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Full Length Research Paper

Effects of the application of organic manure on the fruit yield and components in Dill (*Anethum graveolens*)

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The main objective of this study was to determine the effects of organic manure and biofertilizer on the fruit yield and yield components in the dill plant height, umbel number per plant, weight of 1000 seeds, biologicals and fruit yield. The experiment was carried out at the Hamand Research Station in Damavand in 2011. Vermicompost (0, 4, 8 and 12 ton/ha) and biofertilizer, mixture of *Azotobacter chroococcum* and *Azospirillum lipoferum* (non-inoculated, inoculated seeds and inoculated seeds + spray on the plant base at stem elongation stage) were used as the effecting parameters. The present results have shown that the highest umbel number per plant, weight of 1000 seeds and fruit yield were obtained after applying 8 ton/ha vermicompost. The maximum plant height and biomass yield were obtained respectively after applying 4 and 12 ton/ha vermicompost. Biofertilizer also showed significant effects on plant height, biomass yield and fruit yield. The maximum plant height, biomass yield and fruit yield were obtained by using the biofertilizer twice.

Key words: Vermicompost, *Azotobacter, Azospirillum*, umbel, biomass.

INTRODUCTION

Using organic manure and the application of biofertilizers such as vermicompost and nitrogen fixing bacteria has led to a decrease in the use of chemical fertilizers and has provided high quality products free of harmful agrochemicals for human safety (Mahfouz and Sharaf Eldin, 2007; Moradi et al., 2010). Vermicomposts are the products of the degradation of organic matter through interactions between earthworms and microorganisms. Vermicomposts are finely divided peat-like materials with high porosity, aeration, drainage, and water-holding capacity and usually contain most nutrients in the available forms such as nitrates, phosphates, exchangeable calcium and soluble potassium (Atiyeh et al., 2002; Arancon et al., 2005). Free-living nitrogen fixing bacteria such as; *Azotobacter chroococcum* and
Azospirillum lipoferum, were found to have not only the ability to fix nitrogen but also the ability to release phytohormones similar to gibberellic acid and indole acetic acid, which could stimulate plant growth, absorption of nutrients, and photosynthesis (El Ghadban et al., 2006; Mahfouz and Sharaf Eldin, 2007). Production of medicinal plants is mainly under the circumstances of sustainable agricultural system. In this system, management of environmental parameters is very critical. By using correct nutritional sources through biofertilizers, quantitative and qualitative yield of medicinal plants can be maximized. Dill (*Anethum graveolens*) is a herbaceous annual plant, which is native to mediterranean region. Dill fruit and leaves are used as flavorings in sauces, vinegars, pastries, and soups. The dill fruits have essential oil as an active substance, while carvone is the most important constituent of dill, which is used in pharmaceutical industry as a diuretic, stimulant, and a carminative (Bailer et al., 2001; Callan et al., 2007; Hassan et al., 2010). Several studies have reported that vermicompost can increase the growth and yield of some medicinal plants such as basil (Singh and Ramesh, 2002; Anwar et al., 2005), garlic (Arguello et al., 2006), plantain (Sanchez et al., 2008), coriander (Singh et al., 2009), fennel (Darzi et al., 2007; Moradi et al., 2010), chamomile (Haj Seyed Hadi et al., 2011), cumin (Saeid

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Table 1. Physical and chemical properties of soil on the experimental site.

Cu	Zn	Mn	Fe	Mg	Ca	K	P	N	O.C	EC	pH	Texture
mg/kg									(%)	(ds/m)		
0.46	1.2	8.8	7.4	-	-	550	40	9.0	0.8	0.70	7.1	Loamy-clay

*, Available form of nutrients was measured.

Table 2. Chemical characteristics of vermicompost.

K	P	N	O.C	O.M	EC	pH
(%)					(ds/m)	
3.9	0.67	11.3	26.1	45	1.8	8.5

Nejad and Rezvani Moghaddam, 2011) and anise (Darzi et al., 2012).

Some other studies have reported that nitrogen fixing bacteria such as *A. chroococcum* and *A. lipoferum* could cause increased growth and yield in a few medicinal plants such as coriander (Kumar et al., 2002), celery (Migahed et al., 2004), fennel (Abdou et al., 2004; Mahfouz and Sharaf Eldin, 2007), turmeric (Velmurugan et al., 2008), hyssop (Koocheki et al., 2009) and black cumin (Valadabadi and Farahani, 2011).

