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RESPONSE OF JATROPHA CURCAS L. SHRUBS TO COMPLETE (NPK) FERTILIZER, BIO AND ORGANIC FERTILIZERS UNDER SANDY SOIL CONDITIONS

E.A.A. El-Azzony, E.E.A.M. El-Mogy and N.S.A. El-Shaip

Medicinal and Aromatic Plants Res. Dept., Hort. Res. Inst., ARC, Giza, Egypt.

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ABSTRACT: The present work was carried out during the two successive seasons of 2015 and 2016 at the Experimental Farm of El-Quassassin Horticultural Research Station, Ismailia Governorate, Egypt, to study the effect of complete NPK fertilization rates (control, 50, 75 and 100% from the recommended dose), bio and organic fertilizers (control, EM_1 applied as the rate of 100 ml/shrub and active dry yeast with the concentration of 4 g/l as a rate of 2 liters/shrub) and the interaction treatments between them on the growth, (fruits and seeds yields), fixed oil content and its components in seeds of Jatropha (*Jatropha curcas*) shrubs. The results showed that, the best vegetative growth parameters (increasing percentage of shrub height, number of branches and canopy width/shrub), number and weight of fruits (kg)/shrub, number and weight of seeds (kg)/shrub, the yield of fruits and seeds (ton)/fed, fixed oil percentage, weight of fixed oil (g)/shrub and yield of fixed oil (kg)/fed were recorded from the interaction treatment of 75% complete NPK fertilization + EM_1. The analysis of fixed oil of Jatropha shrub showed that, the treatment of 50% NPK gave the best palmitic acid percentage and the treatment of 50% NPK + EM_1 recorded maximum percentages of stearic and oleic acids, while the treatment of 100% NPK + EM_1 gave the highest percentage of linoleic acid.

Key words: *Jatropha curcas*, NPK fertilizer, EM_1, active dry yeast, fixed oil.

INTRODUCTION

Jatropha (*Jatropha curcas*) belongs to the Family Euphorbiaceae, it can grow well under such adverse climatic conditions, in both alkaline and saline soils, semiarid and arid conditions, low slopes of hilly areas, and degraded and abused soils (Behl, 2006). It is commonly called physic nut, purging nut or pig nut (Igbinosa *et al*., 2009). Furthermore, Staubmann *et al.* (1999) recorded that, Jatropha trees are deciduous, flowering occurs during the wet season and in permanently humid regions, flowering occurs throughout the year. The inflorescence is axillary. Male and female flowers are produced on the same inflorescence. Singh *et al.* (2013) added that, the best seed productivities achieved from five years old plants.

J. curcas oil presents exceptional fuel characteristics and has been recommended for biodiesel production in an even 50% mixture with petro diesel, without need to change diesel engines (Pramanik, 2003). *Jatropha* has a good nutritional value. The seed kernels are known to contain highly oil content, which can be used as fuel and also used for making candles, soap, lubricants and varnishes and is used for illumination. The seed cake can be a good protein source for humans as well as for livestock (Makkar *et al*., 2008).

Concerning the influence of NPK fertilization on growth and oil production, Nour El-Din *et al.* (1983) stated that, the application of 50 kg N/fed increased oil percentage of safflower seeds when compared with control. Eid (1991) on *Carthamus tinctorius* plants found that, the total oil yield per plant significantly increased with high level of nitrogen (100 kg N/fed) over the control. Ghaly (1998) demonstrated that, increasing calcium superphosphate fertilization to 600 kg/fed had a significant effect on plant height, branch number, fresh and dry weight of leaves/plant, seed yield, oil percentage and oil yield of *Ricinus communis* L. plants. Nelson and Watson (2001) stated that, in the United States, seed yields of jojoba (*Simmondsia chinensis*) were increased linearly by N rates (0, 30 and 60 kg N/ha/year) in 4 of the 7 years that crops were produced. El-Mogi *et al.* (2004) demonstrated that, the highest level (200 kg/fed of both ammonium sulphate and calcium superphosphate) gave the highest values of plant height, number of branches/plant, fresh and dry weight of leaves and stem/plant, weight of fruits and seed yield/plant as well as fixed oil content in castor bean (*Ricinus communis* L.). Mashal and Abd-El-Halim (2005) indicated that, nitrogen fertilizer application, seeds and chemical insecticide quantities explain approximately 98% of Jojoba production variations in Assuit Governorate under chemical cultivation.

The concept of effective microorganisms (EM_1) was developed by Professor Teruo Higa at the University of Ryukyus, Okinawa, Japan in the early 1980s (Higa, 1991; Higa and Wididana, 1991). A package of effective microorganisms was developed by Higa in 1991. It consisted of mixed cultures of beneficial and naturally-occurring microorganisms that could be applied as inoculants to increase the microbial diversity of soils and plants. The inoculation of EM cultures to the soil/plant ecosystem could improve soil fertility, plant growth, yield and quality of crops. This package was mainly composed of photosynthetic bacteria (*Rhodopseudomonas* spp.), lactic acid bacteria (*Lactobacillus* spp.) and yeast (*Saccharomyces* spp.) beside other microorganisms (Higa, 1991).

MATERIALS AND METHODS

This investigation was carried out during 2015 and 2016 growing seasons to study the effect of chemical, bio and organic fertilizers on the growth, seed yield and oil content on four years old Jatropha (*Jatropha curcas* L.) shrubs planted at 2 × 2.5 meters apart, as mentioned by Singh *et al.* (2013), in a sandy soil under drip irrigation system and grown at El-Qassassin Horticultural Research Station, Ismailia Governorate, Egypt. The all treatments were arranged in a randomized complete block design with three replicates, each replicate was represented by a single shrub. Thirty six shrubs were carefully selected and devoted for achieving this work, and divided into twelve treatments. These shrubs were similar in their growth vigor, size and shape as well as they received the same cultural management. Mechanical and chemical analysis of soil was carried out prior to the first season and shown in Table (1).

