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Response of Moringa Plants to Mineral, Organic and Bio-Fertilizers Mixtures

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ABSTRACT

This experiment was conducted at the Agriculture Experiments and Research Center, Minia University during the two successive seasons of 2015/2016 and 2016/2017 to study the response of *Moringa oleifera* plants to mineral, organic and bio-fertilizers mixtures. Moringa seedlings were grown on soil enriched with 0, 5,10 and 15 ton/fed of compost as a main split plot, while the sub-plots included control, full dose of NPK,75%NPK+a mixture of bio-fertilizers "effective microorganisms (EM) + phosphorein", and this mixture of bio-fertilizers.The results showed that organic fertilizer, bio-fertilizers and NPK significantly improved the growth and seed yield of the Moringa plants in both seasons. The highest Moringa seed yield was for plant fertilized with bio-fertilization + 75% NPK and 15 ton/fed compost, whereas, the control plants had the lowest seed yield during both seasons. In all cases, bio-fertilization + 75% NPK was more effective in increasing all investigated growth and yield parameters than was 100% NPK or bio-fertilization under the same compost treatments. This trend was coincided with the plant content of the photosynthetic pigments and NPK content. From the results of this study, moringa plants grown under these experimental conditions achieved the highest growth and yield parameters following fertilization with bio-fertilization + 75% NPK at 15 ton/fed of compost.

INTRODUCTION

The *Moringa oleifera* "Moringa' or 'drumstick tree', is a medium-size tree belongs to the family Moringaceae, it is indigenous in north-west India and now widely distributed throughout the tropic area. This tree has been cultivated not only for food, medicine, and fodder but also for feed purpose (Anwar *et al*., 2007; Reyes-Sánchez *et al*., 2006 and Oliveira *et al*., 1999). It contains a high concentration of crude protein, nutrient elements and vitamins A, B, and C in the foliage (Makkar and Becker, 1996). Feeding Moringa leaves to livestock could achieve a weight gain and improve their nutritional status (Ramachandran *et al*., 1980).

Recently, Huda *et al*. (2016) concluded that the best moringa biomass can be acquired under dry and warm conditions once some supplemental fertilizer is applied. Fertilization is one of the most important inputs for sustaining high crop productivity. Moreover, the limited availability of fertilizers and fertilization techniques which include organic and inorganic sources imposes the plant growth and adoption. On the other hand, crops which rely on inorganic fertilizers often lead to unsustainable soil production and threatening the environment (Prasad and Power, 1995). Therefore, many efforts aimed to optimize using organic manures to produce the same amount of food with less inorganic fertilizer, minimizing the loss of nutrients, reducing the accumulation of wastes and limiting greenhouse gas emissions (Prasad, 1998; Ram and Kumar, 1996 and Mathur *et al*., 1993). Organic manure influence soil productivity through correction of the deficiency of secondary and micro-nutrient and their effect on soil physical, chemical and biological properties. Bio-fertilizers, on the other hand, are cost-effective and renewable source of plant nutrients to supplement some parts of the chemical fertilizers (Yadav *et al*., 2013). They became a positive alternative to chemical fertilizers because they are the most important for plant production and soil health in general. Bio-fertilizers play an important and complex role in plant growth, improving fruit quality and yield components of crops by way of various biochemical activities in the soil such as increases the soil fertility, add nutrients through the natural processes of biological N fixation, solubilizing phosphorus, the availability of nutrients by their biological activity and uptake of nutrients (Saraswati and Sumarno, 2008). Agricultural wastes compost is a good source of micro- and macro-nutrients, increasing cation exchange capacity of soil and has been used for centuries to increase soil fertility (Kolay, 2007).

Bio-fertilizer which contains variant microorganisms could promote the adequate supply of nutrients to the plants and guarantee their proper growth, development and regulation (Mall *et al*., 2013). Different kinds of living microorganisms are used in a commercial preparation of bio-fertilizers with specific functions to enhance plant growth and/or reproduction. Bio-fertilizer being essential components of organic farming play vital role in maintaining long term soil fertility and sustainability (Mohapatra *et al*., 2013). As a safe alternative to chemical fertilizer, bio-fertilizer minimizes the ecological disturbance and is cost effective, eco-friendly and could increase crop yield up to 10-40%. Moreover, the initial inoculums are sufficient for growth and multiplication of organisms in subsequent years (Mall *et al*., 2013 and Mohapatra *et al*., 2013). The effect of bio-fertilizers on vegetative growth and chemical constituents of *Moringa oleifera* plants, indicated that the highest values of plant height, stem diameter, branch number and dry weight of shoots increased with application of the bio-fertilizers Microbine, Phosphorine and Nitrobine (Mazher *et al*., 2014 and Youssef, 2016). Therefore, this research was conducted in order to study the effect of different mineral, organic and bio-fertilizer mixtures on the production of *M. oleifera*.