Therefore, the main objective of the present field experiment was to investigate the effects of organic manure and biofertilizer on the fruit yield and yield components in dill (*A. graveolens*).

MATERIALS AND METHODS

Field experiment

A 4×3 factorial experiment, arranged in a randomized complete blocks designed with three replications, was conducted in the Experimental Station of the Research Institute of Forest and Rangeland, Damavand, Iran during the growing season of 2011. The geographical location of the experimental station was 35° 39´ N and 52° 5´ E with an altitude of 1800 m. The treatments consisted of different concentrations of vermicompost (0, 4, 8, 12 ton/ha) and biofertilizer, different inoculation conditions of mixture of *A. chroococcum* and *A. lipoferum* bacteria (non-inoculated, seed inoculated and seed inoculated + spraying on the plant base at stem elongation stage). Inoculation was carried out by dipping the dill seeds in the cells suspension of 10^8 CFU/ml for 15 min. The vermicompost was prepared from cow dung by employing epigeic species of *Eisenia foetida*. The required quantities of vermicompost were applied and incorporated to the top 5 cm layer of soil in the experimental beds before the plantation of dill seeds. Several soil samples (0 to 30 cm depth) were taken for the nutrient and trace element analysis prior to land preparation. Chemical and physical properties of the experimental soil and vermicompost are presented in Tables 1 and 2. Nitrogen (20 kg/ha) was applied to the plots, based on the soil and vermicompost analysis, in the stem elongation stage.

Each experimental plot was 3 m long and 2 m wide with the spacing of 10 cm between the plants and 40 cm between the rows. There was a space of one meter between the plots and two meters between replications. Dill seeds were directly sown by hand into the field at a rate of 12 kg ha^{-1} to a depth of 2 cm. There was no incidence of pest or disease on dill during the experiment. Weeding was done manually and the plots were irrigated weekly. All necessary cultural practices and plant protection measures were followed uniformly for all the plots during the entire period of experimentation.

Data were recorded for the plant height, umbel number per plant, weight of 1000 seeds, biomass yield and fruit yield. Twenty plants were randomly selected from each plot and the observations were recorded. At the beginning of flowering, the plant height, from plant base to the tip of plant, was measured for each plot using a ruler (±0.1 cm) (Azizi et al., 2008; Darzi et al., 2012).

Umbel number per plant was recorded at the end of growth season. In addition, the weight of 1000 seeds was also determined. For evaluating the biomass yield, plants were put in the oven at 80°C for 48 h and dry weight was calculated using a digital balance (Sartorius B310S; ±0.01 g) (Migahed et al., 2004; Badran and Safwat, 2004).

In order to determine fruit yield, the plots were manually harvested following the air-drying of umbels at 23 to 29°C and then the seeds were removed from plants by hand (Abdou et al., 2004; Khalid and Shafei, 2005; Darzi et al., 2012).

Statistical analysis

All the data were subjected to statistical analysis (one-way ANOVA) using SAS software (SAS Institute, version 8, 2001). Differences between the treatments were performed by Duncan's multiple range test (DMRT) at 5% confidence interval. Transformations were applied to the data to ensure that the residuals had normal distribution (Zar, 1996).

RESULTS

Plant height

The present results have indicated that plant heights were significantly affected by the application of vermicompost (Table 3). The most significant plant height (77.8 cm) was obtained by applying 4 ton vermicompost per hectare. Biofertilizer had also a significant effect on

Table 3. Mean comparison of the quantitative characteristics of dill at various levels of vermicompost and biofertilizer (nitrogen fixing bacteria).

