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Organic amendments and nitrogen effects on growth and chemical composition of two cultivars of safflower (*Carthamus tinctorius* L.)

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Abstract

Recently, public concern has been raised about potential environmental pollution caused by excessive use of chemical fertilizers. A greenhouse experiment was conducted to evaluate the effects of municipal waste compost (MWC), vermicompost (VC), cow manure (CM), sheep manure (SM) and nitrogen (N) on the growth and chemical composition of safflower in view as substitutes of fertilizers. Seed yield, plant height, N, Fe^{2+}, Mn^{2+}, Zn^{2+}, and Cu^{2+} content in plant were measured after plant maturity. Plants grown in sheep manure gained more height (59.25±3 cm) than those grown in the other treatments. Padideh cultivar had significantly higher height (54.1±4 cm) than that of Goldasht cultivar (25.5±3 cm). Plants grown in N treated pots produced the greatest seed yield (1.71±0.05 g plant^{-1}) which was not significantly different from those grown in SM pots (1.67±0.03 g plant^{-1}). Additionally, MWC treated pots gained greater seed yield (1.51±0.03 g plant^{-1}) than those treated with VC (1.24±0.02 g plant^{-1}) and CM (1.08±0.4 g plant^{-1}). Our results showed that application of organic amendments have potential to increase the growth and chemical composition of two cultivars of safflower and; therefore, might be a good alternative to chemical fertilizers. Although municipal waste compost slightly increased Zn^{2+} (41.45±4 mg kg^{-1}), Cu^{2+} (25.20±3 mg kg^{-1}), Fe^{2+} (122.80±4 mg kg^{-1}) and Mn^{2+} (120.60±7 mg kg^{-1}) concentration of safflower's cultivars, it had no phytotoxic effects on the plants.

Keywords: Fertilization, Micronutrients, Nutrients, Crop cultivars.
Abbreviations: Municipal waste compost (MWC), vermicompost (VC), cow manure (CM), sheep manure (SM), nitrogen (N).

Introduction

Safflower, a deep rooted oilseed crop, is grown in many areas of the world because it can use as oil crop, vegetable, birdfeed and spices (Weiss, 2000). Safflower is also well adapted to salinity and drought conditions which possessing deep root makes it able to meet its water requirements from a lower layer of soil (Knowles, 1958; Weiss, 2000). In southern areas of Iran with an arid climate, the portion of available water for agriculture is decreasing (Abbasi and Sepaskhah, 2011). Therefore, cultivating crops that are well adapted to dryland conditions such as safflower is one of the main strategies for increasing crop production in these areas. Agricultural soils of southern Iran possess poor physical conditions due to their low organic matter (OM) and thus, increasing OM of these soils is of prime concern (Maftoun et al., 2004).In recent years, public concerns have been raised about the potential environmental pollution made by excessive use of chemical fertilizers as well as the increase in their cost. These along with the concerns over the sustainable agriculture have created an interest in using organic amendments (Maftoun et al., 2004).Recently, there has been an increased interest in using waste products as alternative crop nutrient sources (Pierzynski and Gehl, 2005). Application of municipal waste compost, vermicompost, and animal manure in crop production systems of Iran has increased (Kazemeini, 2007). These amendments can improve soil structure by increasing aggregate stability (Tate, 1987) as well as increase in water holding capacity and aeration (Viator et al., 2002). The other beneficial effects of them have been attributed to improve nutrient availability and soil physical conditions (DeLuca and DeLuca, 1987; Maftoun et al., 2004). It has been shown that organic amendments could increase yield of different crops including wheat (*Triticumaestivum* L.) (Kazemeini, 2007), corn (*Zeamays* L.) (Naderiand Ghadiri, 2010), vegetable amaranth (*Amaranthus* sp.)(Onyango et al., 2012). A concern with the application of these organic amendments is possible contamination of crops and soil with certain trace elements (Epstein, 1997; Lin et al., 2007). Although there are many studies dealing with the use of the organic amendments in cultivated crops (Naderi and Ghadiri, 2010; Carbonell et al., 2011), but, to our knowledge, this has rarely been tested in safflower. Greater knowledge of organic amendments effects on crop yield and nutrition status may allow us for a better understanding of transition to organic farming and would aid development of alternative agricultural practices as components of sustainable agriculture. Therefore, we conducted a greenhouse

Table 1. Analysis of variance results for N, Fe, Zn and Mn content of safflower plants.