MATERIALS AND METHODES

The present study was carried out during the two successive seasons of 2015/2016 and 2016/2017 at the Agricultural Experiments and Research Center, Minia university. This investigation aimed to study the response of *Moringa oleifera* to different combinations of compost, mineral NPK and/or bio-fertilization treatments, as well as, the interaction between these treatments in terms of vegetative growth characters, yield and yield components, and some chemical constituent parameters.

The seeds of *M. oleifera* were collected from the mother trees from nursery of ornamental plants and sown on Jan. 25[th] in 15 cm-diameter plastic pots filled with sandy soil and maintained in the greenhouse until transplanting date. Seedlings were transplanted in the experimental field on March 1[st] in each season.

The experiment was arranged as a complete randomized block in a split–plot design with 3 replicates. The main plots included 4 levels of compost (0, 5, 10 and 15 ton/fed), while the sub-plots included 4 treatments (control, full dose of NPK, 75 % NPK + bio-fertilizers, and bio-fertilizers). The experimental unit was (4 X 10 m) containing 4 rows. The seedlings were transplanted in hills, 1 m apart, therefore, each experimental unit contained 40 plants. The physical and chemical analyses of the experimental soil were determined according to Jackson (1973) and shown in Table (1).

Table 1. physical and chemical analyses of the experimental soil

Physical properties		Chemical properties	
Clay %	3.70	$CaCO_3$ %	1.44
Silt %	8.30	pH (1:2.5 water)	8.17
Sand%	88.00	EC dSm^{-1}	1.35
Soil texture	Sand	Organic Matter%	0.06
Field capacity (F.C)	16.34	Total N%	0.017
Wilting Point (W.P)	5.66	Available P	6.25mg kg^{-1}
Available Water	10.68	Exchangeable K	14 mg kg^{-1}

The compost used (El-Neel compost) was obtained from the Egyptian Co. for solid waste utilization, New Minia City. The compost was added during preparing the soil for cultivation in both experimental seasons. Physical and chemical properties of the compost used are shown in Table (2).

Table 2. Physical and chemical properties of the used compost

Property	Value	Property	Value
Dry weight of 1 m^3	450 kg	C/N ratio	18.5
Fresh weight of 1 m^3	650 kg	NaCl (%)	1.10
Moisture (%)	29.88	Total P (mg kg^{-1})	5.0
pH (1:10)	7.5	Total K (mg kg^{-1})	8.0
E.C (dSm^{-1})	2.33	Fe (mg kg^{-1})	150
Total N (%)	1.0	Mn (mg kg^{-1})	25
Organic matter (%)	32	Cu (mg kg^{-1})	75
Organic carbon (%)	18.5	Zn (mg kg^{-1})	150

Mineral NPK was used as 300 Kg ammonium sulfate (21% N), 200 Kg calcium super phosphate (15.5% P_2O_5) and 100 Kg potassium sulfate (48% K_2O)/fed. for treatment of 100% NPK, while, 75 % mineral NPK was represented by 225, 150 and 75 Kg/fed of the previous fertilizers respectively. The calcium super phosphate was added to soil during the preparation for cultivation while the amounts of NK were divided into 3 equal patches and added after 3 weeks from transplanting, one and two months, thereafter.

Fresh and active bio - fertilizers; effective microorganisms (E.M.) and phosphorein were obtained from the Laboratory of Bio-fertilizers, Department of Genetic, Fac. of Agri. Minia Univ. A 5 ml/hill from each type of these bio-fertilizers were applied 3 times to the soil around the plant. The treatment was commenced 4 weeks after transplanting and repeated every 4 weeks thereafter. All other agricultural practices were performed as usual and recommended.

Twenty months after transplanting, the matured plants were cut above the soil surface to assess the vegetative and yield parameters. The photosynthetic pigments chlorophyll a, b and carotenoids were determined according to Moran (1982). Nitrogen was determined using Kjeldahl method as described by Chapman and Pratt (1982). Potassium was estimated using flame—photometry following Chapman and Pratt (1982). Phosphorus was determined by the molybdenum blue method according to Olsen procedure as described by Chapman and Pratt (1982).