The treatments of this investigation were:

1- Complete NPK fertilizer as follows:

- Control (without any fertilizers).
- 50% (125 g of complete NPK fertilizer/shrub) from the recommended dose.
- 75% (190 g of complete NPK fertilizer/shrub) from the recommended dose.
- 100% (250 g of complete NPK fertilizer/shrub) from the recommended dose.

The complete NPK fertilizer consists of 19:19:19% from nitrogen, phosphorus and potassium. These portions were divided into four equal doses, the first dose was added at the first April, and the other three doses were

Table 1. Chemical and physical analysis of the experimental soil.

Sand %	89.92	**Macro elements (ppm)**	
Silt %	4.00	Nitrogen	8.1
Clay %	6.08	Phosphorus	23
Soil texture	**Sandy**	Potassium	108
F. C. %	11.20		
W. P.	2.20	**Micro elements (ppm)**	
Organic matter %	0.42	Fe	2.0
pH (1 soil : 2.5 water)	8.1	Cu	--
EC (mmohs/cm) (1 soil : 5 water)	0.21	Zn	0.26
$CaCO_3$	2.6	Mn	0.80
Soluble ions (meq/L)			
Ca^{++}	1.00		
Mg^{++}	0.40		
Na^{+}	0.76		
K^{+}	0.31		
HCO_3	1.00		
Cl^{-}	0.50		
SO_4	0.97		

applied at twenty five days interval and between the first one, in both seasons.

2- Bio and organic fertilizers:

- Control.
- Effective microorganisms (EM_1): as bio-fertilizer was applied as the rate of 100 ml/shrub.
- The content of effective microorganisms (EM_1) was photosynthetic bacteria (*Rhodopseudomonas palustrus* and *Rhodobacter spaeroides*), lactic acid bacteria (*Lactobacillus plantarum, Lactobacillus casei* and *Streptococcus lactis*), yeasts (*Saccharomyces cerevisiae* and *Candida utilis*), actinomycetes (*Streptomyces albus* and *Streptomyces griseus*) and fungi (*Aspergillus oryzae* and *Mucor hiemalis*) as described by Higa (2002).
- Active dry yeast: as organic fertilizer, was applied with the concentration of 4 g/l at the rate of 2 liters/shrub.

The analysis of yeast (*Saccharomyces cerevisiae*) showed that, it contains, minerals (Na, Ca, Fe, Mg, K, P, S, Zn, Si, Cu, Se, Mn, Cr, Ni, Va, Mo, Sn and Li), vitamins (yhiamine, riboflavin, niacin, choline and vit. B_{12}), protein, carbohydrate, nucleic acids and lipids, as mentioned by Nagodawithana (1991).

Both EM_1 and active dry yeast were added to the soil under the shrubs two times starting at mid Marsh, while the second after one month from the first with the same doses, during the two seasons.

Data recorded:

1. Vegetative growth:

Shrub height (cm), number of branches and canopy width (cm) were measured at the beginning of the experiment in the two seasons (zero time), and these characters were recorded in the end of investigation in October, in the two seasons, and calculated:

- The increasing percentage of shrub height (%),
- The increasing percentage of number of branches/shrub (%),
- The increasing percentage of canopy width/shrub (%), by calculate the equation of:

$$\%= \frac{\text{Shrub height in the end Exper.} - \text{Shrub height in the zero time}}{\text{Shrub height in the zero time}} \times 100$$

2. Fruits and seed yields:

The dry fruits were harvested continuously starting from July to October, in the two seasons and recorded data with as follows:

- Number of fruits/shrub.
- Weight of fruits (kg)/shrub.
- Yield of fruits (ton)/fed.
- Number of seeds/shrub.
- Weight of seeds (kg)/shrub.
- Yield of seeds (ton)/fed.

The area of one feddan contains 840 shrubs. So, the yield of fruits or seeds (ton)/fed was counted by the equation of :

$$\text{Yield (ton)} = \frac{\text{The weight of fruits or seeds (kg) per shrub} \times 840}{1000}$$

3. Fixed oil:

The fixed oil was extracted from the seeds according to the method described by Sayyar et al (2009). In their research on optimization and kinetics in the extraction of oil from Jatropha found hexane to be the best solvent for the process as compared to petroleum ether. The seeds were selected, broken down into smaller pieces, and ground with a knife mill. The estimation of fixed oil in seeds was by using Soxhlet apparatus and measured:

- Fixed oil percentage.
- Weight of fixed oil (g)/shrub.
- Fixed yield oil (kg)/fed counted by the equation of:

$$\text{Fixed oil yield (kg)} = \frac{\text{The weight of oil (g) per shrub} \times 840}{1000}$$

Fixed oil components:

Samples taken from the oil obtained in the second season were analyzed using gas liquid chromatography, to determine their main constituents.

Methylation of fatty acids:

Gas-liquid chromatographic analysis of fatty acids was done on methyl ester which was prepared and purified by the method of Kinsella (1966) with some modifications. Methyl ester was prepared by refluxing the librated fatty acids of Jatropha seeds with sulphuric acid (5 ml 1% v/v) in dried methanol for 30 min at 55 °C. The fatty acid methyl esters were extracted several times with ether. The combined ether extracts were dried with unhydrous sodium sulphate, filtrated, and concentrated at 55 °C.

