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**Original Research Article**  
**Effects of Fertilization Patterns using Mineral  
and Organic Fertilizers on Growth and Yield of  
Cucumber under Greenhouse**

**ABSTRACT**

This study was conducted to investigate the effects of four fertilization patterns on growth parameters, and yield of cucumber crop under greenhouse cultivation. A field experiment was carried out at the experimental farm of Palestine Technical University Kadoorie located at Tulakrm, Palestine. Cucumber seedlings were planted on 14 February 2012 in greenhouse at a rate of 1500 seedlings per 1000 m<sup>2</sup>. Four fertilization patterns were examined during the growing period of cucumber crop as follows: traditional fertilization (TF), mineral fertilization (MF), mineral fertilization plus humic acids (MFHA), and liquid organic fertilization (LOF). Samples were collected from different sites at soil depths of 0-15 and 15-30 cm for evaluating the physical and chemical properties of the soil. The soil of the experimental plot can be classified as clay texture with bulk density in the upper 30 cm of 1.22 g cm<sup>-3</sup>. The soil had no salinity problem with saturation extract E<sub>Ce</sub> of 0.9 – 1 dS/m. Plant data were collected during the growing period of cucumber crop for evaluating the total yield, plant height, number of harvested fruits per plant, weight of harvested fruits per plant and dry matter of above and under ground parts. Results of this study indicated that the average yield of investigated treatments indicated that the MFHA treatment obtained the highest crop yield of 72.30 t ha<sup>-1</sup>, followed by 67.36, 61.73 and 58.07 t ha<sup>-1</sup>, for MF, TF and LOF treatments, respectively. The MFHA treatment obtained the highest fruit number per plant followed by MF, TF and LOF, respectively. At the end of the growing period, the MFHA obtained the highest dry matter, while the LOF treatment gave the smallest one compared to the other fertilization treatments. The MFHA treatment obtained the highest water use efficiency followed by MF, LOF and TF treatments, respectively.

*Keywords: Cucumber, Greenhouse, Organic fertilizer, Fertilization, Humic acids.*

**1. INTRODUCTION**

During the past few decades, intensive agriculture involving exhaustive high yielding varieties has led to heavy withdrawal of nutrients from the soil. Generally, excessive amounts of inorganic fertilizers are applied to vegetables in order to achieve a higher yield [1], and maximum value of growth [2]; [3]; [4]. However, the overuse of inorganic fertilizers alone damage soil structure, increases soil acidity, causes nutrient imbalance, and decrease crop sustainability and may cause problems for human health and the environment [2]; [5]; [6]. Long-term studies on various crops indicated that the balanced use of NPK fertilizer could not maintain the higher yields over years because of emergence of secondary and micronutrient deficiencies and deterioration of soil physical properties. On the other hand, use of organic manures alone can not fulfill the crop nutrients requirement [7].

It is reported that organic manures, when applied with chemical fertilizers gave better yield than individual ones [8]. [9] observed that nutrient use efficiency might be increased through the combination of manure and inorganic fertilizer. In recent times, consumers are

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demanding higher quality and safer food and highly interested in organic products [10]. Hence there is urgent need to improve organic fertilizers with natural minerals through biological processes. Organic manure has been used as a soil conditioner since ancient times and its benefit have not been fully harnessed due to large quantities required in order to satisfy the nutritional needs of crops [11]. The efficiency of organic material utilization by a crop is determined by the method of application, time to incorporation, and the rate of decomposition in the soil [12]. Improvement of environmental conditions and public health are important reasons for advocating increased use of organic materials [13]; [14]. The complementary use of organic and inorganic fertilizers has been recommended for sustenance of long term cropping in the tropics [15].

Humic substances (humic and fulvic acids) are commercial products contain many elements which improve the soil fertility and increasing the availability of nutrient elements and consequently affects plant growth and yield [16]; [17]. Humic substances which are the major components of soil organic matter are mostly used to eliminate the adverse effects of chemical fertilizers and decrease soil pH [18]; [19]; [20]. Compost enhances the environmental sustainability of agriculture by decreasing chemical inputs and increasing soil organic matter [21]. Adding different organic compost to the soil caused remarkable improvement of different growth characters and yield [22]. It is found that application of organic matter increased the early and final yield [23].

The objectives of this study were to investigate the effects of four fertilization patterns including traditional fertilization, mineral fertilization, mineral fertilization plus humic acid and liquid organic fertilization on growth parameters and yield of cucumber cultivated under protected agriculture.