Statistical Analysis

The obtained data were tabulated and statistically analyzed using MSTAT-C (1986) and the L.S.D. test at 5 % was followed to compare between means following Clewer and Scarisbrick (2001).

RESULTS AND DISCUSSION

The response of *Moringa oleifera* plants to mineral, organic and bio-fertilization was investigated as follows;

1- Plant height and stem diameter

Both, compost and fertilization treatments significantly affected the plant height and stem diameter of the moringa plants. Moreover, there was a significant interaction between the two factors during both seasons as shown in Table (3).

Table 3. Effect of different fertilizer combinations on plant height and stem diameter of *Moringa oleifera* plants during 2015/2016 and 2016/2017 seasons

Treatment	Compost levels (ton/fed.) (A)									
	1[st] Season					2[nd] Season				
	0	5	10	15	Mean (B)	0	5	10	15	Mean (B)
	Plant height (cm)									
Control	171.0	186.2	193.8	206.2	189.3	188.1	205.2	232.8	247.0	218.3
100 % NPK	237.5	261.3	275.5	293.6	267.0	261.3	287.9	330.6	352.5	308.1
Bio. + 75 %NPK	254.6	282.2	295.5	317.3	287.4	280.3	310.7	354.4	381.0	331.6
Bio.	209.0	229.9	240.4	255.6	233.7	229.9	252.7	288.8	306.9	269.6
Mean (A)	218.0	239.9	251.3	268.2		239.9	264.1	301.7	321.9	
L.S.D at 5 %	A : 8.4		B : 9.2		AB : 18.4	A : 10.1		B : 11.3		AB : 22.6
	Stem diameter (cm)									
Control	4.25	4.55	4.83	5.12	4.69	5.52	5.93	6.28	6.65	6.10
100 % NPK	4.91	5.29	5.68	6.12	5.50	6.87	7.40	7.95	8.57	7.70
Bio. + 75 %NPK	6.21	6.59	6.99	7.45	6.81	8.69	9.22	9.79	10.4	9.53
Bio.	4.83	5.10	5.39	5.71	5.26	6.76	7.06	7.55	8.00	7.34
Mean (A)	5.05	5.38	5.72	6.10		6.96	7.40	7.89	8.41	
L.S.D. at 5 %	A : 0.39		B : 0.67		AB : 1.34	A : 0.48		B : 0.92		AB : 1.84

Under the same compost treatments, plants fertilized with bio-fertilizers +75% of NPK had higher plant height and stem diameter measurements than all other treatments. Nevertheless, these two growth parameters were gradually ($p < 0.05$) improved in an ascending order compared to the control plants, bio-fertilization then 100% NPK treated plants in both seasons. During the first season, the non-fertilized plants which grown on soil without any compost application had the lowest plant height and stem diameter of 171 and 4.25 cm, respectively. This plant height was significantly lower than that of all other plants except those grown on soil with 5 ton/fed of compost (186.2 cm). There was no significant difference among the diameter of the control plants which untreated with compost and these fertilized with 100% NPK + 0 or 5 ton/fed compost (Table, 3). In all cases, bio-fertilization + 75% NPK was more effective in increasing plant height and stem diameter than was 100% NPK or bio-fertilization under the same compost treatments. Overall, during both seasons, the bio-fertilized moringa plants which were treated with 75% NPK and 15 ton/fed compost had the highest values of plant height and stem diameter.

2- Fresh and dry weights of plant leaves and aerial parts

The compost as well as the fertilization treatments of the moringa plants significantly affected their leaves fresh and dry weights. Moreover, there was a significant interaction between the two investigated factors with similar trends during both experimental seasons (Table, 4). Under the same compost level the fresh and dry weight of the moringa leaves were gradually increased in the following order; the control, bio-fertilizer, 100% NPK and bio-fertilizer + 75% NPK treatment. The fresh and dry weight of moringa leaves was gradually increased under the same NPK and/or bio-fertilization treatment by increasing compost level, however, in some cases these increments was not significant ($p < 0.05$). During the first season, the 15 ton/fed compost + bio-fertilizer + 75% NPK-fertilized plants had fresh and dry weights of 8.10 kg/plant and 806.8 g/plant, respectively, these values were significantly higher than all other equivalent values. However, the lowest leaves fresh and dry weight (3.65 kg/plant and 400.7 g/plant, respectively in the first season) being for the control plants grown on soil without any compost addition. These values were significantly lower than the weights of the plants treated with any other treatments except that of the control plants grown on soil with 5 ton/fed compost. The moringa plants that were treated with 15 ton/fed of compost + bio-fertilizer + 75% NPK had relative increase of leaves fresh and dry weights of 221 and 200% compared to control plants which grown on soil without any compost addition, respectively.