GLC of fatty acid methyl esters

Separation of fatty acid methyl esters was carried out using cabilary column which contained 15% diethyl glycol succinate DEGS .

The injector port and flame ionization detector were set at 240 °C. The flow rate of carrier gas, nitrogen, was 10 ml/minute. The gas chromatograph (Perkin- Elemar model 8310) had a temperature program from 100 to 190 °C with interment rate of 7 °C/minute. The initial and final time were identified according to their retention time compared to those of authentic samples.

Statistical analysis:

The statistical analysis of the present data was carried out according to Snedecor and Cochran (1980), using L.S.D. at 5% and 1% levels for comparison between means of the different treatments.

RESULTS

1. Vegetative growth:

Data presented in Table (2) show the effect of different rates of complete NPK fertilizers, bio and organic fertilizers and their interaction on the increasing percentages of shrub height, number of branches/shrub and canopy width/shrub. The

Table 2. Effect of complete NPK fertilizer, (bio and organic fertilizers) and their interactions on vegetative characters of *Jatropha curcas* during the two seasons of 2015 and 2016.

Bio and organic fertilizers / Complete NPK fertilizers	First season				Second season			
	Control	EM	Yeast	Mean	Control	EM	Yeast	Mean
				Increasing percentage of plant height				
Control	17.7	19.0	16.3	17.7	19.0	22.3	21.5	21.0
50%	18.5	27.5	20.1	22.0	22.3	35.8	31.7	29.9
75%	21.2	35.5	27.8	28.2	23.4	45.8	33.7	34.3
100%	24.5	32.4	29.2	28.7	32.1	41.8	36.5	36.8
Mean	20.5	28.6	23.3		24.2	36.4	30.8	
	NPK	**Org.**	**Inter.**		**NPK**	**Org.**	**Inter.**	
LSD at 5%	2.4	2.8	4.8		6.2	7.2	12.5	
LSD at 1%	3.3	3.8	6.6		8.5	9.8	16.9	
				Increasing percentage of number of branches				
Control	15.6	34.0	29.4	26.3	16.9	38.1	33.3	29.4
50%	20.5	36.7	30.3	29.2	24.2	42.5	33.4	33.4
75%	20.9	46.1	32.7	33.2	29.4	55.0	38.1	40.8
100%	26.6	41.6	36.8	35.0	36.1	49.1	45.8	43.7
Mean	20.9	39.6	32.3		26.7	46.2	37.7	
	NPK	**Org.**	**Inter.**		**NPK**	**Org.**	**Inter.**	
LSD at 5%	2.7	3.2	5.5		1.8	2.1	3.7	
LSD at 1%	3.7	4.3	7.5		2.5	2.9	5.0	
				Increasing percentage of canopy width				
Control	49.8	109.0	85.6	81.5	89.1	248.1	139.3	158.9
50%	69.6	259.6	141.6	156.9	164.6	319.5	231.9	238.7
75%	127.7	373.0	153.5	218.1	187.7	414.2	244.6	282.2
100%	215.1	274.9	184.9	225.0	390.3	400.3	259.1	349.9
Mean	115.5	254.1	141.4		207.9	345.5	218.7	
	NPK	**Org.**	**Inter.**		**NPK**	**Org.**	**Inter.**	
LSD at 5%	66.0	76.2	131.9		82.1	94.8	164.2	
LSD at 1%	89.6	103.5	179.3		111.6	128.9	223.2	

recorded data reveal that, the highest increasing percentages were obtained from the full dose of NPK fertilizers followed by 75% treatment, and there were non-significant differences between them during the two seasons, in most cases. However, the treatment of EM_1 gave the best results with highly significant increase comparing with yeast and control in the first season. The interaction treatments showed that, the highest increasing percentages were noticed under the interaction treatment of 75% NPK + EM_1, during the two seasons.

The obtained results about complete NPK fertilizer in this study were in harmony with those reported by Ghaly (1998) and El-Mogi *et al.* (2004) on *Ricinus communis* L. plants, who reported that, both ammonium sulphate and calcium superphosphate gave the highest values of plant height and number of branches/plant.

Data resulted when using EM_1 were in line with those obtained by Idris *et al.* (2008) who revealed that, soil application of EM gave better results than foliar application, which resulted in the tallest plant, highest number of primary branches and leaf area index in tomato.

2. Fruit yield parameters:

Data obtained for number of fruits/shrub as affected by complete NPK fertilizer treatments were presented in Table (3). There were highly significant differences between all treatments and control.

Table 3. Effect of complete NPK fertilizer, (bio and organic fertilizers) and their interaction on number and the weight of fruits/plant of *Jatropha curcas* during the two seasons of 2015 and 2016.

