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Effects of Fertilization Patterns Using Mineral and Organic Fertilizers on Growth and Yield of Cucumber under Greenhouse

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Authors' contributions

This work was carried out in collaboration between both authors. Author MR designed the study, wrote the protocol, managed the literature searches, followed the field work and wrote the first draft of the manuscript. Author AQ managed the analyses of the study, followed the field work and performed the statistical analysis. Both authors read and approved the final manuscript.

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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^2. 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^{-3}. The soil had no salinity problem with saturation extract ECe of 0.9–1 dS/m. Plant data were collected during the growing period of

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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 underground 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^{-1}, followed by 67.36, 61.73 and 58.07 t ha^{-1}, 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 [2-4]. 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 cannot 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]. It is observed that nutrient use efficiency might be increased through the combination of manure and inorganic fertilizer. In recent times, consumers are 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 [18-20]. 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. MATERIALS AND METHODS

2.1 Field Experimental Layout

This investigation was carried 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^2 was used for the experiment. Each treatment has an area of 250 m^2, with five replicates per each treatment. Cucumber (*Cucumis sativus* L.), Nasim variety, were planted at a rate of 1500 seedlings per 1000 m^2 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^{-3}. A drip irrigation system with emitter discharge at a rate of 4 l hr^{-1} 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 acids at a rate of 40 l ha^{-1} 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^{1-} were applied for all the investigated treatments and mixed with the soil before planting.

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.

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 photometrically using flame photometer [25]. Physical and chemical properties of the soil were described by [26-28]. 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 underground 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 65ºC 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.

2.4 Statistical Analysis

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

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

Plant growth stages	Nutrient requirements (g du^{-1} day^{-1})		
	N	P_2O_5	K_2O
Transplanting - 14 days	100	100	100
14-35 days	200	100	200
35- end of growing season	250	100	350

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

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

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^{-3}	1.20	1.25
pH		8.3	8.3
EC_e	dS/m	1.0	0.9
Ca^{+2}	ppm	99.2	78.1
Mg^{+2}	ppm	36.5	31.5
Na^+	ppm	58.1	47.3
K^+	ppm	8.7	7.6
Cl^-	ppm	197	166
HCO_3^-	ppm	69.0	54.4
CO_3^-	ppm	10.6	10.2
$CaCO_3^-$	%	18.3	17.6
NO_3 -N	ppm	29.5	29.1
PO_4^-	ppm	8.5	13.8

3. RESULTS AND DISCUSSION

3.1 Yield and Yield Components

The effects of fertilization treatments on cucumber yield are shown in Fig. 1. The average yield of investigated treatments indicated that the MFHA treatment obtained the highest crop yield of 72.30 t ha^{-1}, while the yield of MF, TF and LOF treatments were 67.36, 61.73 and 58.07 t ha^{-1}, 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 [18,29,33,34]. 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 beam [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 [18,29,33,34].

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

The effect of fertilization treatments on plant length of cucumber cultivated under greenhouse was investigated and shown in Fig. 2. The different fertilization treatments had no effect on plant length until the days 89 from transplanting. Furthermore, at the end of the growing period, the MFHA treatment obtained the highest plant length compared to the other treatments; while the smallest plant length was attained under TF treatment.

Data given in Table 5 indicated that the highest significant value of number of fruit per plant (82 fruits) was observed under MFHA treatment, while the LOF treatment gave the lowest significant value (51 fruits).

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 (Fig. 3). 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 (Fig. 4).

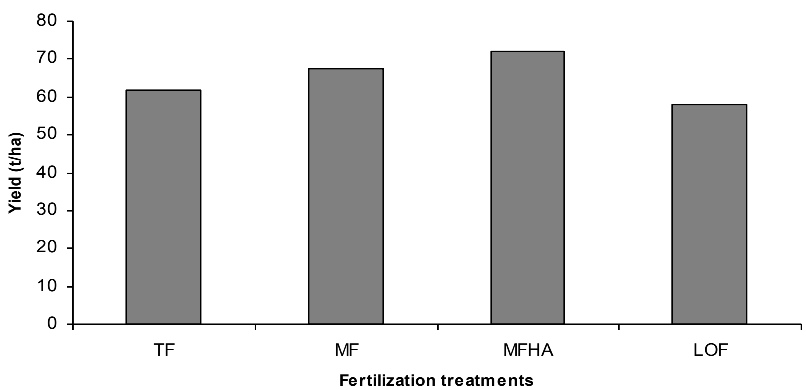

Fig. 1. Yield of cucumber crop under different fertilization treatments

Table 4. Yield components of cucumber plants under different fertilization treatments