## **2. MATERIAL AND METHODS**

### **2.1 Field experimental layout**

This investigation was out at the experimental farm of Palestine Technical University-Kadoorie located at Tulkarm, Palestine (Latitude: 32.31; Longitude: 35.02). A greenhouse with an area of 1000 m<sup>2</sup> was used for the experiment. Each treatment has and area of 250 m<sup>2</sup>, with five replicates per each treatment. Cucumber (*Cucumis sativus* L.), Nasim variety, were planted at a rate of 1500 seedlings per 1000 m<sup>2</sup> on 14 February 2012. The soil of the experimental plot can be classified as clay texture with bulk density in the upper 30 cm of 1.22 g cm<sup>-3</sup>. A drip irrigation system with emitter discharge at a rate of 4 l hr<sup>-1</sup> and with spacing between emitters of 40 cm was installed at spacing between laterals of 120 cm, and plastic mulch was applied at each planting row.

### **2.2 Fertilization treatments**

Four fertilization patterns were examined during the growing period of cucumber crop as follows: traditional fertilization (TF), mineral fertilization (MF), mineral fertilization plus humic acids (MFHA), and liquid organic fertilization (LOF). The amount of mineral fertilizers to be applied under (TF) treatment was estimated according to the recommended amount of fertilizers which usually applied by the farmers in the experimental area. The amount of mineral fertilizer to be applied under (MF) treatment was calculated according to the recommended NPK requirements of cucumber plants during different growth periods as given in Table 1. The amount of mineral fertilizer to be applied under (MFHA) treatment was the same as (MF) treatment plus humic acid at a rate of 40 l ha<sup>-1</sup> was applied at split doses with mineral fertilizers during the growing period. The amount of liquid organic fertilizer under

(LOF) treatment was calculated according to the recommended NPK requirements of cucumber as given in Table 1. Same amount of compost 5 ton ha<sup>-1</sup> were applied for all the investigated treatments and mixed with the soil before planting.

**Table 1. Major nutrient requirements of cucumber crop cultivated in greenhouse.**

Plant growth stages	Nutrient requirements (g du <sup>-1</sup> day <sup>-1</sup> )		
	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Transplanting - 14 days	100	100	100
14-35 days	200	100	200
35- end of growing season	250	100	350

The amount and type of mineral fertilizers, humic acids and liquid organic fertilizer which applied to the four fertilization treatments during the different growth periods of cucumber plants cultivated under greenhouse are given in Table 2.

**Table 2. Type and amount of fertilizers applied during the growing period of cucumber.**

Growth stages (days)	Fertilization Treatments			
	TF	MF	MFHA	LOF
Transplanting -14 days	250 kg/ha (13:13:13)	130 kg/ha (13:13:13)	130 kg/ha (13:13:13) 10 l/ha humic acids	160 l/ha bio-fish
14-35 days	680 kg/ha (11:8:20)	620 kg/ha (11:8:20)	620 kg/ha (11:8:20) 10 l/ha humic acids	210 l/ha bio-fish
35-110 days	4140 kg/ha (11:8:20)	2560 kg/ha (11:8:20)	2560 kg/du (11:8:20) 20 l /ha humic acids	1100 l/ha bio-fish

## 2.3 Measurements

Soil samples' analyses for the experimental site were performed before planting (Table 3). Samples were collected from different sites at soil depths of 0-15 and 15-30 cm for evaluating the physical and chemical properties of the soil. Soil samples were analyzed for gravimetric soil moisture content, soil pH and electrical conductivity by saturation past, soil particle size distribution by hydrometer method, soil bulk density by core method, phosphorus content was determined using spectrophotometer [24], potassium content was determined photo-metrically using flame photometer [25]. Physical and chemical properties of the soil were described by [26]; [27] and [28]. The soil of the experimental site had no salinity problem with saturation extract ECe of 0.9 – 1 dS/m. The results indicated a soil pH of 8.3.

Plant data were collected during the growing period of cucumber crop for evaluating the total yield, plant height, number of harvested fruits per plant, weight of harvested fruits per plant and dry matter of above and under ground parts. Total dry matter was determined after fruit harvesting using three plants from each replicate (whole plants minus fruits). Leaves, roots

and stems were separated and weighed to obtain root and shoot (leaves and stem) dry weight after drying at 65 °C for one week to constant weight. Harvesting was done manually from 40 to 117 days after transplanting. The total cucumber fruits produced were weighed using a digital balance.

