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Integrated fertilizer management to attain sunflower sustainable production under different irrigation regimes

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Nitrogen release studies are of considerable interest in soil and environmental science. The objective of this research was to study integrated fertilizer management for the reduction of nitrogen leaching in sandy soils. An experiment was conducted during 2005–2006 to evaluate the effect of integration of zeolite, manure and urea on some traits of sunflower under different irrigation regimes. The results demonstrated that different irrigation regimes had significant effects on seed yield and yield component, final dry matter, chlorophyll content, leaf area index (LAI) and oil yield. But elements concentration in leaf and seed were not affected by irrigation regimes. Also it was observed that seed yield, oil yield, capitulum diameter, percentage protein, chlorophyll content, final dry matter, yield component, nitrogen concentration of leaf and seed, LAI and water use efficiency (WUE) were affected significantly by manure treatments. Interaction effects were significant on some traits. Finally, regarding the results of this experiment and the significant effect of the application of zeolite, the best treatment is suggested as the supply of 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by manure in combination with 15% of total manure weight zeolite, under the first irrigation regime.

Keywords: cattle manure; nutrition management; sunflower; yield; zeolite

Introduction

In recent years the increase in fossil fuel prices has led to the increase in fertilizer cost. In addition, the economic and environmental costs of excessive N fertilization have become important issues. Alternative forms of fertilizers such as manures can be used as sources of plant nutrients and at the same time increase N use efficiency and crop yield (Fageria and Baligar 2005).

Manure compost is a good source of nutrients for vegetation especially when supplemented with commercial nitrogen fertilizer. Cattle manure application in sandy soil improves the physical and chemical properties of soil. In addition, it increases microorganism activity and water retention capacity (Gupta et al. 2004). Crop yield is usually increased by manure application because of the increased nutrient availability and the improved soil structure (Matsi et al. 2003).

Eghball and Power (1999) found that the application of beef feedlot manure and composted feedlot manure resulted in a maize yield similar to that from commercial fertilizer application.

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Amongst crops, sunflower is known as the most suitable crop and edible oil source in the world. It has a short vegetation period, is relatively drought tolerant and has shown potential to reduce the existing gap between production and consumption of edible oil because it contains 40–50% oil and 17–20% proteins (Wang et al. 1997). It can be grown twice a year and can be fitted well into our present cropping systems. It can be grown successfully over a wide range of geographic areas and is considered a crop adapted to a wide range of environments.

Nitrogen is one of the most important nutrients for sunflower production as it affects dry matter production by influencing leaf area development and maintenance as well as photosynthetic efficiency. Nitrogen use efficiency defined as seed yield produced per kg of N applied is essential in crop production systems as it can provide a balance between nutrient inputs and outputs over the long term and it can also improve crop yield and prevent NO_3^- pollution of the underground water (Fageria and Baligar 2005). One way to increase N use efficiency is to apply nitrogen at different times in the growing season as it is needed by the crop (Fageria and Baligar 2005). Another way is to prevent the leaching of N via soil regeneration.

Manure composting is a useful method of producing a stabilized product that can be stored or spread with little odor or fly breeding potential. The other advantages of composting include killing pathogens and weed seed and improving handling characteristics of manure by reducing its volume and weight (Rynk et al. 1992). Composting also has some disadvantages, which include nutrient and C loss during composting; the cost of land, equipment, and labor required for composting; and the odor associated with composting. Eghball et al. (1997) found 20–40% loss of total N and 46–62% loss of total C during composting of beef cattle feedlot manure, as well as significant losses of K and Na (6.5% of total K and Na) in run-off from composting windrows during rainfall. Nitrogen is often lost by NH_3 volatilization from stored manure. Most studies determining N mineralization from applied manure have been conducted in the laboratory. Other studies have determined availability of nutrients by plant nutrient uptake or by seed yield.

Zeolites are a group of minerals, highly crystalline hydrated aluminosilicates that, when dehydrated, develop a porous structure with minimum pore diameters of between 0.3–1 nm The structural frame is made up of Si-O (SiO_4^{4-}) and Al-O (AlO_4^{5-}) tetrahedrons, which bond together sharing vertices and forming square and hexagonal structures.

Zeolites are one of the greatest cationic interchangers and their cationic interchange capacity is two to three times greater than other types of minerals found in soils. The application of zeolites to soils increases cation exchange capacity, and as a result, it increases nutrient retention capacity (Ming and Boettinger 2001). Huang and Petrovic (1994) reported that the application of zeolites to soil reduces the leaching of nitrates. Subsequently, it was demonstrated that zeolite is an important resource in agriculture due to its water and ammonium retention capacity and because it helps to reduce N loss (John et al. 1998; Polat et al. 2004). Furthermore, it has been verified that, when zeolite was mixed with N, P and K compounds, zeolite enhances the action of such compounds as slow release fertilizers, both in horticultural and extensive crops (Dwairi 1998a).