Table 4. Effect of different fertilizer combinations on leaves fresh and dry weight of *Moringa oleifera* plants during 2015/2016 and 2016/2017 seasons

Treatment	Compost levels (ton/fed.) (A)									
	1st Season					2nd Season				
	0	5	10	15	Mean (B)	0	5	10	15	Mean (B)
	Leaves fresh weight (kg/plant)									
Control	3.65	3.97	4.13	4.38	4.03	5.01	5.56	5.79	6.06	5.61
100 % NPK	5.57	6.11	6.44	6.87	6.25	7.79	6.35	9.02	9.62	8.20
Bio. + 75 %NPK	6.49	7.20	7.54	8.10	7.33	9.09	10.0	10.5	11.3	10.22
Bio.	4.67	5.14	5.37	5.70	5.22	6.46	7.20	7.52	7.98	7.29
Mean (A)	5.10	5.61	5.87	6.26		7.09	7.28	8.21	8.74	
L.S.D. at 5 %	A : 0.38		B : 0.27		AB : 0.54	A : 0.49		B : 0.38		AB : 0.76
	Leaves dry weight (g/plant)									
Control	400.7	436.1	454.3	482.3	443.4	540.9	632.4	658.7	698.9	632.7
100 % NPK	556.2	611.2	644.5	686.2	624.5	806.5	886.1	934.6	994.9	905.5
Bio. + 75 %NPK	649.0	719.3	752.3	806.8	731.9	941.1	1043.0	1090.0	1169.0	1060.8
Bio.	467.1	514.1	536.9	568.4	521.6	677.3	745.5	778.5	824.3	756.4
Mean (A)	518.3	570.2	597.0	635.9		741.5	826.8	865.5	921.8	
L.S.D. at 5 %	A : 32.0		B : 26.1		AB : 52.2	A : 46.0		B : 37.0		AB : 74.0

The fertilization and the compost treatments significantly affected the fresh and dry weights of the moringa aerial parts. Moreover, results show a significant interaction between these two factors (Table, 5). Under the same compost level the moringa plants treated with bio-fertilizer and 75% NPK yielded ($p < 0.05$) higher fresh and dry weights of the aerial parts than those fertilized with 100% NPK during both seasons. It was obvious that increasing the compost level gradually increased the fresh and dry weights of these aerial parts of the plants regardless the fertilization treatment. However, in many cases the difference between each consecutive level was not significant. During the first season, the control plants which did not treat with compost had aerial parts fresh weight of 9.8 kg/plant, which was significantly lower than those of the plants treated with bio-fertilizers (13.1 kg/plant) however, for the aerial parts dry weight there were no significant differences between the control plants (3.98 kg/plant) and the plants treated with bio-fertilizers (4.89 kg/plant). Similar trends were observed during the second experimental seasons.

Table 5. Effect of different fertilizer combinations on the aerial parts fresh and dry weight of *Moringa oleifera* plants during 2015/2016 and 2016/2017 seasons

Treatment	Compost levels (ton/fed.) (A)									
	1st Season					2nd Season				
	0	5	10	15	Mean (B)	0	5	10	15	Mean (B)
	The aerial plant parts fresh weight (kg/plant)									
Control	9.8	11.1	12.0	13.2	11.52	11.9	13.6	14.7	16.1	14.08
100 % NPK	15.4	17.7	19.6	22.0	18.68	19.0	19.7	24.2	27.0	22.48
Bio. + 75 %NPK	19.7	22.8	24.9	27.9	23.83	24.2	28.0	30.5	34.2	29.23
Bio.	13.1	15.0	16.2	17.9	15.55	16.1	18.5	20.0	22.1	19.18
Mean (A)	14.5	16.7	18.2	20.3		17.8	20.0	22.4	24.9	
L.S.D. at 5 %	A : 2.00		B : 1.50		AB : 3.00	A : 2.10		B : 1.62		AB : 3.24
	The aerial plant parts dry weight (kg/plant)									
Control	3.98	4.70	5.18	5.82	4.92	4.66	5.53	6.09	6.80	5.77
100 % NPK	5.97	7.00	7.89	8.98	7.46	7.03	8.22	9.26	10.5	8.75
Bio. + 75 %NPK	7.28	8.50	9.43	10.5	8.93	8.56	10.0	11.0	12.3	10.47
Bio.	4.89	5.65	6.20	6.82	5.89	5.77	6.49	7.29	8.02	6.89
Mean (A)	5.53	6.46	7.18	8.03		6.51	7.56	8.41	9.41	
L.S.D. at 5 %	A : 0.76		B : 0.53		AB : 1.06	A : 0.85		B : 0.56		AB : 1.12