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122 **Table 3. Some selected physical and chemical properties of the soil.**

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Parameters	unit	Soil depth (cm)	
		0-15	15-30
Texture		clay	clay
Sand	%	19	8
Silt	%	26	29
Clay	%	55	63
FC	%	36	36
PWP	%	16	16
Bulk density	g cm <sup>-3</sup>	1.20	1.25
pH		8.3	8.3
EC <sub>e</sub>	dS/m	1.0	0.9
Ca <sup>+2</sup>	ppm	99.2	78.1
Mg <sup>+2</sup>	ppm	36.5	31.5
Na <sup>+</sup>	ppm	58.1	47.3
K <sup>+</sup>	ppm	8.7	7.6
Cl <sup>-</sup>	ppm	197	166
HCO <sub>3</sub> <sup>-</sup>	ppm	69.0	54.4
CO <sub>3</sub> <sup>-</sup>	ppm	10.6	10.2
CaCO <sub>3</sub> <sup>-</sup>	%	18.3	17.6
NO <sub>3</sub> <sup>-</sup> -N	ppm	29.5	29.1
PO <sub>4</sub> <sup>-</sup>	ppm	8.5	13.8

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## 126 **2.4 Statistical analysis**

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128 The effects of fertilization treatments on growth and yield of cucumber crop cultivated in  
 129 greenhouse were analyzed using a randomized complete block design, using four  
 130 treatments with five replicates per each treatment. Collected data in this study were  
 131 analyzed and examined statistically using analysis of variance (ANOVA) from the Statistical  
 132 Analysis System (SPSS) appropriate for a randomized complete block design. Means were  
 133 compared by LSD test at 5% level of significance. The mean values of each treatment are  
 134 designated by letters (a, b, c) which represent the significance degree of the difference  
 135 between the means. Means represented by two letters in common indicate that the  
 136 difference is not significant or weakly significant.

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## 139 **3. RESULTS AND DISCUSSION**

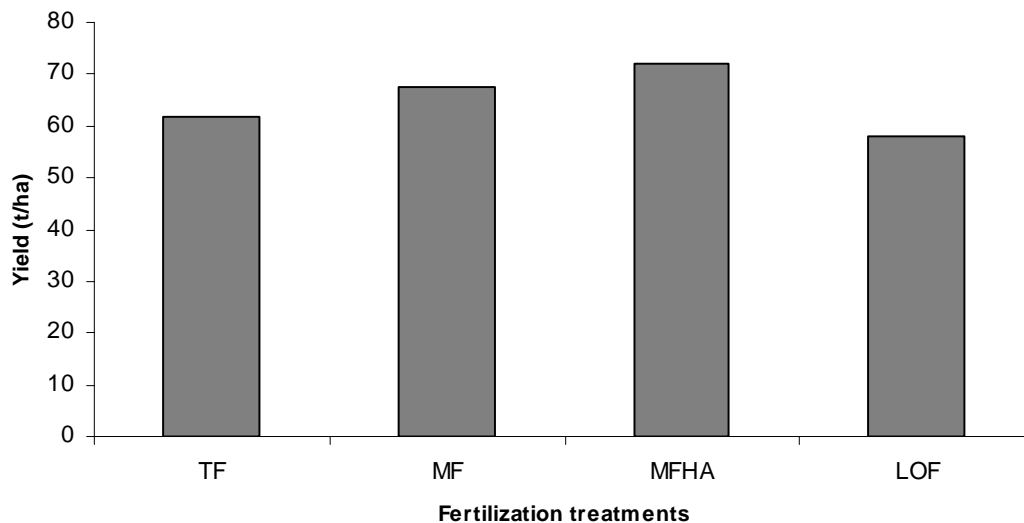
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### 141 **3.1 Yield and yield components**

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The effects of fertilization treatments on cucumber yield are shown in Figure 1. The average yield of investigated treatments indicated that the MFHA treatment obtained the highest crop yield of 72.30 t ha<sup>-1</sup>, while the yield of MF, TF and LOF treatments were 67.36, 61.73 and 58.07 t ha<sup>-1</sup>, respectively. Statistical analysis given in Table 4 indicated that the yield obtained under MFHA was significantly higher than that under TF, MF and LOF treatments. On average, cucumber yield under MFHA treatment was 19%, 14% and 6% higher than that under LOF, TF and MF, respectively. These results may be attributed to the fact that humic acids when combined with inorganic fertilizers had positive impact on plant growth through enhancing soil fertility, increasing cation exchange capacity and increasing nutrient availability. These results agree with the findings of [29]; [18] and [29]. Moreover, it is reported that humic acids have positive effects on plant biomass under condition of adequate mineral nutrition [20]. Similar results were reported by studies in climbing bean [30]; canola [18]; common millet [31] and common vetch [32] in which the combined use of humic substance with recommended inorganic fertilizer doses significantly increased the forage yields of common millet and common vetch, the marketable yield of climbing bean and the dry matter of yield of canola.

Despite their lower nutrient supply, humic substances increase the availability of nutrient element by holding the mineral elements on the mineral surfaces and converting them into forms available to plants, which eventually leads to a great uptake of nutrients into the plant root and through the cell membrane [18]; [33]; [34] and [29].