Bio and organic fertilizers / Complete NPK fertilizers	First season				Second season			
	Control	EM	Yeast	Mean	Control	EM	Yeast	Mean
				Number of fruits/plant				
Control	237.5	662.5	325.0	408.3	258.3	825.0	350.0	477.8
50%	258.3	775.0	433.3	488.9	283.3	983.3	650.0	638.9
75%	308.3	1133.3	533.3	658.3	341.7	1258.3	508.3	702.8
100%	383.3	1100.0	775.0	752.8	483.3	1150.0	733.3	788.9
Mean	296.9	917.7	516.7		341.7	1054.2	560.4	
	NPK	Org.	Inter.		NPK	Org.	Inter.	
LSD at 5%	43.1	37.4	74.7		65.2	56.5	113.0	
LSD at 1%	58.6	50.8	101.5		88.7	76.8	153.5	
				Weight of fruits (kg)/plant				
Control	0.408	1.125	0.708	0.747	0.550	1.213	0.788	0.850
50%	0.800	1.933	1.483	1.406	0.913	2.500	1.600	1.671
75%	1.233	3.000	2.025	2.086	1.375	3.375	2.125	2.292
100%	1.875	2.533	2.625	2.344	2.150	2.900	2.875	2.642
Mean	1.079	2.148	1.710		1.247	2.497	1.847	
	NPK	Org.	Inter.		NPK	Org.	Inter.	
LSD at 5%	0.135	0.117	0.233		0.164	0.142	0.283	
LSD at 1%	0.183	0.159	0.317		0.222	0.193	0.385	
				Yield of fruits (ton)/fed				
Control	0.343	0.945	0.595	0.628	0.462	1.019	0.662	0.714
50%	0.672	1.624	1.246	1.181	0.767	2.100	1.344	1.404
75%	1.036	2.520	1.701	1.752	1.155	2.835	1.785	1.925
100%	1.575	2.128	2.205	1.969	1.806	2.436	2.415	2.219
Mean	0.907	1.804	1.437		1.048	2.098	1.552	
	NPK	Org.	Inter.		NPK	Org.	Inter.	
LSD at 5%	0.112	0.097	0.193		0.138	0.120	0.240	
LSD at 1%	0.152	0.131	0.262		0.188	0.163	0.326	

The highest value was resulted from the treatment of full dose of NPK. Regardless, the effect of bio fertilizers, it could be concluded that, there were highly significant effects due to EM_1 comparing with yeast and control. On the other hand, the interaction treatment of 75% NPK plus EM_1 resulted in the highest value, with highly significant differences when compared to all interaction treatments, in most cases, in the two seasons. Furthermore, there was non-significant difference between the interaction treatments of 75% NPK + EM_1 and 100% NPK + EM_1 during both seasons.

The results of fruit weight (kg)/shrub as affected by complete NPK fertilizer presented in Table (3) show that, increasing NPK rates increased fruit weight. Moreover, the differences between treatments were highly significant. The best treatment was that of 100% NPK compared to the other doses, in the two seasons. It is obvious from data in the same Table that, all examined treatments of bio and organic fertilization resulted in highly significant increments in the fruit weight/shrub. However, the heaviest fruit weight was recorded by using the treatment of EM_1 with highly significant increases over the yeast and control, during both seasons.

According to data tabulated in Table (3), fruit weight (kg)/shrub as affected by the combined treatments between complete NPK fertilizer rates and bio and organic fertilizers on *Jatropha curcas*, it could be concluded that, the highest effects were observed with

the interaction treatment of 75% NPK + EM_1, followed by full dose of NPK + EM_1. The differences between both treatments were highly significant during the two seasons.

From the results presented in Table (3), EM_1 treatment increased fruit weight (kg)/shrub over the treatment of active dry yeast by 25.6 and 35.2% during the two seasons, respectively. EM_1 raised the results over the control by 99.1 and 100.2% in 1st and 2nd seasons, respectively. In the same trend, the interaction treatment of 75% NPK+EM_1 increased the fruit weight over the treatment of 100% NPK + EM_1 by 18.4 and 16.4% during the two seasons, respectively.

Data observed in Table (3) indicate also that, complete NPK fertilizer had a promotive effect on the yield of fruits (ton)/fed. The differences between all treatments were highly significant. The highest yield resulted from the treatment of full dose of NPK, which yielded 1.969 and 2.219 ton/fed in the first and second seasons, respectively. Furthermore, the bio and organic fertilizers significantly affected the yield of fruits (ton)/fed. The differences between them and control were highly significant. EM_1 treatment resulted the highest yield (1.804 and 2.098 ton/fed) during the two seasons, respectively. In the same Table, the interaction treatments show obvious effects on the yield of fruits. The combined treatment of 75% + EM_1 gave the highest yield, which yielded 2.520 and 2.835 ton/fed in the 1st and 2nd seasons, respectively. The difference between 75% + EM_1 and 100% + EM_1 was highly significant, in both seasons.

3. Seed yield parameters

Data presented in Table (4) show the effect of complete NPK fertilizer on number of seeds/shrub. The differences between treatments were highly significant. The highest number of seeds was found in shrubs fertilized with 100% NPK followed by 75% NPK, in both seasons. As for the main effect of bio and organic fertilization, the results in Table (4) clear that, there were highly significant increases between treatments in number of seeds/shrub. Moreover, the superior treatment in this respect was EM_1. The results stated also that, there were effects due to the interaction treatments and the differences between them were highly significant. The treatment of 75% NPK + EM_1 gave the highest number of seeds followed by 100% NPK + EM_1 in the 1st and 2nd seasons.

As for seed weight (kg)/shrub, data tabulated in Table (4) show that, the different doses of complete NPK fertilization treatments, had highly significant effects. The best result was obtained from the full dose of NPK fertilizer, followed by 75% treatment. The 100% NPK treatment raised the weight of seeds (kg)/shrub over control by 212.8 and 210.8% in 1st and 2nd seasons, respectively. From the same Table, the bio and organic fertilization treatments showed obvious effects, and the differences between treatments were highly significant. The highest seed weight was obtained from shrubs fertilized with EM_1, followed by active dry yeast. The EM_1 treatment increased the seed weight over active dry yeast by 26.0 and 35.3%, during the two seasons, respectively. Furthermore, the interaction treatment of 75% NPK + EM_1 gave the highest weight of seeds (kg)/shrub, with highly significant differences comparing with other combined treatments, in the two seasons. This interaction treatment raised the seed weight over the treatment of 100% NPK + EM_1 by 18.2 and 16.4%; and over the treatment of 75% only by 142.4 and 145.5%, in both seasons, respectively.