3-Number of pods and number of seeds/pod

Results showed that the compost and different fertilization application significantly ($p < 0.05$) affected the number of pods as well as the number of seeds/pod of moringa plants. Moreover, there was a significant interaction between the two investigated factors and similar response of the plants during both seasons as shown on Table (6). Under the 5, 10 or 15 ton/fed compost treatments the plant which fertilized with the bio-fertilizers had significantly higher number of pods/plant and seeds/pod than that of the control plants. However, plants only treated with bio-fertilizers have significantly lower number of pod/plant as well as number of seeds/pod than plants treated with 100% NPK. Overall, the significantly lowest number of pods/plant (11.9) being for the control plants with non-compost treatment. These plants also, had the lowest number of seeds/pod (21.05) which was significantly lowest than that of all other treatment except that of the control plant grown on soil with 5 ton/fed of compost. During both seasons, the bio-fertilized moringa plants which were treated with 75% NPK and 15 ton/fed compost had the highest number of pods/plant (33.2 and 39.8 in the first and second season, respectively) and number of seeds/pod (33.58 and 36.94 in the first and second season, respectively).

Table 6. Effect of different fertilizer combinations on number of pods/plant and number of seeds/pod of *Moringa oleifera* plants during 2015/2016 and 2016/2017 seasons

Treatment	Compost levels (ton/fed.) at (A)									
	1st Season					2nd Season				
	0	5	10	15	Mean (B)	0	5	10	15	Mean (B)
	Number of pods/plant									
Control	11.9	15.3	18.4	21.5	16.76	13.0	16.8	20.3	23.7	18.45
100 % NPK	20.7	23.8	25.7	28.9	24.78	24.9	28.5	30.9	34.6	29.73
Bio. + 75 %NPK	22.9	26.6	29.5	33.2	28.05	27.5	31.9	35.5	39.8	33.68
Bio.	15.0	18.6	21.7	25.4	20.18	18.0	22.4	26.1	30.5	24.25
Mean (A)	17.6	21.1	23.8	27.3		20.9	24.9	28.2	32.2	
L.S.D. at 5 %	A : 0.51		B : 0.45		AB : 0.90	A : 0.68		B : 0.55		AB : 1.10
	Number of seeds/pod									
Control	21.05	22.43	23.81	25.64	23.23	22.14	24.67	26.20	28.21	25.31
100 % NPK	25.19	26.92	28.99	31.16	28.07	27.71	29.61	31.89	34.28	30.87
Bio. + 75 %NPK	26.23	28.64	29.66	33.58	29.53	28.85	31.51	32.62	36.94	32.48
Bio.	22.78	24.50	25.88	28.05	25.30	25.05	26.95	28.47	30.86	27.83
Mean (A)	23.81	25.62	27.09	29.61		25.94	28.19	29.80	32.57	
L.S.D. at 5 %	A : 0.65		B : 1.1		AB : 2.2	A : 0.63		B : 1.0		AB : 2.0

4-Weights of 100 seeds/plant and seed yield/plant

Compost and fertilization application had significant effects on the weights of 100 seeds/plant as well as the seed yield/plant. Moreover, there was a significant interaction between the two factors during both seasons (Table, 7). Regardless, the type of fertilization treatments there was a significant increase on both traits by increasing the compost level. Nevertheless, under the same compost treatments, the plant which fertilized with bio-fertilizers +75% of NPK had the highest values of both traits followed by those of plants treated with 100% of NPK then the bio-fertilized plants. During the first season, the control plants which grown on soil without compost application had the lowest weight of 100 seeds and seed weight/plant (10.4 and 26.05 g, respectively). Overall, during both seasons, the bio-fertilized moringa plants which were treated with 75% NPK and 15 ton/fed compost gave significantly the highest weight of 100 seeds (14 and 14.6 g in the first and second season, respectively) and seed weight/plant (156.08 and 214.65 g in the first and second season, respectively).