Treatment	Plant height (cm)	Umbel no./plant (g)	Weight of 1000 seeds	Biomass yield (kg/ha)	Fruit yield (kg/ha)
Vermicompost (ton/ha)					
v1	72.7[b]	11.1[c]	1.48[b]	2671.7d	1280.5[c]
v2	77.8[a]	13.8[b]	1.56[a]	4882.5[c]	1945.6[b]
v3	77.7[a]	15.1[a]	1.58[a]	5613.1[b]	2196.8[a]
v4	77.0[a]	13.9[b]	1.53[ab]	6169.7[a]	2157.2[a]
Nitrogen fixing bacteria					
n1	74.2[b]	13.8[a]	1.55[a]	4376.0[b]	1700.4[c]
n2	76.5[a]	13.4[a]	1.55[a]	4854.4[a]	1884.2[b]
n3	78.1[a]	13.1[a]	1.50[a]	5272.3[a]	2100.5[a]

Means, in each column for each factor followed by at least on letter in common, are not significantly different at 5% probability level using Duncans' multiple range test.
v1, v2, v3 and v4 represent 0, 4, 8 and 12 ton vermicompost per hectare, respectively. n1, n2 and n3 represent non-inoculated, inoculated seeds and inoculated seeds + spraying on the plant base at stem elongation stage, respectively.

plant height (Table 3), as higher plant height (78.1 cm) was recorded twice using nitrogen fixing bacteria (inoculated seeds + spraying on the plant base at stem elongation stage).

Umbel number per plant

The results presented in Table 3 have demonstrated that umbel number per plant was influenced by the application of vermicompost, significantly (Table 3). Among various treatments, the application of 8 ton vermicompost per hectare has indicated maximum increase in umbel number per plant (15.1). Biofertilizer did not show significant effect on this trait. The present results show that the interaction of vermicompost and Biofertilizer was significant (Table 4). The highest umbel number per plant (17.2) was obtained after the integrated application of 8 ton/ha vermicompost and twice application of nitrogen fixing bacteria. The interaction of vermicompost and biofertilizer on the umbel number per plant, revealed that the application of 4 and 8 ton/ha vermisompost successively in the level of twice application of nitrogen fixing bacteria, which resulted in a significant increase in umbel number per plant.

Weight of 1000 seeds

The results indicated that the weight of 1000 seeds was significantly affected by the application of vermicompost (Table 3). The highest weight of 1000 seeds was obtained with applying 8 ton/ha vermicompost (1.58 g). Biofertilizer did not show significant effect on weight of 1000 seeds (Table 3).

Biomass yield

The results have indicated that biomass yield was affected by the application of vermicompost (Table 3). Significant increase in biomass yield was observed in three treatments of vermicompost application (4, 8 and 12 ton/ha) as compared to the control experiment (non-vermicompost). The highest biomass yields were obtained with applying 12 ton/ha vermicompost (6169.7 kg/ha).

Biofertilizer showed significant effect on biomass yield (Table 3), as the highest biomass yield (5272.3 kg/ha) was obtained in the third treatment level of biofertilizer (a two-times application of nitrogen fixing bacteria).

Fruit yield

The results presented in Table 3 have revealed that various levels of vermicompost had significant effects on the fruit yield. The maximum fruit yield (2196.8 kg/ha) was obtained by using 8 ton vermicompost per hectare. Significant increase in fruit yield was observed in two treatments of biofertilizer (once and twice application of nitrogen fixing bacteria) as compared to the control (non-inoculated cultures; Table 3). The highest fruit

Table 4. Mean comparison for umbel number per plant and fruit yield after the interaction of different factors.

Treatment	Umbel number per plant	Fruit yield (kg/ha)
Vermicompost × Nitrogen fixing bacteria (V × N)		
v1n1	12.6^{cde}	950.0^{g}
v1n2	11.8^{e}	1520.0^{ef}
v1n3	9.0^{f}	1371.6^{f}
v2n1	13.6^{cd}	1975.1^{cd}
v2n2	13.5^{cd}	1935.1^{cd}
v2n3	14.1^{bc}	1926.6^{cd}
v3n1	13.7^{cd}	1775.0^{de}
v3n2	14.3^{bc}	2144.1^{bc}
v3n3	17.2^{a}	2671.2^{a}
v4n1	15.5^{b}	2101.6^{cd}
v4n2	14.1^{bc}	1937.5^{cd}
v4n3	12.2^{de}	2432.5^{ab}

Means, in each column for each factor followed by at least one letter in common, are not significantly different at 5% probability level using Duncan,s multiple range test.

yield (2100.5 kg/ha), however, was found after the two times application of nitrogen fixing bacteria (mixture of *A. chroococcum* and *A. lipoferum*).