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167 **Fig. 1. Yield of cucumber crop under different fertilization treatments.**

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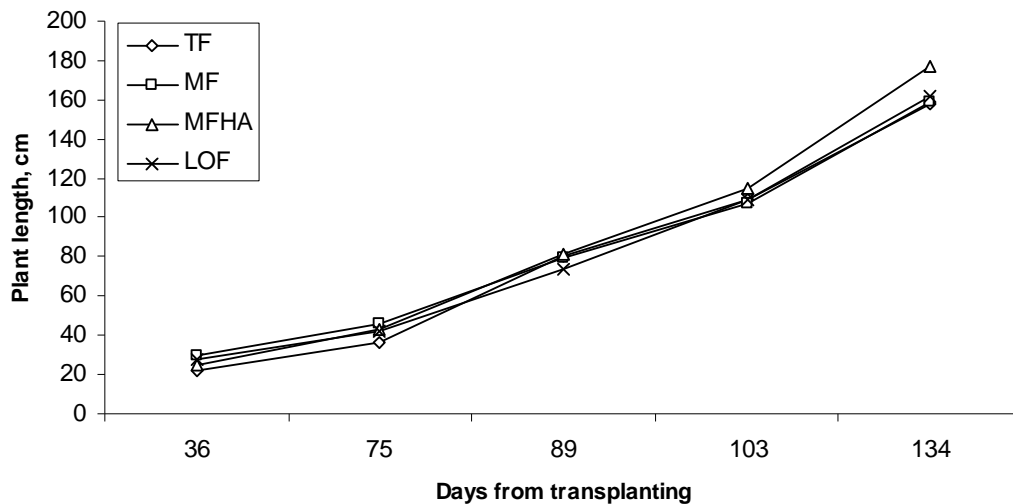
169 The yield components are given in Table 4. The yield components; total yield, plant yield,  
170 number of fruit per plant were significantly affected by applied fertilization treatments. The  
171 MFHA treatment obtained the highest fruit number per plant followed by MF, TF and LOF,  
172 respectively. These results indicated that the humic acids when applied with mineral  
173 fertilizers increased the absorption and assimilation of nutrients by plant roots. The yield of  
174 cucumber was significantly reduced by the application of liquid organic fertilization treatment.  
175 Statistical analysis given in Table 4 indicated that the number of fruit per plant, the plant  
176 length and the dry matter under MFHA was significantly higher than that under TF, MF and  
177 LOF treatments.

178 **Table 4. Yield components of cucumber plants under different fertilization treatments.**  
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Yield components	Treatments			
	TF	MF	MFHA	LOF
Total yield, t ha <sup>-1</sup>	61.73 <sup>ab</sup>	67.36 <sup>bc</sup>	72.30 <sup>c</sup>	58.07 <sup>a</sup>
Plant yield, kg plant <sup>-1</sup>	4.12 <sup>a</sup>	4.48 <sup>ab</sup>	5.122 <sup>b</sup>	3.909 <sup>a</sup>
Number of fruits per plant during the season	67 <sup>b</sup>	73 <sup>bc</sup>	82 <sup>c</sup>	51 <sup>a</sup>
Plant length, cm	158 <sup>a</sup>	159 <sup>a</sup>	177 <sup>a</sup>	162 <sup>a</sup>
Above-ground dry matter at last stage, g plant <sup>-1</sup>	110 <sup>b</sup>	110 <sup>b</sup>	123 <sup>c</sup>	91 <sup>a</sup>
Under-ground dry matter at last stage, g plant <sup>-1</sup>	1.50 <sup>a</sup>	1.70 <sup>a</sup>	2.28 <sup>b</sup>	1.61 <sup>a</sup>

180 *Within rows means followed by the same letters are not significantly different according to LSD at 0.05*  
 181 *level. TF: traditional fertilization, MF: mineral fertilization, MFHA: mineral fertilization plus humic acids,*  
 182 *LOF: liquid organic fertilization.*  
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184 The effect of fertilization treatments on plant length of cucumber cultivated under  
 185 greenhouse was investigated and shown in Figure 2. The different fertilization treatments  
 186 had no effect on plant length until the days 89 from transplanting. Further more, at the end of  
 187 the growing period, the MFHA treatment obtained the highest plant length compared to the  
 188 other treatments; while the smallest plant length was attained under TF treatment.