Yield components	Treatments			
	TF	**MF**	**MFHA**	**LOF**
Total yield, t ha^{-1}	61.73^{ab}	67.36^{bc}	72.30^{c}	58.07^{a}
Plant yield, kg $plant^{-1}$	4.12^{a}	4.48^{ab}	5.122^{b}	3.909^{a}
Number of fruits per plant during the season	67^{b}	73^{bc}	82^{c}	51^{a}
Plant length, cm	158^{a}	159^{a}	177^{a}	162^{a}
Above-ground dry matter at last stage, g $plant^{-1}$	110^{b}	110^{b}	123^{c}	91^{a}
Under-ground dry matter at last stage, g $plant^{-1}$	1.50^{a}	1.70^{a}	2.28^{b}	1.61^{a}

Within rows means followed by the same letters are not significantly different according to LSD at 0.05 level. TF: traditional fertilization; MF: mineral fertilization; MFHA: mineral fertilization plus humic acids; LOF: liquid organic fertilization

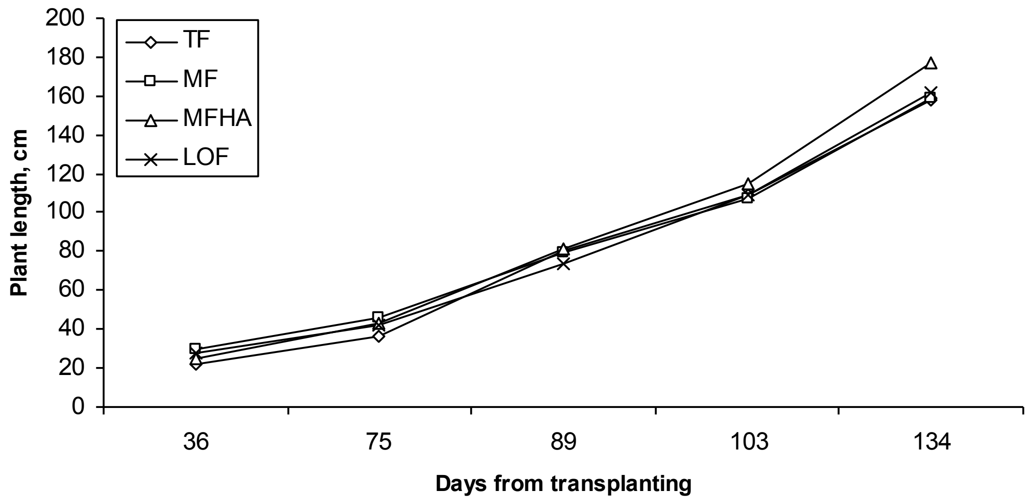

Fig. 2. Plant length of cucumber plants under different fertilization treatments

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

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.

3.4 Soil Moisture Content

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

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^{3-}	Yield (t ha^{-1})
TF	5070 kg ha^{-1} N-P-K	367	17 [a]	61.73 [ab]
MF	3310 kg ha^{-1} N-P-K	300	22 [c]	67.36 [bc]
MFHA	3310 kg ha^{-1} N-P-K 40 l ha^{-1} humic acids	300	24 [c]	72.03 [c]
LOF	1470 l ha^{-1} bio-fish	300	19 [b]	58.07 [a]