The trend of promoting effect of complete NPK fertilizer on seed weight/shrub was clearly observed by Ghaly (1998) and El-Mogi *et al.* (2004) on *Ricinus communis* L. plants.

As for the yield of seeds (ton)/fed, data presented in Table (4) revealed that, there was gradual increase due to using

Table 4. Effect of complete NPK fertilizer, bio and organic fertilizers and their interaction on seed yield characters of *Jatropha curcas* during the two seasons of 2015 and 2016.

Bio and organic fertilizers / Complete NPK fertilizers	First season				Second season			
	Control	EM	Yeast	Mean	Control	EM	Yeast	Mean
				Number of seeds/plant				
Control	885.0	1290.0	1260.0	1145.0	990.0	1455.0	1365.0	1270.0
50%	1050.0	1612.5	1305.0	1322.5	1192.5	1740.0	1417.5	1450.0
75%	1155.0	2100.0	1410.0	1555.0	1297.5	2325.0	1492.5	1705.0
100%	1257.5	1942.5	1867.5	1689.2	1335.0	2040.0	2040.0	1805.0
Mean	1086.9	1736.3	1460.6		1203.8	1890.0	1578.8	
	NPK	Org.	Inter.		NPK	Org.	Inter.	
LSD at 5%	24.1	20.9	41.7		28.7	24.8	49.6	
LSD at 1%	32.7	28.3	56. 7		39.0	33.7	67.5	
				Weight of seeds (Kg)/plant				
Control	0.198	0.540	0.342	0.360	0.264	0.582	0.378	0.408
50%	0.384	0.930	0.702	0.672	0.438	1.200	0.768	0.802
75%	0.594	1.440	0.972	1.002	0.660	1.620	1.020	1.100
100%	0.900	1.218	1.260	1.126	1.032	1.392	1.380	1.268
Mean	0.519	1.032	0.819		0.598	1.199	0.886	
	NPK	Org.	Inter.		NPK	Org.	Inter.	
LSD at 5%	0.062	0.054	0.107		0.076	0.066	0.131	
LSD at 1%	0.084	0.073	0.146		0.103	0.089	0.178	
				Yield of seeds (ton)/fed				
Control	0.166	0.454	0.287	0.302	0.222	0.489	0.318	0.343
50%	0.323	0.781	0.590	0.565	0.368	1.008	0.645	0.674
75%	0.499	1.210	0.816	0.842	0.554	1.361	0.857	0.924
100%	0.756	1.023	1.058	0.946	0.867	1.169	1.159	1.065
Mean	0.436	0.867	0.688		0.503	1.007	0.745	
	NPK	Org.	Inter.		NPK	Org.	Inter.	
LSD at 5%	0.054	0.046	0.093		0.069	0.060	0.120	
LSD at 1%	0.073	0.063	0.126		0.094	0.081	0.163	

complete NPK fertilizer. Full dose treatment gave the best yield and recorded highly significant differences compared with other treatments and control, which yielded 0.946 and 1.065 ton/fed in the two seasons, respectively. The treatments of EM_1 and yeast recorded highly significant increases compared to control and among themselves. The highest yield resulted from using EM_1 which yielded 0.867 and 1.007 ton/fed of seeds during the two seasons, respectively.

From the same Table, the interaction treatments between compete NPK fertilizer and bio and organic fertilizers had highly significant effects on seed yield (ton)/fed. The treatment of 75% + EM_1 recorded highest yield comparing with the other combined treatments, and yielded 1.210 and 1.361 ton/fed and raised over the treatment of full dose + EM_1 by 18.3 and 16.4% and over the treatment of 100% complete NPK fertilizer only by 60.1 and 57.0% in the first and second seasons, respectively.

4. Fixed oil content:

Data observed in Table (5) show that, there were clear and gradual effects of the different doses of complete NPK fertilizer on fixed oil percentage in Jatropha seeds. The highest percentage was obtained from full dose during the two seasons. As for the effect of bio and organic fertilizers, both EM_1 and yeast treatments increased the oil percentage compared to control, but EM_1 gave the best result in both seasons. In the same Table, the interaction treatments

Table 5. Effect of complete NPK fertilizer, bio and organic fertilizers and their interaction on the oil percentage and content (g)/plant of *Jatropha curcas* during the two seasons of 2015 and 2016.

Bio and organic fertilizers / Complete NPK fertilizers	First season				Second season			
	Control	EM	Yeast	Mean	Control	EM	Yeast	Mean
				Oil percentage				
Control	8.8	23.3	18.2	16.8	8.3	22.8	17.7	16.3
50%	11.1	26.1	18.8	18.6	11.6	26.6	19.3	19.1
75%	16.9	27.3	20.5	21.6	16.4	26.8	20.0	21.1
100%	18.1	26.7	21.4	22.1	19.1	27.7	22.4	23.1
Mean	13.7	25.8	19.7		13.9	26.0	19.8	
				The weight of oil (g)/shrub				
Control	17.5	125.6	62.4	68.5	22.0	132.4	67.0	73.8
50%	42.7	242.3	131.6	138.9	50.9	318.6	147.8	172.4
75%	100.3	393.4	199.3	231.0	108.1	434.4	204.0	248.9
100%	162.9	325.5	269.3	252.6	197.1	385.9	308.7	297.3
Mean	80.8	271.7	165.6		94.5	317.8	181.9	
	NPK	**Org.**	**Inter.**		**NPK**	**Org.**	**Inter.**	
LSD at 5%	19.8	17.1	34.2		23.9	20.7	41.4	
LSD at 1%	26.9	23.3	46.5		32.5	28.2	56.3	
				The yield of oil (Kg)/fed				
Control	14.7	105.5	52.4	57.5	18.5	111.2	56.3	62.0
50%	35.8	203.5	110.6	116.7	42.7	267.6	124.2	144.8
75%	84.2	330.4	167.4	194.0	90.8	364.9	171.4	209.0
100%	136.8	273.4	226.2	212.2	165.6	324.2	259.3	249.7
Mean	67.9	228.2	139.2		79.4	267.0	152.8	
	NPK	**Org.**	**Inter.**		**NPK**	**Org.**	**Inter.**	
LSD at 5%	16.6	14.4	28.8		20.1	17.4	34.8	
LSD at 1%	22.6	19.6	39.1		27.3	23.7	47.3	

