kg DAP ha^{-1} together attained the highest value of harvest index in a clay loam soil.

TABLE 4. Impact of bio, organic and mineral fertilizers on sesame yield components in 2015 and 2016 seasons.

Treatments	T_1	T_2	T_3	T_4	T_5	T_6	T_7	L.S.D. (5 %)
Yield components: Number of plants ha^{-1} (1000)	$114.00^{ab}\pm$ 6043.29	$119.80^{a}\pm$ 6844.27	$67.33^{f}\pm$ 2901.23	$106.30^{b}\pm$ 5828.66	$76.00^{e}\pm$ 6389.46	$87.83^{d}\pm$ 7367.76	$97.00^{c}\pm$ 2495.69	7.963
Plant height (cm)	$124.78^{c}\pm$ 2.54	$127.08^{bc}\pm$ 2.59	$111.00^{e}\pm$ 3.30	$121.19^{cd}\pm$ 1.56	$135.33^{a}\pm$ 6.35	$116.28^{de}\pm$ 3.09	$133.81^{ab}\pm$ 2.13	7.61
Fruiting zone length (cm)	$75.50^{ab}\pm$ 1.03	$75.78^{ab}\pm$ 4.76	$63.39^{d}\pm$ 2.73	$67.22^{cd}\pm$ 2.86	$81.06^{a}\pm$ 2.99	$72.44^{bc}\pm$ 2.48	$70.08^{bcd}\pm$ 1.66	7.44
Number of fruiting nodes $plant^{-1}$	$34.28^{ab}\pm$ 1.27	$34.28^{ab}\pm$ 2.78	$32.83^{bc}\pm$ 4.03	$29.06^{bc}\pm$ 2.53	$29.53^{bc}\pm$ 2.04	$28.58^{c}\pm$ 3.17	$38.72^{a}\pm$ 1.52	5.33
Number of capsules $plant^{-1}$	$62.72^{bc}\pm$ 3.17	$56.64^{cd}\pm$ 3.54	$48.83^{d}\pm$ 4.87	$57.67^{c}\pm$ 4.74	$77.06^{a}\pm$ 8.54	$59.83^{c}\pm$ 3.89	$68.67^{b}\pm$ 7.62	7.96
Number of seeds $capsule^{-1}$	$54.02^{ab}\pm$ 2.28	$50.31^{bc}\pm$ 1.51	$46.07^{cd}\pm$ 1.70	$59.06^{a}\pm$ 4.33	$44.35^{d}\pm$ 2.72	$45.33^{cd}\pm$ 2.49	$45.44^{cd}\pm$ 2.04	5.54
Number of seeds $plant^{-1}$	$3359.02^{ab}\pm$ 322.29	$3088.92^{ab}\pm$ 240.12	$2284.77^{b}\pm$ 375.53	$3354.44^{ab}\pm$ 293.39	$3880.68^{a}\pm$ 666.57	$3101.69^{ab}\pm$ 307.99	$2891.87^{ab}\pm$ 438.00	1197
Seed yield $plant^{-1}$ (g)	$13.73^{a}\pm$ 1.05	$15.37^{a}\pm$ 1.14	$8.61^{c}\pm$ 1.18	$15.23^{a}\pm$ 1.40	$13.27^{ab}\pm$ 2.43	$10.46^{bc}\pm$ 0.73	$14.21^{a}\pm$ 0.65	3.08
Seed index (g)	$4.58^{a}\pm$ 0.12	$4.40^{abc}\pm$ 0.10	$4.44^{abc}\pm$ 0.09	$4.25^{bc}\pm$ 0.09	$4.61^{a}\pm$ 0.09	$4.14^{c}\pm$ 0.07	$4.46^{ab}\pm$ 0.13	0.315

T_1= Mineral (M), T_2= Compost (C), T_3= Bioformulations (B), T_4= 50% (M) × 50% (C), T_5= 100% (B) × 50% (M), T_6= 100% (B) × 50% (C) and T_7= 100% (B) × 33% (C) × 33% (M).

TABLE 5. Impact of bio, organic, and mineral fertilizers on sesame yields and oil quality in 2015 and 2016 seasons:

Treatments	T_1	T_2	T_3	T_4	T_5	T_6	T_7	L.S.D. (5 %)
Yields: Biological yield (kg ha^{-1})	$4877.00^{ab}\pm$ 390.62	$5721.00^{a}\pm$ 270.97	$2723.00^{d}\pm$ 336.13	$5005.00^{ab}\pm$ 607.00	$4199.00^{bc}\pm$ 413.29	$3705.00^{c}\pm$ 362.81	$4786.00^{b}\pm$ 325.63	860.70
Seed yield (kg ha^{-1})	$1260.00^{b}\pm$ 132.17	$1544.00^{a}\pm$ 88.21	$763.30^{d}\pm$ 112.91	$1202.00^{b}\pm$ 189.10	$1096.00^{bc}\pm$ 92.91	$951.40^{cd}\pm$ 70.94	1146.00^{bc} ±120.07	237.30
Oil yield (kg ha^{-1})	$693.00^{b}\pm$ 73.44	$865.60^{a}\pm$ 51.18	$432.40^{c}\pm$ 62.32	$620.70^{b}\pm$ 97.65	$636.50^{b}\pm$ 59.64	$561.50^{bc}\pm$ 41.67	$664.10^{b}\pm$ 66.58	132.70
Harvest index (%)	$25.89^{ab}\pm$ 1.98	$26.99^{ab}\pm$ 0.73	$27.64^{a}\pm$ 1.79	$23.56^{b}\pm$ 1.80	$26.30^{ab}\pm$ 0.56	$25.95^{ab}\pm$ 0.71	$23.74^{b}\pm$ 1.80	3.67
Oil quality: Seed oil percentage	$54.88^{c}\pm$ 0.96	$56.05^{bc}\pm$ 0.58	$56.71^{bc}\pm$ 0.64	$51.62^{d}\pm$ 1.19	$57.88^{ab}\pm$ 0.83	$59.03^{a}\pm$ 0.49	$58.16^{ab}\pm$ 0.75	2.20

T_1= Mineral (M), T_2= Compost (C), T_3= Bioformulations (B), T_4= 50% (M) × 50% (C), T_5= 100% (B) × 50% (M), T_6= 100% (B) × 50% (C) and T_7= 100% (B) × 33% (C) × 33% (M).

Oil quality

All treatments did significant influence on seed oil percentage, as well as the treatment of 100% of bioformulations mixed with 50% of compost was the best treatment, but the treatment of 50% of mineral in interaction with 50% of compost was the worst treatment for seed oil percentage in both seasons. However, all treatments did not significant impact on the fatty acids composition in the oil when compared with the control treatment (100% of mineral) in both seasons.

Seed oil percentage

Results in Table 5 clear that the treatment of 100% of bioformulations mixed with 50% of compost produced the highest value (59.03%), but the treatment of 50% of mineral in interaction with 50% of compost produced the least value (51.62%) with significant difference between them in both seasons. This result is in accordance with those obtained by Shaban et al. (2012) who noticed that the interaction of the organic materials i.e., 5mg compost fed^{-1}, 200L compost tea fed^{-1} and 5kg humic acid fed^{-1} × the strain of PGPR *viz*., *Azospirillum brasilense* significantly increased seed oil content of Shandaweel-3 cv. in a sandy loam soil. Additionally, Jahan et al. (2012 and 2013 b) found that the combination of the inoculation by *Azotobacter* sp*., Azospirillum* sp., *Bacillus* sp., *Pseudomonas* sp. and *Thiobacillus* spp. + the two cover crops *viz.*, *Lathyrus* sp. and *Trifolium resopinatum* produced a maximum value of seed oil content. On the other hand, Motaka et al. (2016 a) found that the combination of 50% RDN via urea + 50% RDN via vermicompost recorded a maximum value of seed oil content. Moreover, Teshome (2016) observed that the addition of 5ton FYM ha^{-1}, 60kg urea ha^{-1} and 30kg DAP ha^{-1} together produced a maximum value (60.36%) of seed oil content of Abasena var. in a clay loam soil.

Fatty acids composition

Data in Table 6 show the effect of bio, organic, and mineral fertilizers on fatty acids composition of sesame cultivar Shandaweel-3. The fatty acids in sesame oil is ranging from medium chain of fatty acids (C14-C16) to long chain of fatty acids (C18-C22). Sesame oil contain monounsaturated fatty acids (40.23%) in the first season and (39.64%) in the second season, but polyunsaturated fatty acids (45.50%) in the first season and (46.29%) in the second season. The main saturated fatty acids are palmitic acid (8.74%) in the first season and (8.81%) in the second season, as well as stearic acid (4.75%) in the first season and (4.63%) in the second season. While, the major unsaturated fatty acids are oleic acid (39.87%) in the first season and (39.32%) in the second season, linoleic acid (45.16%) in the first season and (46.01%) in the second season, also γ-linolenic acid (an omega-6) (0.01%) in the first season and below instrumental detection limit (LOD) in the second season.