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 191 **Fig. 2. Plant length of cucumber plants under different fertilization treatments.**  
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193 Data given in Table 5 indicated that the highest significant value of number of fruit per plant  
 194 (82 fruits) was observed under MFHA treatment, while the LOF treatment gave the lowest  
 195 significant value (51 fruits).  
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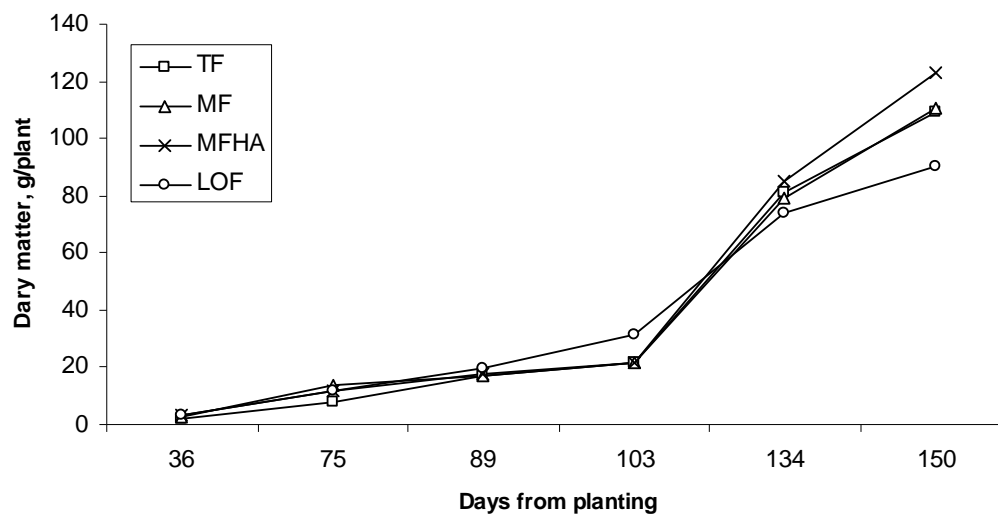
**Table 5. The number of fruit per plant under four fertilization treatments.**

Harvesting event	Fertilization treatments			
	TF	MF	MFHA	LOF
Week 1	7.0 ± 0.76	7.8 ± 0.46	7.0 ± 0.0	5.0 ± 2.0
Week 2	4.3 ± 0.89	6.3 ± 1.16	5.5 ± 0.53	4.3 ± 0.89
Week 3	5.5 ± 0.53	4.8 ± 1.39	6.8 ± 1.75	4.5 ± 0.53
Week 4	6.3 ± 1.39	5.3 ± 1.16	7.3 ± 1.16	3.0 ± 1.31
Week 5	5.5 ± 1.77	7.0 ± 0.0	9.0 ± 1.31	6.3 ± 1.58
Week 6	7.0 ± 1.69	7.0 ± 2.0	8.8 ± 0.89	2.5 ± 3.42
Week 7	7.8 ± 0.89	8.8 ± 0.46	10.3 ± 1.16	8.5 ± 1.20
Week 8	8.0 ± 3.12	9.5 ± 2.20	11.3 ± 1.39	7.0 ± 2.27
Week 9	8.3 ± 1.91	8.8 ± 2.87	7.5 ± 1.77	4.8 ± 0.89
Week 10	7.5 ± 0.93	7.5 ± 0.93	9.0 ± 1.55	5.0 ± 3.46
Sum	67 ± 5.8	73 ± 4.8	82 ± 3.8	51 ± 10.5

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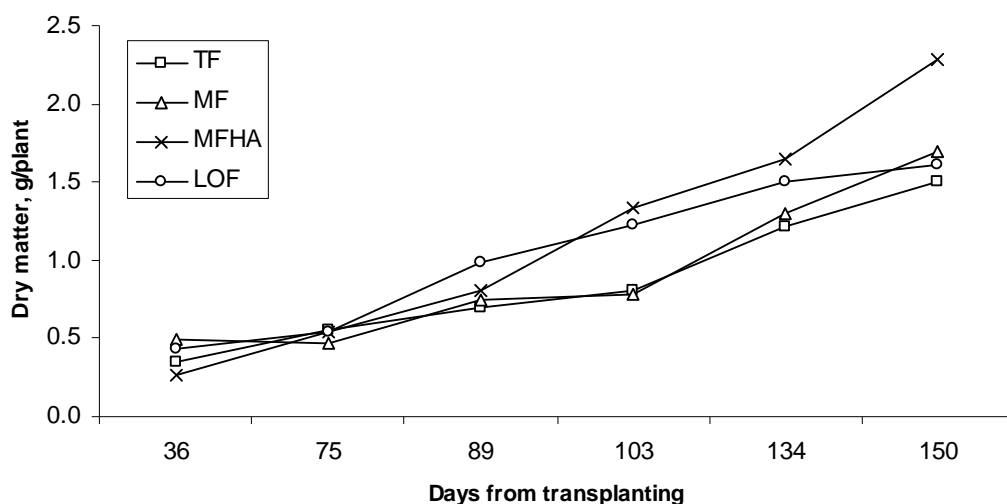
### 3.2 Plant dry matter

Plant dry matter was measured for both above and under-ground organs. The investigations of this study indicated that, at the end of the growing period, the MFHA obtained the highest above-ground dry matter, while the LOF treatment gave the smallest one compared to the other fertilization treatments. It is observed that plant growth was inhibited under LOF treatment after the days 105 from transplanting. Moreover, results of this study indicated that the highest dry matter of the underground organs was obtained under MFHA treatment and the lowest one was under TF treatment.