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

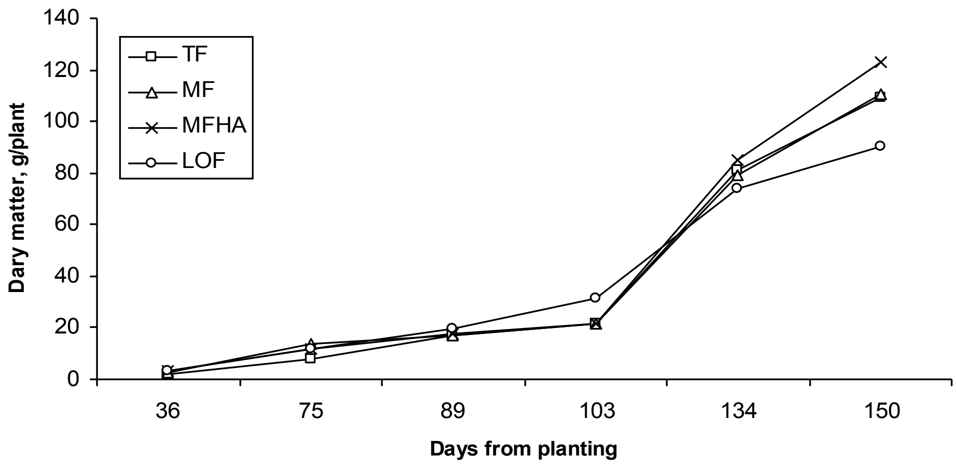

Fig. 3. Above-ground dry matter of cucumber plants under different fertilization treatments

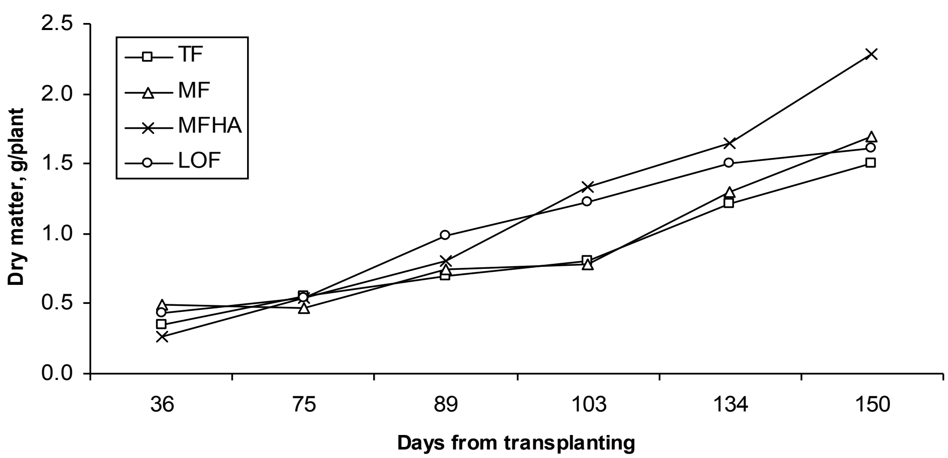

Fig. 4. Under-ground dry matter of cucumber plants under different fertilization treatments

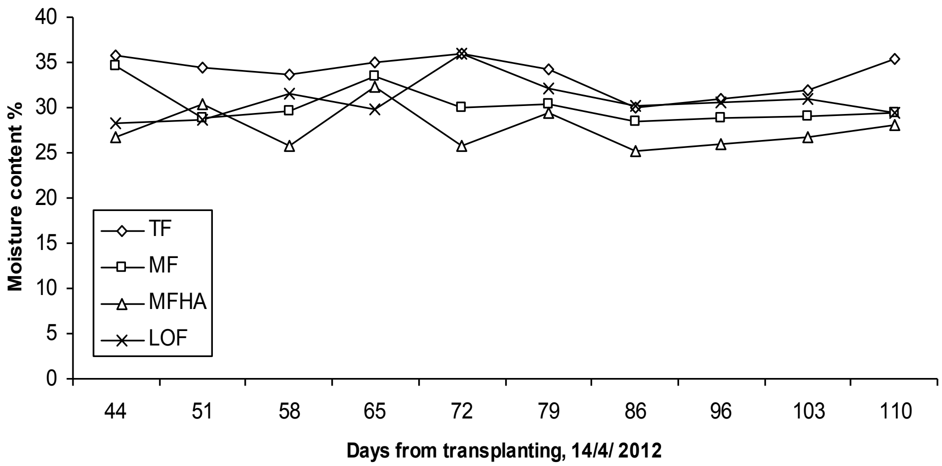

Fig. 5. Soil moisture content under different fertilization treatments at soil depth 0-15 cm

4. CONCLUSION

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

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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