The present results show that the interaction of vermicompost and biofertilizer was significant (Table 4). The highest fruit yield (2671.2 kg/ha) was obtained after the integrated application of 8 ton/ha vermicompost and twice applying of nitrogen fixing bacteria. The interaction of vermicompost and biofertilizer, on the fruit yield, revealed that the application of 4 and 8 ton/ha vermisompost successively in the level of the twice application of nitrogen fixing bacteria, which resulted in a significant increase in fruit yield.

DISCUSSION

According to the present analysis, vermicompost with high water-holding capacity and proper supply of macro-and micro-nutrients (Cavender et al, 2003; Arancon et al., 2006; Kumawat et al., 2006), has a positive effect on biomass production and subsequently enhanced plant height. Improved growth, development and height of medicinal plants and other crops have previously been reported in the presence of optimal amounts of vermicompost (Singh and Ramesh, 2002; Arguello et al., 2006; Darzi et al., 2012; Haj Seyed Hadi et al., 2011). According to the present analysis, biofertilizer increased plant height by enhancing the nitrogen content and the rate of photosynthesis (Migahed et al., 2004). The present result were derived from the improvement of nitrogen fixing bacteria' activities in soil at the third treatment level (inoculated seed + spraying on plant base at stem elangation stage), which are in agreement with the previous studies carried out on fennel, turmeric and hyssop (Mahfouz and Sharaf Eldin, 2007; Velmurugan et al., 2008; Koocheki et al., 2009).

Vermicompost significantly influenced flowering and umbel number per plant. On the other hand, vermicompost application through the improvement of biological activities of soil and mineral element absorption (Jat and Ahlawat, 2006; Zaller, 2007), caused more biomass production and umbel number. These findings are in accordance with the observations of Pandey (2005) on *Artemisia pallens,* Moradi et al. (2010) on *Foeniculum vulgare*, Saeid Nejad and Rezvani Moghaddam (2011) on cumin and Darzi et al. (2012) on
Pimpinella anisum.

According to the present analysis, vermicompost have increased weight of 1000 seeds by enhancing the rate of photosynthesis and the biomass production (Roy and Singh, 2006). The present result is in agreement with the report of Darzi et al. (2007) on *F. vulgare*.

The results clearly demonstrate the effectiveness of vermicompost in increasing the biomass yield. Vermicompost increases the growth rate because of the water and mineral uptake such as; nitrogen and phosphorus (Arancon et al., 2006; Zaller, 2007), which leads to the biomass yield improvement. This finding is in accordance with previous observations (Anwar et al., 2005; Moradi et al. 2010; Darzi et al. 2012; Saeid Nejad and Rezvani Moghaddam, 2011). Effect of nitrogen fixing bacteria on the biomass yield was due to increased nitrogen uptake (Mahfouz and Sharaf Eldin, 2007; Kalyanasundaram et al., 2008). The result of present work are in agreement with the reports of Swaminathan et al. (2008) and Kumar et al. (2009) on *A. pallens* and Valadabadi and Farahani (2011) on *Nigella sativa*.

Increased fruit yield in vermicompost treatments can be as a result of improvement of yield components such as; plant height, umbel number per plant and biomass yield. Our findings are in accordance with the observations of

Saeid Nejad and Rezvani Moghaddam (2008), Sanchez et al. (2008), Singh et al. (2009), Moradi et al. (2010) and Darzi et al. (2012). Biofertilizer (nitrogen fixing bacteria), promoted fruit yield through the enhancement of yield attributes. These results are in agreement with the investigation of Kumar et al. (2002) on *Coriandrum sativum*, Migahed et al. (2004) on *Apium graveolens*, Abdou et al. (2004) and Mahfouz and Sharaf Eldin (2007) on *F. vulgare* and Valadabadi and Farahani (2011) on *N. sativa*. The results likely shows that the positive and synergistic effect of interaction between two factors on fruit yield is highly dependent on the effect of organic matter, contained in vermicompost, on the activity of nitrogen fixing bacteria.

Conclusion

It is clear from the present study that vermicompost and biofertilizer successfully manipulate the growth of dill, resulting in beneficial changes in yield and yield components. The highest fruit yield was obtained by using 8 ton vermicompost per hectare. Maximum fruit yield was observed twice by using nitrogen fixing bacteria (inoculated seeds + spraying on the plant base at stem elongation stage). Thus, combined application of vermicompost and nitrogen fixing bacteria can be helpful in the development, production and yield in dill.

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