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**Fig. 3. Above-ground dry matter of cucumber plants under different fertilization treatments.**



**Fig. 4. Under-ground dry matter of cucumber plants under different fertilization treatments.**

### 3.3 Irrigation depths and water use efficiency

All treatments received the same amount of irrigation water (300 mm) during the growing period, except for the TF treatment which received higher amount (367 mm). Irrigation depth was estimated using modified FAO Penman–Monteith method [35]. A CROPWAT Software version 7.0 was used for estimating the crop evapotranspiration [36]. A set of climatic data, air temperature, relative humidity, wind speed and solar radiation outside the greenhouse was collected for estimating reference evapotranspiration. The crop coefficient was taken 0.6 for initial stage, 1.15 for mid-season stage and 0.8 for the late stage. The irrigation depth of the TF treatment was estimated according to the amount of irrigation water used by the farmers in the experimental area. The amount of irrigation water applied for the different fertilization treatments presented in Table 6. The TF treatment used the highest amount of irrigation water during the growing period.

Water use efficiency (WUE) was estimated as the ratio of the cucumber yield to irrigation water applied according to FAO [37]. Data on WUE for all fertilization treatments are presented in Table 6. The results of the investigated treatments indicated that, the MFHA treatment obtained the highest WUE followed by MF, LOF and TF treatments, respectively.

**Table 6. Amount of applied fertilizers, irrigation depth, and yield of cucumber under different fertilization treatments**

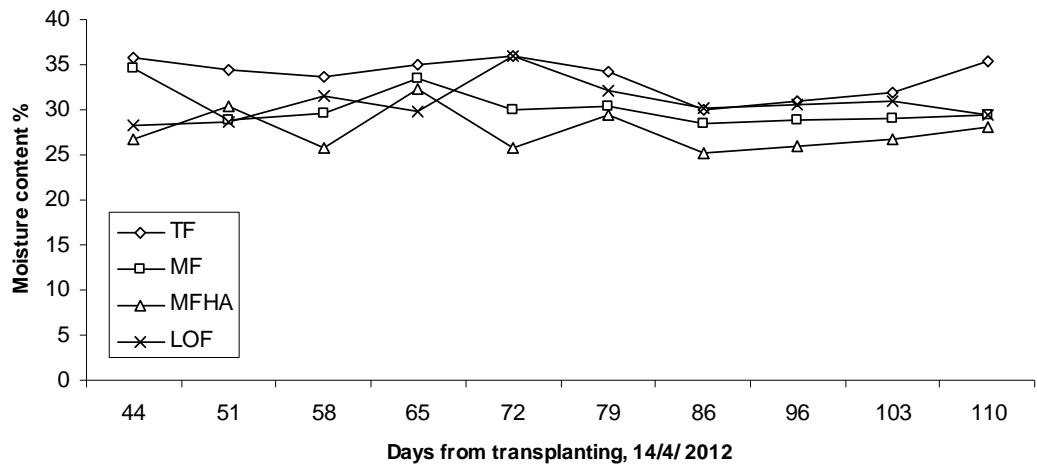
Treatments	Applied fertilizers	Irrigation depth (mm)	WUE kg m <sup>-3</sup>	Yield (t ha <sup>-1</sup> )
TF	5070 kg ha <sup>-1</sup> N-P-K	367	17 <sup>a</sup>	61.73 <sup>ab</sup>
MF	3310 kg ha <sup>-1</sup> N-P-K	300	22 <sup>c</sup>	67.36 <sup>bc</sup>
MFHA	3310 kg ha <sup>-1</sup> N-P-K 40 l ha <sup>-1</sup> humic acids	300	24 <sup>c</sup>	72.03 <sup>c</sup>
LOF	1470 l ha <sup>-1</sup> bio-fish	300	19 <sup>b</sup>	58.07 <sup>a</sup>



248 Within columns means followed by the same letters are not significantly different according to LSD at  
249 0.05 level. WUE: water use efficiency.

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252 **3.4 Soil moisture content**

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254 The soil moisture content of different fertilization treatments is presented in Figure 5. It is  
255 observed that the soil moisture content of the TF treatment was higher than that under the  
256 other treatments. This is attributed to the fact that, high amount of irrigation water was  
257 applied for this treatment. In MFHA treatment, it is observed that the soil moisture content  
258 was lower than the other treatment during the whole growing period. This can be explained  
259 by higher water uptake that took place by plant roots during the growing period.



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261 Fig. 5. Soil moisture content under different fertilization treatments at soil depth 0-15 cm.