Table 7. Effect of different fertilizer combinations on weight of 100 seeds and seed weight/plant of *Moringa oleifera* plants during 2015/2016 and 2016/2017 seasons

Treatment	Compost levels (ton/fed.) (A)									
	1st Season					2nd Season				
	0	5	10	15	Mean (B)	0	5	10	15	Mean (B)
	Weight of 100 seeds (g)									
Control	10.4	11.2	11.3	12.0	11.23	10.9	11.8	11.9	12.6	11.80
100 % NPK	11.5	12.5	12.6	13.2	12.45	12.1	13.0	13.2	13.9	13.05
Bio. + 75 %NPK	12.2	13.0	13.3	14.0	13.13	12.7	13.7	13.8	14.6	13.70
Bio.	11.2	11.9	12.2	12.9	12.05	11.6	12.4	12.9	13.5	12.60
Mean (A)	11.3	12.2	12.4	13.0		11.8	12.7	13.0	13.7	
L.S.D. at 5 %	A : 0.13		B : 0.09		AB : 0.18	A : 0.18		B : 0.12		AB : 0.24
	Seed weight/plant (g)									
Control	26.05	38.44	49.51	66.15	45.04	31.37	49.91	63.29	84.24	57.20
100 % NPK	59.96	80.09	93.88	118.87	88.20	83.49	109.71	130.07	164.87	122.04
Bio. + 75 %NPK	73.28	99.04	116.37	156.08	111.19	100.76	137.71	159.81	214.65	153.23
Bio.	38.27	54.23	68.51	91.91	63.23	52.30	74.86	95.86	127.07	87.52
Mean (A)	49.39	67.95	82.07	108.25		66.98	93.05	112.26	147.71	
L.S.D. at 5 %	A : 4.48		B : 4.41		AB : 8.83	A : 5.62		B : 5.01		AB : 10.02

5-The photosynthetic pigments

The photosynthetic pigments; chlorophyll a, b and carotenoids of moringa plants were significantly affected by the compost application and the applied fertilization treatments during both seasons. Moreover, there was a significant interaction between the two investigated factors during both seasons (Table, 8). In all cases, these three parameters were significantly increased by increasing the compost level under the same fertilization treatment. Moreover, the chl. a and b and carotenoids were gradually increased under the same compost level in the following order; the control, bio-fertilizer, 100% NPK then bio-fertilizer + 75% NPK treatment, however, in some cases this increments was not significant. During the second season, the plants of the treatment (15 ton/fed + bio-fertilizer + 75% NPK) gave the highest values of chl. a and b and carotenoids (3.738, 1.244 and 1.303 mg/g fresh weight, respectively), these values were significantly higher than all other equivalent values. However, the lowest values of these traits (2.897, 0.928 and 0.992 mg/g fresh weight, respectively) being for the control plants grown on soil without any compost addition during the first season.

Table 8. Effect of different fertilizer combinations on photosynthetic pigments (chlorophyll a, b and carotenoids) in the leaves of *Moringa oleifera* plants during 2015/2016 and 2016/2017 seasons

Treatment	Compost levels (ton/fed.) (A)									
	1st Season					2nd Season				
	0	5	10	15	Mean (B)	0	5	10	15	Mean (B)
	Chlorophyll a (mg/g fresh weight)									
Control	2.897	3.037	3.191	3.357	3.121	2.921	3.077	3.229	3.385	3.153
100 % NPK	3.167	3.322	3.484	3.664	3.409	3.196	3.352	3.526	3.697	3.443
Bio. + 75 %NPK	3.194	3.352	3.527	3.698	3.444	3.226	3.385	3.558	3.738	3.477
Bio.	2.925	3.076	3.223	3.389	3.152	2.957	3.109	3.258	3.426	3.187
Mean (A)	3.046	3.197	3.355	3.527		3.075	3.231	3.393	3.562	
L.S.D. at 5 %	A : 0.112		B : 0.025		AB : 0.050	A : 0.104		B : 0.015		AB : 0.030
	Chlorophyll b (mg/g fresh weight)									
Control	0.928	0.986	1.033	1.084	1.008	0.944	0.993	1.048	1.095	1.021
100 % NPK	1.034	1.104	1.135	1.197	1.118	1.044	1.114	1.145	1.208	1.127
Bio. + 75 %NPK	1.036	1.117	1.172	1.234	1.140	1.045	1.128	1.188	1.244	1.151
Bio. NPK	0.945	0.998	1.048	1.098	1.022	0.955	1.009	1.058	1.105	1.031
Mean (A)	0.985	1.052	1.097	1.153		0.997	1.061	1.109	1.163	
L.S.D. at 5 %	A : 0.035		B : 0.005		AB : 0.010	A : 0.031		B : 0.011		AB : 0.022
	Carotenoids (mg/g fresh weight)									
Control	0.992	1.046	1.095	1.146	1.070	1.009	1.054	1.105	1.156	1.081
100 % NPK	1.114	1.163	1.194	1.256	1.181	1.125	1.173	1.205	1.269	1.193
Bio. + 75 %NPK	1.124	1.177	1.233	1.290	1.206	1.135	1.189	1.245	1.303	1.218
Bio.	1.005	1.059	1.105	1.154	1.081	1.014	1.066	1.116	1.177	1.093
Mean (A)	1.058	1.111	1.156	1.215		1.071	1.121	1.168	1.226	
L.S.D. at 5 %	A : 0.043		B : 0.011		AB : 0.022	A : 0.041		B : 0.012		AB : 0.024