between complete NPK fertilizer and bio and organic fertilizers raised the oil percentage over the control. The combined treatments of EM_1 with all of 50, 75 and 100% NPK fertilizer doses gave the highest percentages, during the two seasons.

Data presented in Table (5) point out that, complete NPK fertilizer had a gradual effect on fixed oil content (g)/shrub. There were highly significant differences between treatments and control. The highest result was obtained from the treatment of 100% NPK during the two seasons. As for the effect of bio and organic fertilizers, both EM_1 and yeast had positive and highly significant effects on the fixed oil content (g)/shrub comparing with control. The treatment of EM_1 recorded the highest value, and raised over the yeast treatment by 64.1 and 74.7% in the 1st and 2nd seasons, respectively. Furthermore, the differences among themselves were highly significant in both seasons.

The role of NPK fertilizers in increasing fixed oil content was recognized by Nour El-Din *et al.* (1983), and Eid (1991) on *Carthamus tinctorius* seeds. They concluded that, the application of 50 kg N/fed increased fixed oil percentage, and total oil yield per plant was significantly increased with the high level of nitrogen (100 kg N/fed).

Data also presented in Table (5) demonstrate that, all the interaction treatments between complete NPK fertilizer doses and bio and organic fertilizers (EM_1 and yeast) gave highly significant differences compared with control for the fixed oil

content (g)/Jatropha shrub. The highest value was recorded from the interaction treatment of 75% NPK + EM_1 and gave the best result over the combined treatment of 100% + EM_1 by 20.9 and 12.6% in the first and second seasons, respectively.

Concerning the yield of fixed oil (kg)/fed, data observed in Table (5) reveal that, there were highly significant effects due to using complete NPK fertilizer treatments. The treatment of 100% NPK gave the highest yield compared to the other treatments. In the same Table the treatment of EM_1 show highly significant differences comparing with yeast and control during the two seasons. Furthermore, the interaction treatment of 75% complete NPK fertilizer + EM_1 recorded highly significant differences comparing with the other interaction treatments which nearly resulted 330.4 and 364.9 kg fixed oil/fed and raised over the combined treatment of 100%+EM_1 by 20.8 and 12.6%, and over the treatment of 100% NPK only by 141.5 and 120.4% during the two seasons, respectively.

5. Fatty acids percentage in Jatropha fixed oil:

From Jatropha fixed oil analysis recorded in Table (6) and illustrated in Fig. (1), we can observe that, the oil contains the fatty acids of palmitic, stearic, oleic and linoleic acids. The treatment of 50% complete NPK fertilizer gave the highest percentage of palmitic acid (21.05%), and the highest stearic acid percentage (9.78%) was observed with the combined treatment of 50% NPK+EM_1, while control and 50% NPK+EM_1 gave the highest value of oleic acid (18.75 and 17.65%, respectively) and finally, the interaction treatment of 100% NPK+EM_1 gave the highest percentage of linoleic acid (30.77%).

6. The correlation between some studied characters:

Data presented in Table (7) show that:

- There were highly significant positive correlations between weight of oil (g)/shrub and other characters under complete NPK fertilizer, bio and organic fertilizers and interaction treatments, but only significant with increasing percentage of No. branches and No. seeds/shrub, and not significant with increasing percentage of canopy/shrub under bio and organic fertilizer treatments during the two seasons.
- There were positive and highly significant correlations between increasing percentage of branch number/shrub with number and weight of fruits and seeds/shrub under all treatments, but recorded non-significant positive correlation with number of fruits/shrub under bio and organic fertilizer treatments, during both seasons.
- There were highly significant positive correlations between increasing percentage of canopy/shrub with all other characters under complete NPK fertilizer and the interaction treatments. However, there was positive and non-significant correlations with all fruits and seed yield/shrub under bio and complete fertilizers treatments during the two seasons.

From the previous results we can state that, the increase in fixed oil content, reflect positively the raise in increasing percentage of No. branches and canopy, No. fruits and seeds/shrub and weight of fruits and seeds/shrub under the interaction treatments between complete NPK fertilizer and bio and organic fertilizers. While, the yield of fruits and seeds/shrub will reflect positively with the increase in increasing percentage of No. branches and canopy/shrub under the interaction treatments of NPK and bio and organic fertilizers.

DISCUSSION

The recommended doses of complete NPK fertilizer resulted in the highest results in vegetative growth characters and fixed oil content/shrub. These findings may be due to that, N, P and K elements play an important role in composition of many metabolic compounds such as proteins, sugars, carbohydrates, lipids and DNA, which consequently may increase these characters (Devlin, 1979).

Table 6. Effect of complete NPK fertilizer, bio and organic fertilizers and the interaction treatments on the Jatropha oil fatty acids percentage during the second season of 2016.