Source of variation	df	Plant height F	Aboveground biomass F	Seed yield F	N content F	Fe^{2+} content F	Zn^{2+} content F	Mn^{2+} content F	Cu^{2+} content F
Fertilizer (F)	5	31.5**	4.52**	50.32**	412.94**	3.89*	315.64**	7.34**	252.08**
Cultivar (C)	1	222.9**	3.18*	194.94**	96.80**	4.42*	26.02**	13.93**	44.02**
F×C	5	2.82*	1.33^{ns}	1.76^{ns}	51.52**	0.81^{ns}	1.96^{ns}	0.56^{ns}	0.77^{ns}

* P < 0.05, **P <0.01, *** P < 0.001.

Table 2. Main effects of fertilizers and cultivars on aboveground biomass, seed yield and micronutrients content in plants.

Treatments						
Fertilizer	Aboveground biomass (g)	Seed yield (g)	Zn^{2+} content (mg kg^{-1})	Cu^{2+} content (mg kg^{-1})	Mn^{2+} content (mg kg^{-1})	Fe^{2+} content (mg kg^{-1})
Control	0.33 e	0.73 e	17.80 c	10.43 c	90.43 c	35.97 d
Municipal waste compost	2.85 b	1.51b	41.45 a	25.20 a	120.60 a	122.80 a
Vermicompost	2.11c	1.24 c	36.20 b	14.50 b	103.93 b	69.42b
Cow manure	0.98 d	1.08 d	36.10 b	15.73 b	102.78 b	60.83bc
Sheep manure	3.93 a	1.67 a	36.41 b	14.23 b	108.24 b	58.98bc
Nitrogen	4.04 a	1.71 a	35.90 b	13.81 b	101.30 b	55.97c
LSD (0.05)	0.25	0.15	4	2	9	12
Cultivar						
Padideh	2.77 a	1.42 a	32.87 a	15.77 a	122.12 a	91.41 a
Goldasht	1.86 b	1.22 b	32.28 a	15.31 a	120.32 a	65.82 b
LSD (0.05)	0.18	0.2	5	3	5	19

experiment to evaluate the effects of municipal waste compost, vermicompost, cow manure, sheep manure, and nitrogen on the growth and chemical composition of safflower.

Results and Discussion

Plant height, aboveground biomass and grain yield

There was a significant effect of organic amendments and N fertilizer for plant height (p≤ 0.05) (Table 1). Plants grown in SM gained more height (59.25±3 cm) than those grown in the other treatments. This showed that SM has the potential to increase growth of the plants and may make them able to capture more light. Padideh cultivar had significantly higher height (54.1±4 cm) than that of Goldasht cultivar (25.5±3 cm). There was a significant fertilizers × cultivars interaction for plant height (p≤0.05) (Table 1). Padideh cultivar plants treated with SM had the highest height (76.2±5 cm) and Goldasht cultivar plants grown in CM had the lowest height (8.5±4 cm) (Fig. 1). It has been reported that the ability of nutrients uptake by plants and as a result their growth varied by different cultivars (Hossain et al., 2011; Ferreiraet al., 2012). There was a significant effect of fertilizers treatments for seed yield (p≤0.05) (Table1). Plants grown in N treated pots produced the greatest seed yield (1.71±0.05 g $plant^{-1}$) which was not significantly different from those grown in sheep manured pots (1.67±0.03 g $plant^{-1}$). This showed that SM could increase safflower seed yield similar to N fertilizer. It has been also reported that SM increased soybean (*Glycine max*) yield and yield components (Mahmudabadiet al., 2011). Additionally, MWC treated pots gained greater seed yield (1.51±0.03 g $plant^{-1}$) than those treated with VC (1.24±0.02 g $plant^{-1}$) and CM (1.08±0.4 g $plant^{-1}$) (Table 2). This might be because of improving soil porosity, water holding capacity and aeration caused by organic amendments (Kazemeini, 2007). Organic amendments are also known as sources of plant nutrients and able to improve soil physicochemical characteristics (Aggelides