262 **4. CONCLUSION**

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264 Results of this study indicated that the inorganic fertilizer when combined with humic acids  
265 had positive impact on plant growth and yield of cucumber plants. It is indicated that the yield  
266 components; total yield, plant yield, number of fruit per plant were significantly affected by  
267 the fertilization treatments. On average, cucumber yield under MFHA treatment was 19%,  
268 14% and 6% higher than that under LOF, TF and MF, respectively. The investigations of this  
269 study indicated that the MFHA obtained the highest above-ground dry matter, while the LOF  
270 treatment gave the smallest one compared to the other fertilization treatments. The results of  
271 the investigated treatments indicated that, the MFHA treatment obtained the highest WUE  
272 followed by MF, LOF and TF treatments, respectively.

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274 **COMPETING INTERESTS**

275  
276 Authors have declared that no competing interests exist.

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278 **AUTHORS' CONTRIBUTIONS**

279  
280 Author MR designed the study, wrote the protocol, managed the literature searches,  
281 followed the field work and wrote the first draft of the manuscript. Author AQ managed the  
282 analyses of the study and performed the statistical analysis.

## 285 REFERENCES

- 286
- 287 [1] Stewart MW, Dibb WD, Johnston EA, Smyth JT. The contribution of commercial fertilizer  
288 nutrients to food production. *Agron. J.* 2005;(97): 1-6.
- 289 [2] Arisha HM, Bradisi A. Effect of mineral fertilizers and organic fertilizers on growth, yield  
290 and quality of potato under sandy soil conditions. *Zagazig J. Agric. Res.* 1999; 26: 391–  
291 405.
- 292 [3] Badr LA, Fekry WA. Effect of intercropping and doses of fertilization on growth and  
293 productivity of taro and cucumber plants. *Zagazig J. Agric. Res.* 1998; 25: 1087–101.
- 294 [4] Dauda SN, Ajayi FA, Ndor E. Growth and yield of water melon (*Citrullus lanatus* ) as  
295 affected by poultry manure application. *J. Agric. Soc. Sci.* 2008;(4): 121–4.
- 296 [5] Khan HZ, Malik MA, Saleem MF. Effect of rate and source of organic material on the  
297 production potential of spring maize (*Zea mays* L.). *Pak. J. Agric. Sci.* 2008;(45): 40–43.
- 298 [6] Obi ME, Ebo PO. The effect of different management practices in the soil physical  
299 properties and maize production in severely degraded soil in /Southern Nigeria. *Biol.*  
300 *Res. Technol.* 1995;(51): 117-123.
- 301 [7] Kondapa D, Radder BM, Patil PL, Hebsur NS, Alagundagi SC. Effect of integrated  
302 nutrient management on growth, yield and economics of chilli (*Cv. Byadgi dabbi*) in a  
303 vertisol. *Karnataka J. Agric. Sci.* 2009; 22(2): 438-440.
- 304 [8] Bokhtiar SM, Paul GC, Alam KM. Effects of organic and inorganic fertilizer on growth,  
305 yield, and juice quality and residual effects on ratoon crops of sugarcane. *Journal of*  
306 *Plant Nutrition.* 2008; 31(10):1832 – 1843.
- 307 [9] Murwira HK, Kirchman AK. Carbon and nitrogen mineralization of cattle manures  
308 subjected to different treatment in Zimbabwean and Swedish soils: In Mulongoy K and  
309 Merckr KR (editors) *Soil organic matter dynamics and sustainability of tropical*  
310 *agriculture.* 1993; pp. 189-198.
- 311 [10] Ouda BA, Mahadeen AY. Effect of fertilizers on growth, yield, yield components, quality  
312 and certain nutrient contents in broccoli (*Brassica oleracea*) *Int. J. Agri. Biol.*  
313 2008(10):627-632.
- 314 [11] Makinde EA, Ayoola OT, Akande MO. Effects of organo-mineral fertilizer application on  
315 the growth and yield of egusi melon. *Australian J. Basic Appl. Sci.* 2007;(1):15-19.
- 316 [12] Achieng JO, Ouma G, Odhiambo G, Muyekho F. Effect of farmyard manure and  
317 inorganic fertilizers on maize production on alfisols and ultisols in Kakamega, western  
318 Kenya. *Agric. Biol. J. N. Am.* 2010; 1: 430–43.
- 319 [13] Maritus CH, Vleic PL. The management of organic matter in tropical soils. What are the  
320 priorities? *Nutrient cycling in Agroecosystems.* 2001;(61):1-6.
- 321 [14] Ojeniyi SO. Effect of goat manure on soil nutrients and okra yield in a rain forest area of  
322 Nigeria. *Appl. Tropical Agric.* 2000;(5):20-23.