Complete NPK fertilizer	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Unknown
Control	14.29	7.69	18.75	7.96	64.6
EM_1	11.43	3.51	5.63	5.60	83.26
Yeast	16.67	6.06	7.27	15.38	68.29
50 % NPK	21.05	4.70	4.26	7.27	79.77
75 % NPK	5.75	3.68	5.05	3.88	81.39
100 % NPK	18.75	6.52	6.00	7.31	72.17
50 % NPK + EM_1	11.11	9.78	17.65	13.64	53.93
75 % NPK + EM_1	11.11	4.17	3.91	0.88	84.04
100 % NPK + EM_1	14.81	6.66	15.38	30.77	38.19
100 % NPK + Yeast	5.79	5.64	5.58	4.80	73.98

Table 7. Effect of complete NPK fertilizer, bio and organic fertilizers and their interaction treatments on the correlation measure between fixed oil content, vegetative growth characters, fruits and seed yield/shrub during the two seasons of 2015 and 2016.

The treatments / Characters	NPK		Bio fertilizers		Interaction	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
			Weight of oil (g)/shrub			
Increasing percentage of No. branches	0.996 **	0.983 **	0.982 *	0.980 *	0.915 **	0.941 **
Increasing percentage of canopy	0.989 **	0.989 **	0.960 ns	0.947 ns	0.944 **	0.875 **
No. of fruits/plant	0.982 **	0.992 **	0.995 **	0.996 **	0.945 **	0.909 **
weight of fruits (kg)/shrub	0.998 **	0.999 **	0.986 *	0.995 **	0.970 **	0.978 **
number of seeds/shrub	0.992 **	0.992 **	0.989 *	0.984 *	0.971 **	0.951 **
weight of seeds (kg)/shrub	0.998 **	0.999 **	0.987 *	0.995 **	0.971 **	0.978 **
			Increasing % of Branch number/shrub			
Number of fruits/plant	0.995 **	0.954 *	0.957 ns	0.957 ns	0.936 **	0.809 **
Weight of fruits/plant	0.996 **	0.981 **	0.999 **	0.995 **	0.847 **	0.875 **
Number of seeds/plant	0.999 **	0.998 **	0.999 **	0.999 **	0.942 **	0.752 **
Weight of seeds/plant	0.996 **	0.981 **	0.999 **	0.995 **	0.846 **	0.875 **
			Increasing % of canopy/shrub			
Number of fruits/plant	0.946 *	0.992 **	0.984 *	0.973 ns	0.863 **	0.809 **
Weight of fruits/plant	0.990 **	0.986 **	0.900 ns	0.909 ns	0.899 **	0.875 **
Number of seeds/plant	0.969 *	0.975 **	0.907 ns	0.874 ns	0.879 **	0.752 **
Weight of seeds/plant	0.990 **	0.986 **	0.902 ns	0.909 ns	0.900 **	0.875 **