Results in Table 6 indicate that the treatment of 100% of bioformulations mixed with 50% of compost gave a maximum value of palmitic acid (8.88%), but the treatment of 100% of bioformulations in combination with 50% of mineral gave a minimum value of palmitic acid (8.54%) in the first season. While, the treatment of 100% of mineral (control treatment) gave a maximum value of palmitic acid (8.81%), but the treatment of 100% of bioformulations combined with 33% of compost and 33% of mineral gave a minimum value of palmitic acid (8.68%) in the second season. The treatment of 50% of mineral in interaction with 50% of compost recorded the highest value of oleic acid (41.15%), but the treatment of 100% of bioformulations mixed with 50% of compost recorded the least value of oleic acid (38.32%) in the first season. On the other hand, Salama et al. (2015) found that the combination of photosynthetic bacteria, lactic acid bacteria and yeast + fermented with plant extracts + 4.5% Zn, 3% Fe and 1.5% Mn resulted in an increase in 27% of oleic acid (18:1 - omega 9). Whereas, the treatment of 100% of mineral (control treatment) recorded the highest value of oleic acid (39.32%), but the treatment of 100% of compost recorded the least value of oleic acid (38.20%) in the second season. This result is in parallel with that obtained by Ali et al. (2016) who concluded that increasing N-rates up to 120kg N ha^{-1} useful for the content of palmitic acid and oleic acid in seeds in a silty clay loam soil.

Results in Table 6 show that the treatment of 50% of mineral in interaction with 50% of compost attained a maximum value of stearic acid (4.80%) in the first season and (4.65%) in the second season, but the treatment of 100% of bioformulations mixed with 50% of compost attained a minimum value of stearic acid (4.50%) in the first season and (4.43%) in the second season.

TABLE 6. Influence of bio, organic and mineral fertilizers on fatty acids composition of sesame plant in 2015 and 2016 seasons.

Common name	Lipid numbers	2015							2016						
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Myristic acid	C14:0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	ND	0.01	0.01	0.01	0.01	0.01	0.01
Palmitic acid	C16:0	8.74	8.84	8.62	8.66	8.54	8.88	8.69	8.81	8.75	8.78	8.76	8.69	8.78	8.68
9 Hexadecenoic acid	C 16:1 ω7	0.12	0.13	0.12	0.12	0.14	0.12	0.14	0.10	0.13	0.14	0.14	0.14	0.13	0.14
Margarinic acid	C17:0	0.06	0.07	0.07	0.05	0.07	0.06	0.06	0.08	0.07	0.07	0.07	0.07	0.07	0.07
Heptadecenoic acid	C 17:1	0.04	0.05	0.05	0.03	0.05	0.04	0.04	0.05	0.04	0.05	0.04	0.05	0.05	0.04
Stearic acid	C 18:0	4.75	4.51	4.60	4.80	4.61	4.50	4.67	4.63	4.55	4.55	4.65	4.60	4.43	4.62
Oleic acid	C 18:1 ω9	39.87	38.59	38.64	41.15	39.20	38.32	40.07	39.32	38.20	38.77	39.17	39.02	38.28	39.07
Linoleic acid	C 18:2 ω6	45.16	46.56	46.62	43.93	46.04	46.72	45.04	46.01	46.97	46.36	45.87	46.14	47.04	46.05
γ-Linolenic acid, an omega-6	C 18:3 n6	0.01	0.03	0.08	0.01	0.12	0.13	0.09	ND	0.06	0.09	0.08	0.11	0.03	0.10
α-Linolenic acid, an omega-3	C 18:3 n3	0.33	0.30	0.29	0.29	0.28	0.30	0.29	0.28	0.31	0.29	0.29	0.29	0.29	0.29
Arachidic acid	C 20:0	0.56	0.55	0.55	0.57	0.57	0.54	0.56	0.54	0.55	0.55	0.57	0.54	0.53	0.56
5-Ecosenic acid	C 20:1 ω9	0.20	0.20	0.19	0.21	0.20	0.20	0.20	0.17	0.20	0.19	0.20	0.19	0.19	0.20
Docosanoic acid	C 22:0	0.13	0.14	0.13	0.14	0.14	0.13	0.14	ND	0.14	0.13	0.14	0.13	0.13	0.14
Un known		0.02	0.02	0.03	0.03	0.03	0.05	0	0.01	0.02	0.02	0.01	0.02	0.04	0.03
Total saturated fatty acids		14.25	14.12	13.98	14.23	13.94	14.12	14.13	14.06	14.07	14.09	14.2	14.04	13.95	14.08
Total unsaturated fatty acids		85.73	85.86	85.99	85.74	86.03	85.83	85.87	85.93	85.91	85.89	85.79	85.94	86.01	85.89
Monounsaturated fatty acids		40.23	38.97	39	41.51	39.59	38.68	40.45	39.64	38.57	39.15	39.55	39.40	38.65	39.45
Polyunsaturated fatty acids		45.50	46.89	46.99	44.23	46.44	47.15	45.42	46.29	47.34	46.74	46.24	46.54	47.36	46.44

T_1 = Mineral (M), T_2 = Compost (C), T_3 = Bioformulations (B), T_4 = 50% (M) × 50% (C), T_5 = 100% (B) × 50% (M), T_6 = 100 % (B) × 50 % (C), and T_7 = 100% (B) × 33% (C) × 33% (M).