Hence, zeolite acts as a slow release fertilizer, giving the plant access to water and nutrients for longer, which results in a significant saving in water resources and reducing the amount of fertilizer to be applied (Grande et al. 1995), thus helping to decrease the amount of water used per crop and the contamination of aquifers resulting from the overuse of fertilizers.

Since there is limited published work about the effect of application of cattle manure combined with zeolite and chemical fertilizer, this research was conducted to compare the effects of composted cattle manure in combination with supplemental inorganic fertilizer and zeolite on sunflower yield and quality. The primary objective of this demonstration was to determine the effects of compost application combined with zeolite in order to decrease consumption of chemical fertilizers in sandy soil lands. Also, one hypothesis for this research was that adding zeolite to cattle manure would bind the ammonia and reduce the amount of N lost. The second hypothesis was that zeolite application would lead to an increase of yield.

Material and method

Study site

The experiment was conducted on the research farm of Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran (35°41′ N latitude, 51°19′ E longitude and altitudes of 1215 m) during the 2006–2007 growing seasons. The yearly average precipitation (30 years long-term period), which mostly occurred during the autumn and winter months, was 298 mm. The mean annual temperature was 18.8°C.

Soil sampling and analysis

Before the beginning of the experiment, soil samples were taken in order to determine the physical and chemical properties. A composite soil sample was collected at a depth of 0–30 cm. It was air-dried, crushed, and tested for physical and chemical properties. The research field had a sandy loam soil. Details of soil properties are shown in Table 1.

Manure and zeolite composting

In early March, fresh dairy cattle manure and zeolite were transported to the field. The zeolite was provided from Miane city, Iran. The chemical properties of manure and zeolite were analyzed before composting. The results are shown in Tables 2 and 3, respectively.

In order to compost, four rows of dairy cattle manure with equal weight were stored in heaps 4.5 m long, 0.8 m wide and 0.7 m high and then 5, 10 and 15% weight of cattle manure was added as zeolite to three rows. To prevent direct sunshine, the heaps were covered by straw and stubble. The temperature and moisture of the heaps was monitored every other day. Manure rows were aerobically composted for 85 days.

Compost sampling and analysis

At the end of the composting process, one composite sample of each row was collected and analyzed. It was observed that 38% N was lost in the row without zeolite. In the rows that contained 5, 10 and 15% zeolite, N was lost at rates of 29, 22 and 19%, respectively. Therefore, N content was 0.77, 0.88, 0.97 and 1.01% in the rows that contained 0, 5, 10 and 15% zeolite, respectively. According to sunflower N

Table 1. Physical and chemical soil properties.

Physical	Depth	Sand	Silt	Clay	Texture	FC	CEW	AW	B_d	
	0–30 cm	69%	20%	11%	Sandy loam	21%	9%	12%	1.45 gr cm^{-2}	
Chemical	Depth	CEC	pH	O.M	N	P	K	Fe	Cu	Zn
	0–30 cm	4.6 meq $(100g)^{-1}$	7.7	1.06%	0.07%	>12 mg kg^{-1}	>350 mg kg^{-1}	7.6 mg kg^{-1}	0.7 mg kg^{-1}	1 mg kg^{-1}

FC, field capacity; CEW, crop extractable water; AW, available water; B_d, bulk density; CEC, cation exchange capacity; OM, organic matter; N, total nitrogen; P, absorbable phosphorous; K, absorbable potassium.

Table 2. Fresh manure properties.

EC	N	P	K	Na	OC	OM
21.2 dS m^{-1}	1.25%	0.56%	2.55%	1.22%	28.85%	49.91%
SC	C:N	pH	Fe	Cu	Zn	Mn
240%	23	9	7435 mg kg^{-1}	25.5 mg kg^{-1}	109.3 mg kg^{-1}	267.6 mg kg^{-1}

EC, electrical conductivity; OC, organic carbon; OM, organic matter; SC, saturated capacity.

Table 3. Percentage of chemical compounds and CEC of applied zeolite (provided from Miane city, Iran).