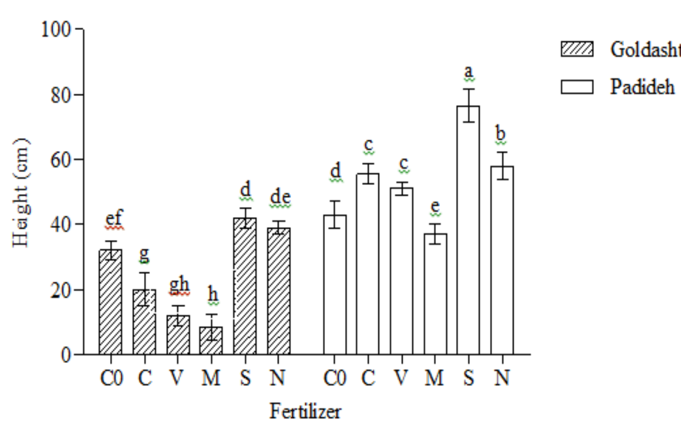

Fig 1. Effects of fertilizers on height of two safflower cultivars (Padideh and Goldasht). C0, C, V, M, S and N refer to control, municipal waste compost, vermicompost, cow manure and sheep manure, respectively. Error bars indicate SEs.

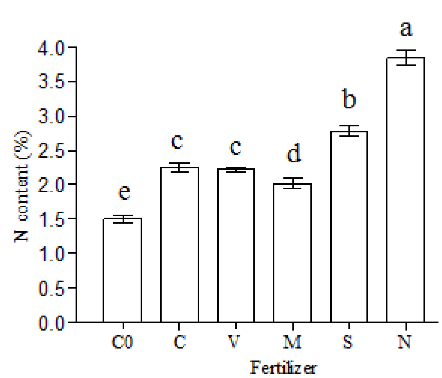

Fig 2. Effects of fertilizers on N content in safflower. C0, C, V, M, S and N refer to control, municipal waste compost, vermicompost, cow manure and sheep manure, respectively. Error bars indicate SEs.

Table 3. Simple correlation coefficients among the traits in two safflower cultivars.

	SY	H	Mn^{2+}	Fe^{2+}	Cu^{2+}	Zn^{2+}	N	DM
SY†	1							
H	0.39^{*}	1						
Mn^{2+}	0.31^{ns}	0.54^{**}	1					
Fe^{2+}	0.25^{ns}	0.09^{ns}	-0.06^{ns}	1				
Cu^{2+}	0.33^{*}	-0.29^{ns}	-0.04^{ns}	0.13^{ns}	1			
Zn^{2+}	0.44^{**}	-0.37^{*}	-0.05^{ns}	0.14^{ns}	0.52^{**}	1		
N	0.49^{**}	-0.12^{ns}	0.14^{ns}	0.24^{ns}	0.02^{ns}	0.35^{*}	1	
DM	0.38^{*}	0.14^{ns}	0.12^{ns}	0.03^{ns}	-0.08^{ns}	-0.01^{ns}	0.54^{**}	1

†SY: seed yield, H: height, DM: dry matter.

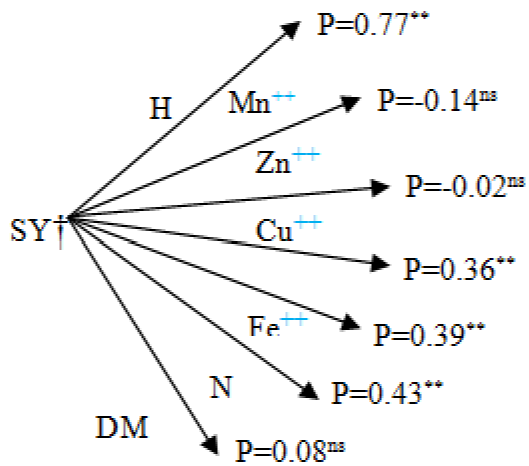

Fig 3. Path coefficient diagram showing the direct effects of some safflower traits and seed yield. †SY: seed yield, H: height, DM: dry matter.

and Londra, 2000; Soumare et al., 2003). Padideh cultivar plants produced greater seed yield (1.42±0.6 g $plant^{-1}$) than Goldasht cultivar plants (1.23±0.03 g $plant^{-1}$) (Table 2). There was no significant fertilizers treatments × cultivars interaction ($p \leq 0.05$).