- 323 [15] Ipimoroti RR, Daniel MA, Obatolu CR. Effect of organic mineral fertilizer on tea growth at  
324 Kusuku Mabila Plateau Nigeria. *Moor. J. Agric. Res.* 2002;(3): 180-183.
- 325 [16] Akinremi OO, Janzen HH, Lemke RL, Larney FJ. Response of canola, wheat and green  
326 beans to leonardite additions. *Can. J. Soil. Sci.* 2000; 437–443.
- 327 [17] Stevenson FJ. Humates: facts and fantasies on their value as commercial soil  
328 amendment. *Crops Soils.* 1979;(31): 14–16.
- 329 [18] Akinci S, Buyukkeskin T, Eroglu A, Erdogan BE. The effect of humic acid on nutrient  
330 composition in broad bean (*Vicia faba* L.) *Roots Not. Sci. Biol.* 2009; 1: 81–87.
- 331 [19] Katkat AV, Lelik H, Turan MA, Asik BB. Effects of soil and foliar applications of humic  
332 substances on dry weight and mineral nutrients uptake of wheat under calcareous soil  
333 conditions. *Aust. J. Basic Appl. Sci.* 2009;(3): 1266–1273.
- 334 [20] Chen Y, Aviad T. Effect of humic substances on plant growth. In: P. MacCarthy, editor.  
335 *Humic Substances in Soil and Crop Sciences: Selected Readings.* Madison, WI USA:  
336 American Society of Agronomy, 1990; pp. 161–186.
- 337 [21] Mathur G, Owen G, Dinell H, Schnitzer M. Determination of compost biomaturity. *Biol.*  
338 *Agric. Hortic.* 1993;(10): 65-85.
- 339 [22] Tara A, Brien O, Allen VB. Growth of peppermint in compost. *J. Herbs, Spices Med.*  
340 *Plants.* 1996;(4): 19-27.
- 341 [23] Abou-Hadid AF, Amin OM, Abdel-Fattah AI, Ezzat MS. Effect of composted greenhouse  
342 wastes on macro-nutrients concentration and productivity of cucumber. *Acta Hort.* 2011;  
343 549: 123-130.
- 344 [24] Wantanabe FS, Olsen SR. Test of an ascorbic acid method for determining phosphorus  
345 in water and NaHCO<sub>3</sub> extracts from soil. *Soil Sci. Soc. Amer. Proc.* 1965; (29): 677-678.
- 346 [25] Chapman HD, Pratt F. *Methods of analysis for soils, plants and water.* Univ. of Calif.,  
347 USA; 1961.
- 348 [26] Piper CS. *Soil and plant analysis.* Inter Science Publisher Inc., NY, USA; 1950
- 349 [27] Jackson ML. *Soil chemical analysis.* Prentice-Hall Inc., Englewood Cliffs, NJ, USA;  
350 1967.
- 351 [28] Black CA. *Methods of soil analysis.* Amer. Soc. of Agron. Inc., Madison, USA, 1969.
- 352 [29] Stevenson FJ. *Humus Chemistry: Genesis, Composition, Reactions.* 2nd ed. New York,  
353 NY, USA: Wiley; 1994.
- 354 [30] Ece A, Saltali K, Eryigit N, Uysal F. The effects of leonardite applications on climbing  
355 bean (*Phaseolus vulgaris* L.) yield and soil properties. *J. Agron.* 2007;( 6): 480–483.
- 356 [31] Saruhan V, Kusvuran A, Kkten K. The effect of different replications of humic acid  
357 fertilization on yield performances of common vetch (*Vicia sativa* L.). *Afr. J. Biotechnol.*  
358 2001a;(10): 5587–5592.

- 359 [32] Saruhan V, Kuşvuran A, Babat S. The effect of different humic acid fertilization on yield  
360 and yield components performances of common millet (*Panicum miliaceum* L.). *Sci. Res.*  
361 *Essays*. 2011b;(6): 663–669.
- 362 [33] Kulikova NA, Stepanova EV, Koroleva OV. Mitigating activity of humic substances:  
363 direct influence on biota. In: Perminova IV, Hatfield K, Hertkorn N, editors. *Use of Humic*  
364 *Substances to Remediate Polluted Environments: From Theory to Practice*. Netherlands:  
365 Springer. 2005; pp. 285–310.
- 366 [34] Tipping E. *Cation Binding by Humic Substances*. Cambridge, UK: Cambridge University  
367 Press; 2002.
- 368 [35] Allen RG, Pereira L, Raes D, Smith M. *Crop evapotranspiration guidelines for computing*  
369 *crop water requirements*. FAO Irrigation and Drainage Paper 56. UN-FAO, Rome, Italy,  
370 1998.
- 371 [36] Smith M. *CROPWAT: a computer program for irrigation planning and management*.  
372 FAO Irrigation and Drainage Paper 46. UN-FAO, Rome, Italy; 1992.
- 373 [37] Food and Agriculture Organization. *Crop water requirements*. Irrigation and Drainage  
374 Paper No. 24, FAO, Rome, Italy; 1982.