SiO_2	AL_2O_3	K_2O	Na_2O	MgO	CaO
65	12.02	3	1.08	0.1	2.3
Fe_2O_3	MnO	TiO_2	P_2O_5	CEC	SO_3
1.5	0.04	0.03	0.01	200 meq $(100g)^{-1}$	–

requirement and soil N content, 130 kg ha^{-1} N was needed; 50 kg of N was supplied by composted manure and 80 kg was supplied by chemical fertilizers as urea at two stages, sowing and flowering (R-2 stage, described by Schneiter and Miller 1981).

Field preparation and applying the treatments

The preceding crop was wheat. After plow and disk, plots were prepared. The experimental design was laid out in a randomized complete block with a split plot arrangement of treatments in four replications. The plots were 4 m long and consisted of eight rows, 0.5 m apart. Between all main plots, a 2-m alley was kept to eliminate all influence of lateral water movement. A polyethylene pipeline and installation of counter was performed for the control of irrigation. The different compost levels were distributed in subplots and mixed with surface soil. According to the results of soil analysis, no fertilizer such as P and K were needed. Different treatments of manure included:

- (i) M1 – 100% N of plant requirement from chemical fertilizer (130 kg ha^{-1} N by urea);
- (ii) M2 – 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure;
- (iii) M3 –80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 5% weight of cattle manure zeolite;
- (iv) M4 – 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 10% weight of cattle manure, zeolite; and
- (v) M5 – 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 15% weight of cattle manure, zeolite;

According to formula given below (Equation 1) the amount of cattle manure to attain 50 kg ha^{-1} N was calculated. It was assumed that 35% of total nitrogen of manure is available for the plant in the first year (Eghball et al. 2001).

$$Rn = Md \times Mn \times An \tag{1}$$

where Rn: Requirement nitrogen from manure; Md: Manure dry weight; Mn: Manure nitrogen percent; An: Available nitrogen in percent.

Seed sowing and irrigation

The early mature sunflower seeds (*Helianthus annuus* L. cv. Blizar) were disinfected and sown in early July. The distance between plants rows was 30 cm and the plant density was around 65,000 plants per ha at sowing time. Soil volumetric water contents were monitored daily on the surface to a depth of 70 cm using the time-domain reflectometry (TDR, FM-Trime -IMKO- Gmbh, D-76275- Germany) and a probe of 70 cm length were inserted in the middle subplot of each treatment and previously calibrated. Irrigation was carried out similarly in all plots when 35% available water was consumed until flowers appeared. After this stage, different irrigation regimes were carried out. Two irrigation regimes [Irrigation after using 35% available water (I1) and irrigation after using 70% available water (I2)] were randomized to the main plots.

Plant sampling, harvesting and scrutiny

At flowering stage, leaf samples were taken to determine the N, P and K content of leaves. Leaf area index was measured by leaf area meter (Delta-T Devices Ltd, UK) at this stage too. Total N, P and K were determined through the titration method by Kjeltec Auto 1030 Analyzer, Tecator, calorimetric method by Spectrophotometer, 6505 JenWay and flame photometry by flame-photometer JenWay PFP7, respectively.

Chlorophyll content readings were taken with a handheld dual-wavelength meter (SPAD-502 Minolta, Japan). For each plot 30 younger fully expanded leaf blades per plot were used when the plants were at seed filling stage. The instrument stored and automatically averaged these readings to generate one reading per plot.

At the physiological maturity stage, the plants were harvested and yield and yield components included seed number in capitulum, 1000-seed weight (at 10% moisture) and capitulum diameter were measured.

Seed percentage oil and percentage protein were measured by Inframatic 8620 Percor. Oil yield was calculated via product seed yield and percentage oil. Concentration of N, P and K were determined in seeds according to the methods mentioned above. Five plants of each plot were also sampled and dried in an oven at 60°C for 72 h to calculate final dry matter. Water use efficiency was calculated according to the proportion of yield and consumed water.

Statistical analysis of data

All data were analyzed from analysis of variance (ANOVA) using the GLM procedure in SAS (SAS Institute 2002). The assumptions of variance analysis were tested by insuring that the residuals were random, homogenous, with a normal distribution about a mean of zero. Duncan's Multiple Range test was used to measure statistical differences between treatment methods and controls.

Results and discussion

Results demonstrated that the effect of different irrigation regimes was significant on seed yield, oil yield, number of seeds in capitulum, capitulum diameter, chlorophyll content, final dry matter, 1000-seed weight and leaf are index (Table 4). Manure

Table 4. Analysis of variance on yield, yield components, seed and leaf quality and other traits of sunflower.