The same trend as seed yield was found for aboveground biomass. N fertilizer and SM produced higher aboveground biomass (4.04±0.06 g $plant^{-1}$ and 3.93±0.05 g $plant^{-1}$, respectively) (Table 2). Padideh cultivar had greater aboveground biomass (2.77±0.07 g $plant^{-1}$) than Goldasht cultivar (1.86±0.09 g $plant^{-1}$) (Table 2). There was also no significant fertilizers treatments × cultivars interaction for aboveground biomass ($p \leq 0.05$) (Table 1). These results are in accordance with a number of researchers who have found that organic amendments have potential to increase crops yield and yield components (Naderi and Ghadiri, 2010; Prabhakar et al., 2011; Meade et al., 2011; Mahmudabadi et al., 2011).

Nitrogen (N) and micronutrients uptake in plant

N content in plants affected significantly by fertilizers ($p \leq 0.05$) (Table 1). Not surprisingly, plants received N fertilizer had the highest N content (3.48±0.11 %) (Fig. 2). These results are in accordance with those find by Naderi et al. (2012) in rapeseed and Onyango et al. (2012) in vegetable amaranth (*Amaranthus hypochondriacus*). Plants treated with SMhad greater N content (2.78±0.08 %) than those grown in MWC (2.25±0.07 %), VC (2.22±0.03 %) (Fig. 2) and CM (2.02±0.06 %). This showed sheep manure might be more efficient than the other organic fertilizer. Padideh cultivar plants had higher N content (2.51±0.05 %) than Goldasht cultivar plants (2.07±0.04 %) (Fig. 2). This indicated that nutrients absorption varied among cultivars due to the differences in ability of uptake by each cultivar (Hossain et al., 2011). There was no significant fertilizers treatments × cultivars interaction for N content ($p \leq 0.05$) (Table 1). Concentration of Zn^{2+}, Cu^{2+}, Mn^{2+} and Fe^{2+} in plant was affected significantly by fertilizers ($p \leq 0.05$) (Table 1). Plants treated with MWC had more Mn^{2+} concentration (120.6±7mg kg^{-1}) than those treated with SM (108.24±6mg kg^{-1}**)**, VC (103.93±4 mg kg^{-1}), CM (102.78±4 mg kg^{-1}), and N (101.30±5 mg kg^{-1}). These results are in agreement with those of Maftoun et al. (2004) who have found that Mn^{2+} uptake of spinach increased due to application of municipal waste compost. There was no significant effect of cultivars for Mn^{2+} concentration in plants and there was also no significant fertilizers × cultivars interaction for the trait ($p \leq 0.05$).

Plants received MWC had also significantly higher Fe^{2+} concentration (122.80±4 mg kg^{-1}) than the other treatments. There were no significant differences among SM, CM, VC, N and control for Fe^{2+} concentration in plants (Table 2). Padideh cultivar had significantly higher Fe^{2+} concentration (91.4±3 mg kg^{-1}) than that of Goldasht cultivar (65.82±5 mg kg^{-1}). A genetic variation in micronutrients (Zn^{2+}, Cu^{2+} and Fe^{2+}) uptake by corn cultivars has also been reported by Ferreira et al. (2012). Cu^{2+} and Zn^{2+} concentration in plants was also significantly affected by fertilizers ($p \leq 0.05$) (Table 1). Plants grown in MWC showed the highest Cu^{2+} (25.2±3 mg kg^{-1}) and Zn^{2+} (41.45±4 mg kg^{-1}) concentration. Control treatment showed the lowest Cu^{2+} (10.43±3 mg kg^{-1}) and Zn^{2+} (17.8±2 mg kg^{-1}) concentration. There were no significant differences among SM (14.23±2 mg kg^{-1}, 36.41±2.6 mg kg^{-1}), CM (15.73±1.5 mg kg^{-1}, 36.1±2 mg kg^{-1}), VC (14.5±1 mg kg^{-1}, 36.2±2 mg kg^{-1}), and N (13.81±3 mg kg^{-1}, 35.9±2.2 mg kg^{-1}) for Cu^{2+} and Zn^{2+} concentration, respectively. Uyanöz et al. (2006) reported the same results for wheat in which plants grown in MWC had more Zn^{2+}, Fe^{2+} and Mn^{2+} than those grown in manure. This is also in accordance with the results obtained by Soumare et al. (2003), who studied the response of ryegrass (*Loliumperenne*) to MWC and found that increasing compost rate caused a significant increase in plant uptake for Fe^{2+}, Mn^{2+}, Zn^{2+} and Cu^{2+}. Neither cultivars nor fertilizer × cultivars had a significant effect on Zn^{2+} and Cu^{2+} concentration in plants (Table 2). Additionally, Simple correlation coefficients calculated among the traits are given in Table 3. There were significant positive relationships between seed yield and height ($r=0.39$, $p\leq0.05$), Cu^{2+} content ($r=0.33$, $p\leq0.05$), Zn^{2+} content ($r=0.44$, $p\leq0.01$), N content ($r=0.49$, $p\leq0.01$) and aboveground biomass ($r=0.38$, $p\leq0.05$).The relationships determined by path analysis between seed yield and the measured traits are shown in Figure 3. There was a significant path coefficient, direct effect, among seed yield and height ($p=0.77$, $p\leq0.01$), Cu^{2+} content ($p=0.36$, $p\leq0.01$) and N content ($p=0.43$, $p\leq0.01$) (Fig. 3).