6- Nitrogen, phosphorus and potassium (NPK) content

Results showed that the significant effect of compost and fertilization application on the growth of moringa plants was coincided with significant increase on N, P and K content, moreover results (Table, 9) show a significant interaction between investigated factors on moringa content of these elements during both experimental seasons. Moringa plants which fertilized with bio-fertilizers + 75% NPK and 15 ton/fed compost had the highest content of these elements. This promotion of content was significantly higher than those of most of other treatments. Under the same compost level results showed that there was no significant difference on N, P and K content between plants fertilized with bio-fertilizers + 75% NPK and 100% NPK. However, in all cases the content was gradually increased by increasing the compost level. Overall, the highest plant content in the second season (4.14, 1.38 and 3.84 g/kg for N, P and K, respectively) being for plants fertilized with 15 ton/fed compost and bio-fertilizers + 75% NPK.

The superiority of the plant height, stem diameter and fresh and dry weight of moringa plants following the treatment of bio-fertilizers + 75% NPK compared with plants of other treatments, and the variations among the compost rates treatments could resulted from the alterations in the nutrient availability, organic matter content of the compost and the capacity of bio-fertilizers on increasing nutrient availability. The nutrients could increase plant growth directly; however, organic fertilizers could affect plant growth via improvements the soil physical properties, and its C, N, P and K status, as well as by the microbial biomass. González-González and Crespo-López (2016) found that different moringa plant growth parameters were significantly improved via combination of organic and non-organic fertilizers. Isaiah (2013) observed that inorganic fertilizers played a significant role in sustaining moringa plants growth. On the other hand, organic fertilizers might improve soil texture, pH, water holding capacity and other properties of soil. Moreover, they produce plant growth promoting substances (Mohapatra *et al*., 2013). They added that C and N were higher in soils receiving only organic manures or with the combined application of organic manures and chemical fertilizers than with chemical fertilizer treatments alone. The enhancement of moringa growth due to bio-fertilization has been previously found by Mazher *et al.* (2014). They found that bio-fertilizer inoculation produced a beneficial effect on all growth parameters of *Moringa oleifera* and the efficiency in improving growth varied among the bio-fertilizers applied.

The obtianed results indicated that NPK and/or bio-fertilizers and the organic fertilizers significantly improved the photosynthetic pigments and the NPK content of the moringa plants. Similarly, Mazher *et al*. (2014) treated moringa plants with different bio-fertilizers and found that the chlorophyll a, b and carotenoids increased with Phosphorine, Nitrobine and Microbine as well as total carbohydrates. All bio-fertilizers treatments increased nutrients contents compared with the control.

Table 9. Effect of different fertilizer combinations on nitrogen, phosphorus and potassium content of *Moringa oleifera* plants during 2015/2016 and 2016/2017 seasons