Results in Table 6 clear that the treatment of 100% of bioformulations mixed with 50% of compost produced the highest value of linoleic acid (46.72%) in the first season and (47.04%) in the second season, but the treatment of 50% of mineral in interaction with 50% of compost produced the least value of linoleic acid (43.93%) in the first season and (45.87%) in the second season. This result is in harmony with that obtained by Salama et al. (2015) who found that the combination of photosynthetic bacteria, lactic acid bacteria, and yeast + fermented with plant extracts + 4.5% Zn, 3% Fe and 1.5% Mn resulted in an increase in 33% of linoleic acid (omega 6-18:2).

Results in Table 6 indicate that the treatment of 100% of bioformulations mixed with 50% of compost gave a maximum value of γ-linolenic acid (an omega-6) (0.13%), but the treatment of 100% of mineral (control treatment) and the treatment of 50% of mineral in interaction with 50% of compost gave a minimum value of γ-linolenic acid (an omega-6) (0.01%) in the first season. While, the treatment of 100% of bioformulations in combination with 50% of mineral gave a maximum value of γ-linolenic acid (an omega-6) (0.11%), but the treatment of 100% of bioformulations mixed with 50% of compost gave a minimum value of γ-linolenic acid (an omega-6) (0.03%) in the second season.

Conclusion

It can be concluded that the mineral fertilizer was completely replaced via 100% of compost attained the highest values of number of plants ha^{-1} (119.80 thousands ha^{-1}), seed yield $plant^{-1}$ (15.37g), biological yield (5721.00kg ha^{-1}), as well as gave the highest significant values of seed yield (1544.00kg ha^{-1}) and oil yield (865.60kg ha^{-1}) in both seasons. However, it was partially replaced by 100% of bioformulations in combination with 50% of mineral gave maximum values of plant height (135.33cm), fruiting zone length (81.06cm), number of seeds $plant^{-1}$ (3880.68), seed index (4.61g) and recorded a maximum significant value of number of capsules $plant^{-1}$ (77.06) in both seasons. While, the treatment of 100% bioformulations mixed with 50% compost attained the highest value of seed oil percentage (59.03%) in both seasons. Whereas, all treatments did not significant effect on the fatty acids composition when compared with the control treatment (100% of mineral) in both seasons.

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الأسمدة الحيوية و العضوية كبديل للمصدر المعدنى التقليدى على إنتاج وجودة زيت السمسم فى مصر

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تم تقييم إحتماليات الإستبدال الجزئى أو الكلى للأسمدة المعدنية عن طريق الأسمدة الحيوية و العضوية لتحسين خصائص محصول البذور ومحصول الزيت للسمسم، كما تساهم في تقليل التلوث البيئى. تم تنفيذ تجربتين ناجحتين خلال الموسمين الصيفيين 2015 و 2016 بمحطة التجارب والبحوث الزراعية، كلية الزراعة، جامعة القاهرة. كان التصميم التجريبى تصميم القطاعات الكاملة العشوائية مع سبع معاملات. تم اختبار السمسم تحت تأثير ثلاثة أنواع من الأسمدة هى 33، 50 و 100% من المعدنى و الكموبست و 100% من bioformulations. أظهرت النتائج أن المعاملة 100% من الكمبوست حققت أعلى قيم من عدد النباتات بالهكتار (119.80 ألف هكتار-1) و وزن البذور لكل نبات (15.37 جم) و المحصول البيولوجى (5721.00 كجم هكتار-1) كما أعطت أعلى قيم معنوية لمحصول البذور(1544.00 كجم هكتار-1) ولمحصول الزيت (865.60 كجم هكتار-1)، لكن المعاملة 100% من bioformulations بالإضافة إلى 50% من السماد المعدنى سجلت أقصى قيم من طول النبات (135.33 سم) وطول المنطقة الثمرية (81.06 سم) وعدد البذور لكل نبات (3880.68) ودليل البذرة (4.61 جم) وأنتجت أقصى قيمة معنوية من عدد الكبسولات لكل نبات (77.06) فى كلا الموسمين. بينما المعاملة 100% من bioformulations بالإضافة إلى 50% من الكمبوست حققت أعلى قيمة من نسبة الزيت بالبذرة (59.03%)، فى حين أن جميع المعاملات لم يكن لها تأثيرا معنويا على تركيب الأحماض الدهنية بالزيت بالمقارنة بالمعاملة الكنترول (100% من السماد المعدنى) فى كلا الموسمين. ويمكن إستنتاج أن الإستبدال الكلى للسماد المعدنى من خلال 100% من الكمبوست والإستبدال الجزئى للسماد المعدنى بواسطة 100% من bioformulations بالإضافة إلى 50% من السماد المعدنى سجلوا أفضل النتائج فى كلا الموسمين.