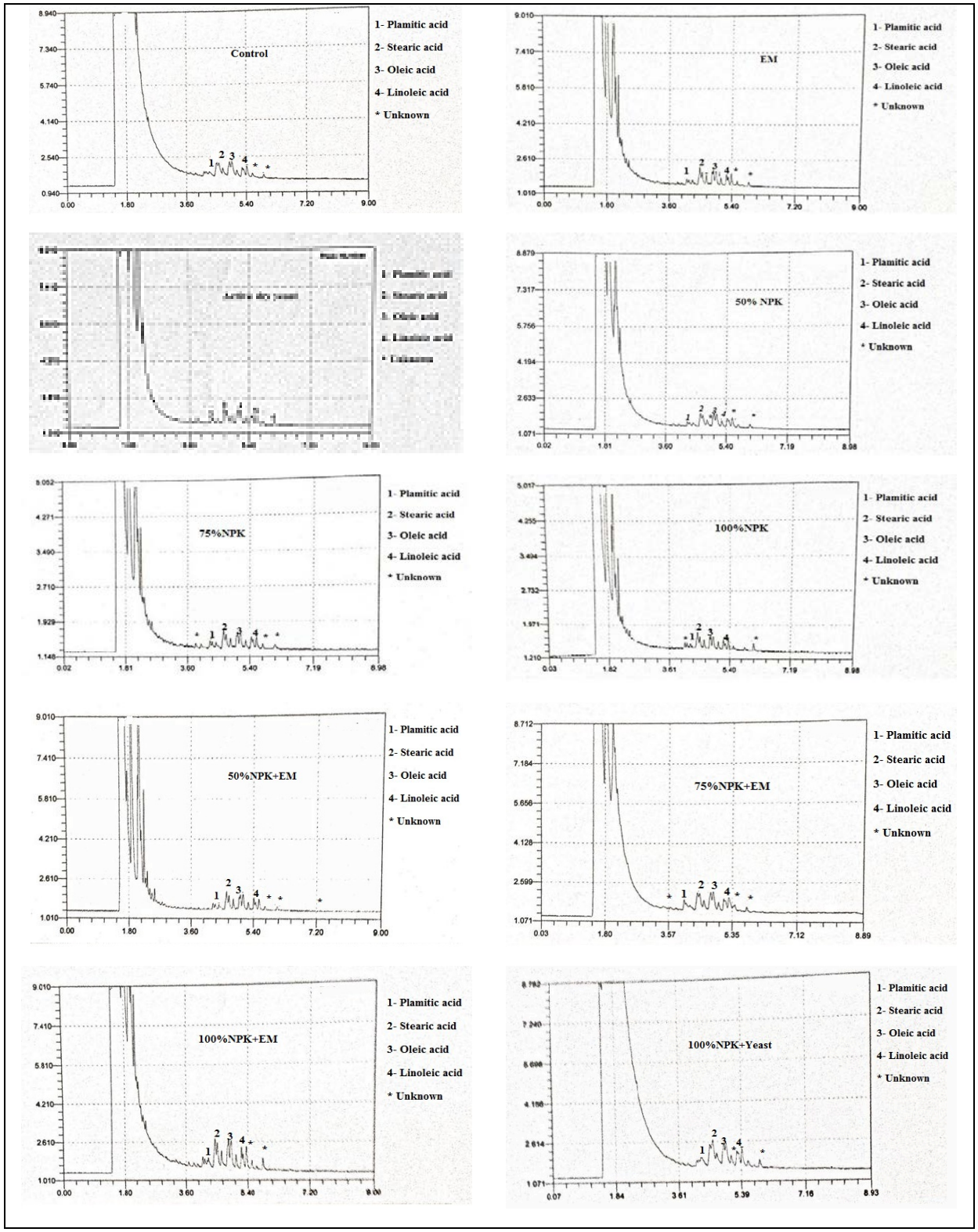

Fig. 1. Effect of complete NPK fertilizer, bio and organic fertilizers and the interaction treatments on the Jatropha fixed oil fatty acids percentage during the second season of 2016.

In the same trend, the stimulative effect of NK on growth parameters may be due to that, N is an essential element for building up protoplasm, amino acids and proteins which induce cell division and initiate meristematic activity. Also, it's positive effects on activation of photosynthesis and metabolic processes of organic compounds in plants which in turn, encourage the plant vegetative growth. Moreover, potassium element is very important in overall metabolism of plant enzymes activity, it was found to serve a vital role in photosynthesis by direct increasing in growth and leaf area. Potassium also has a beneficial effect on water consumption (Mengel and Kirkby, 1978 and Gardener *et al*., 1985).

Asia-Pacific Natural Agriculture (1995) reported that, application of EM_1 into the soil induced an increase in soil microorganisms that are beneficial for the growth of the plant that result in rapid mineralization of organic materials as well as improvement of crop yield and quality due to an increase in plant nutrients and suppression of soil-borne pathogens.

The positive impact of EM_1 that happened, may due to presence of the following five families of micro-organisms: a) Lactic acid bacteria: these bacteria are differentiated by their powerful sterilizing properties. They suppress harmful micro-organisms and encourage quick breakdown of organic substances. In addition, they can suppress the reproduction of Fusarium, a harmful fungus. b) Yeasts: these manufacture anti-microbial and useful substances for plant growth. Their metabolites are food for other bacteria such as the lactic acid and actinomycetes groups. c) Actinomycetes: these suppress harmful fungi & bacteria and can live together with photosynthetic bacteria. d) Photosynthetic bacteria: these bacteria play the leading role in the activity of EM_1. They synthesize useful substances from secretions of roots, organic matter and/or harmful gases (e.g. hydrogen sulfide) by using sunlight and the heat of soil as sources of energy. They contribute to a better use of sunlight or, in other words, better photosynthesis. The metabolites developed by these micro-organisms are directly absorbed by plants. In addition, these bacteria increase number of other bacteria and act as nitrogen binders. e) Fungi: that bring about fermentation as these break down the organic substances quickly. This suppresses smell and prevents damage that could be caused by harmful insects (Higa and Parr, 1994 and Xu, 2000).

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إستجابة شجيرات الجاتروفا للسماد الكامل (ن فو بو) والأسمدة الحيوية والعضوية تحت ظروف الأرض الرملية

عصام عبد الكريم عبد العظيم العزونى، عصام الدين أحمد محمد الموجى، ناهد سيد أحمد الشايب

قسم بحوث النباتات الطبية والعطرية، معهد بحوث البساتين، مركز البحوث الزراعية، الجيزة، مصر.

تم إنجاز هذا العمل خلال عامى ٢٠١٥ و ٢٠١٦ فى المزرعة البحثية لمحطة بحوث البساتين بالقصاصين، محافظة الإسماعيلية، جمهورية مصر العربية، لدراسة تأثير معدلات من السماد الكامل (NPK) (كنترول، ٥٠ ، ٧٥ ، ١٠٠ % من الجرعة الموصى بها) والأسمدة الحيوية والعضوية (كنترول ، الكائنات الحية الدقيقة النشطة EM_1 بمعدل ١٠٠ ملليلتر/شجيرة ، الخميرة الجافة النشطة بتركيز ٤ جم/لتر وبمعدل ٢ لتر/شجيرة) ومعاملات التفاعل بينهما على النمو ومحصول الثمار والبذور ومحتوى البذور من الزيت الثابت ومكوناته فى شجيرات الجاتروفا. وقد أظهرت النتائج أن أفضل نمو خضرى (نسبة الزيادة فى كل فى طول النبات وعدد الأفرع ومساحة تاج الشجيرة)، وعدد ووزن الثمار (كجم)/شجيرة، وعدد ووزن البذور (كجم)/شجيرة ومحصول الثمار والبذور (طن)/فدان ونسبة ووزن الزيت الثابت (جم)/شجيرة ومحصول الزيت الثابت (كجم)/فدان تم الحصول عليها من معاملة التفاعل ٧٥% من السماد الكامل + EM_1. وأظهر تحليل الزيت الثابت فى بذور الجاتروفا أن المعاملة (٥٠% من السماد الكامل ن فو بو) حققت أفضل نسبة من الحامض الدهنى البالميتيك، والمعاملة ٥٠% من السماد الكامل ن فو بو + EM_1 حققت أعلى نسبة من الأحماض الدهنية الإستياريك والأوليك، فى حين أن المعاملة ١٠٠% من السماد الكامل ن فو بو + EM_1 أعطت أعلى نسبة من الحامض الدهنى اللينوليك.