Materials and Methods

Pant materials

The experiment was conducted in a greenhouse at College of Agriculture and Natural Resources of Darab, Shiraz University, Iran (28.45° N, 54.31° E), from 8 December 2011 to 8 June 2012. The greenhouse conditions were set at 24°C:16°C (day:night), controlled light 16h/8h (day/night) and natural humidity. The surface 30-cm layer of a silty clay soil collected from wheat-rapeseed planting area of Darab, Fars province was used in this experiment. The soil was air dried, crushed and passed through a 2-mm sieve before analyzing and potting. Treatments consisted of two safflower cultivars (Padideh and Goldasht), six nutrient treatments [sheep manure (SM), municipal waste compost (MWC), vermicompost (VC), cow manure (CM), nitrogen (N) (150 kg ha^{-1}) and control (C0)] which were arranged in a randomized complete block design with three replications so that the experiment was spread out over three greenhouse benches (12 pots per bench), resulting in a total of 36 pots. All the organic amendments was applied at the rate of 50 t ha^{-1} and N fertilizer was applied at the rate of 150 kg ha^{-1}.Each pot was filled with 2 kg air-dry soil thoroughly mixed with the appropriate amounts of the fertilizers to reach the above-mentioned application rate. Five seeds of safflower cultivars were sown in each pot and seedlings were thinned to 3 after 3 weeks. The pots were watered with tap water every three days. Half of N fertilizer was applied at planting, and the remaining was applied at 6-leaves stage. All organic amendments were evenly mixed into the soil of each pot. The pesticide Confidor was applied on every other week basis to control for aphids and larvae.

Measurements

After 23 week, plants from each pot were harvested for determination of safflower aboveground biomass, oven-dried at 75 °C for 72 h, and weighed. We also measured the following traits: seed yield, plant height, N, Fe^{2+}, Mn^{2+}, Zn^{2+}, and Cu^{2+} content in plant. To determinate N content, one plant from each pot was sampled and oven-dried at 75 ºC for 72 h, finely ground and analyzed for N content using micro Kjeldahl method. The ground plant samples were also dry-ashed at 550 °C and analyzed for Fe^{2+}, Mn^{2+}, Zn^{2+}, and Cu^{2+} by atomic absorption spectrophotometer.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) and the means were compared (LSD test, $p<0.05$) using SAS (version 9.1, 2002) software.

Conclusion

Our results showed that application of organic amendments had potential to increase the growth and chemical composition of two cultivars of safflower and; therefore, might be a good alternative to chemical fertilizer treatment. Although municipal waste compost slightly increased Zn^{2+}, Cu^{2+}, Fe^{2+} and Mn^{2+} concentration of safflower's cultivars, it had no phytotoxic effects on the plants. Besides, long term effects of repeated application of these organic amendments should be carefully considered; especially in extended period of time. Further work should be done in order to study the effects of these organic amendments on safflower yield and micronutrients in the field.

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