Treatment	Compost levels (ton/fed.) (A)									
	1st Season					2nd Season				
	0	5	10	15	Mean (B)	0	5	10	15	Mean (B)
Nitrogen (g/kg)										
Control	3.47	3.61	3.71	3.79	3.65	3.50	3.67	3.78	3.87	3.71
100 % NPK	3.68	3.82	3.94	4.02	3.87	3.75	3.89	4.01	4.09	3.94
Bio. + 75 %NPK	3.71	3.87	3.98	4.06	3.91	3.79	3.94	4.06	4.14	3.98
Bio.	3.60	3.76	3.86	3.94	3.79	3.66	3.80	3.92	4.00	3.85
Mean (A)	3.62	3.77	3.87	3.95		3.68	3.83	3.94	4.03	
L.S.D. at 5 %	A : 0.08		B : 0.04		AB : 0.08	A : 0.08		B : 0.06		AB : 0.12
Phosphorus (g/kg)										
Control	0.98	1.02	1.06	1.08	1.04	1.03	1.09	1.15	1.20	1.12
100 % NPK	1.07	1.12	1.17	1.20	1.14	1.16	1.23	1.29	1.35	1.26
Bio. + 75 %NPK	1.09	1.15	1.19	1.24	1.17	1.17	1.25	1.33	1.38	1.28
Bio.	1.02	1.07	1.10	1.12	1.08	1.07	1.14	1.20	1.24	1.16
Mean (A)	1.04	1.09	1.13	1.16		1.11	1.18	1.24	1.29	
L.S.D. at 5 %	A : 0.03		B : 0.03		AB :0.06	A : 0.04		B : 0.03		AB : 0.06
Potassium (g/kg)										
Control	3.21	3.35	3.44	3.51	3.38	3.24	3.40	3.50	3.58	3.43
100 % NPK	3.41	3.54	3.65	3.70	3.58	3.47	3.60	3.71	3.78	3.64
Bio. + 75 %NPK	3.44	3.58	3.68	3.72	3.61	3.51	3.65	3.76	3.84	3.69
Bio.	3.34	3.48	3.57	3.65	3.51	3.39	3.52	3.63	3.70	3.56
Mean (A)	3.35	3.49	3.59	3.65		3.40	3.54	3.65	3.73	
L.S.D. at 5 %	A : 0.07		B : 0.03		AB : 0.06	A : 0.08		B : 0.05		AB : 0.10

CONCLUSION

Different combinations of organic, inorganic and bio-fertilizers had produced a beneficial effect on all growth and yield parameters of *Moringa oleifera* plants compared to control. Moringa growth and yield parameters were significantly improved via different combinations of organic, inorganic and bio-fertilizers and it was observed that all moringa growth and yield parameters were significantly increased by increasing the compost level under the same fertilization treatments. The results of this research indicated that addition of bio-fertilizers + 75% NPK was more effective in increasing all investigated growth and yield parameters than 100% NPK or bio-fertilizers alone under the same compost treatments. In view of obtained and discussed results, it could be concluded that bio-fertilizers played a significant role in sustaining moringa plants growth and quality and can be partially substitute chemical fertilizers. Replacing 25% of the chemical NPK using effective microorganisms plus phosphorein was more effective in increasing all investigated growth and yield parameters of moringa plants than 100% NPK. This partial substituion of mineral NPK by using bio-fertilizers can also be useful in reducing overall cost of chemical fertilizers and avoiding their environmental hazards and harmful impacts on public health.

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استجابة نباتات المورينجا لمخاليط الأسمدة المعدنية والعضوية والحيوية

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أجرى هذا البحث فى مركز التجارب والبحوث الزراعية بجامعة المنيا خلال الوسمين ٢٠١٦/٢٠١٥ و ٢٠١٧/٢٠١٦ لدراسة استجابة نباتات المورينجا لمخاليط الأسمدة المعدنية والعضوية والحيوية. زرعت شتلات المورينجا فى أرض تم تسميدها بالكمبوست بمستويات صفر، ٥، ١٠ و١٥ طن/فدان فى القطع المنشقة الرئيسية فى حين خصصت القطع تحت المنشقة لمعاملات التسميد المعدنى و/أو الحيوى كالتالى: كنترول "بدون تسميد"، ١٠٠% NPK، ٧٥% NPK + خليط من الأسمدة الحيوية "effective microorganisms (EM)+ phosphorein" وأخيرا خليط الأسمدة الحيوية بمفردها. ولقد أوضحت النتائج المتحصل عليها أن إضافة السماد العضوى والمعدنى والأسمدة الحيوية حسنت معنويا نمو ومحصول نباتات المورينجا فى كلا الموسمين. ولقد أعطت نباتات المورينجا المسمدة بالأسمدة الحيوية + ٧٥% NPK و١٥ طن/فدان كمبوست أعلى محصول للبذور، فى حين أن نباتات الكنترول أعطت أقل محصول بذرة وذلك خلال موسمى الدراسة. فى جميع الحالات كانت معاملة التسميد الحيوى + ٧٥% NPK أكثر فاعلية فى زيادة جميع قيم قياسات النمو والمحصول المختبرة وذلك عند مقارنتها بمعاملة التسميد المعدنى (١٠٠% NPK) والتسميد الحيوى عند نفس مستوى الكمبوست. هذه الزيادات في النمو والمحصول تزامنت مع الزيادة في صبغات الكلوروفيل و محتوي النباتات من NPK. تبعا لنتائج هذه الدراسة فلقد أعطت نباتات المورينجا أعلي قيم لمقاييس النمو والمحصول مع التسميد بالأسمدة الحيوية + ٧٥% NPK عند مستوى ١٥ طن/فدان كمبوست.