SOV	DF	SY	OY	SH	HD	P	O	C	DM	SW	LN	SN	LK	SK	LP	SP	LAI	WUE
Replication	3	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns
Irrigation	1	*	*	**	**	ns	ns	**	*	*	ns	ns	ns	ns	ns	ns	*	ns
E(a)	3	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Manure	4	**	**	**	**	**	ns	**	**	**	**	**	ns	ns	ns	ns	**	**
Interaction	4	ns	ns	ns	**	ns	**	*	**	ns	ns	ns	ns	ns	ns	ns	**	**
E(b)	24	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

ns, not significant, * and **: significant at $p < 0.05$ and $p < 0.01$, respectively. SOV, source of variation; DF, degree of freedom; SY, seed yield; OY, oil yield; SH, seed number in capitulum; HD, capitulum diameter; P, percentage seed protein; O, percentage seed oil; C, chlorophyll (Spad); DM, dry matter; SW, 1000-seed weight; LN, leaf nitrogen content; SN, seed nitrogen content; LK, leaf potassium content; SK, seed potassium content; LP, leaf phosphorous content; SP, seed phosphorus content; LAI: leaf area index; WUE: water use efficiency.

treatment also had a significant effect on all of the evaluated traits except percentage of oil, potassium and phosphorous content of leaves and seeds (Table 4). It was observed that interaction of treatments was significant on capitulum diameter, percentage oil, and chlorophyll content, final dry matter, LAI and WUE.

Seed and oil yield was decreased in the second irrigation regime (I2: irrigation after using 70% available water) when compared to the first irrigation regime (I1: irrigation after using 35% available water). This is supported by the results of other research on sunflower (Unger 1992). With the emphasis on the soil's unfavorable condition, related to poor water retention capacity, it seems that the decrease in seed yield and oil yield is explainable. In addition, seed yield was affected by different manure levels. The highest (2332.71 kg ha^{-1}) and the lowest (1446.81 kg ha^{-1}) seed yield were obtained from M5 and M1 treatments, respectively (Table 5). Composted cattle manure mixed with zeolite application improved soil physico-chemical properties such as cation exchange capacity (CEC) and water retention capacity (data are not shown) therefore seed yield was increased. This is in agreement with the findings of other researchers, who reported yield increases due to manure application (Loeche et al. 2004). The zeolite had an important role in the prevention of N leaching during composting process. The NH_4^+ is bonded to negative exchange station of zeolite and released at the suitable time for absorption by plant, so an increase of yield can be referred to this occurrence.

The number of seed per capitulum was significantly decreased due to increase of interval between two irrigations (Table 5). The decrease of seed numbers is parallel with the decrease in capitulum diameter. Irrigation after using 70% available water decreased significantly capitulum diameter. Decrease of sunflower seed numbers under water deficit has been reported by D'Andria et al. (1995). The highest and the lowest seed number were observed in plants treated with M5 and M1, respectively. Application of 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 15% zeolite (M5) increased seed number compared with M1 and M2 by 23 and 10%, respectively.

There was a significant difference between the two irrigation regimes in respect to the percentage of seed protein. Seed protein percentage obviously increased corresponding to an increase of zeolite application. It seems that N leaching in heaps and soil is decreased as a result of zeolite application and therefore seed protein percentage was increased.

Irrigation after using 70% available water decreased 1000-seed weight than irrigation after using 35% available water. Water deficit stress at the filling stage period causes a decrease in photosynthesis, assimilates transport and decreases seed weight (Pandey et al. 2000). The effect of manure compound was different on 1000-seed weight. The minimum (54.03 g) and maximum seed weights (65.72 g) were related to M1 and M4 treatment, respectively. Increment of 1000-seed weight was due to an increase in N availability as a result of zeolite application. Zeolite has high cation exchange capacity (Table 3). It can improve soil cation exchange capacity and enhance elements availability around roots (Ming and Boettinger 2001).

There was no significant difference between the effects of irrigation on leaf N content (Table 5); however, irrigation after using 70% available water decreased leaf N content. It seems that N uptake by the plant is correlated with soil moisture. There is a good agreement between our results and those obtained by Hagin and Tucker (1982). As mentioned before, all of the plots were irrigated uniformly before

Table 5. Main effects of irrigation regimes and different manure composts on yield, yield components, seed and leaf quality and other traits of sunflower.

Treatment	SY	OY	SH	P	SW	LN	SN	LK	SK	LP	SP
I1	2297.50a	1119.30a	586.00a	20.18a	69.03a	3.30a	3.15a	2.92a	0.47a	0.62a	0.80a
I2	1717.00b	849.40b	424.45b	20.60b	54.11b	2.57a	3.21a	2.87a	0.44a	0.60a	0.77a
M1	1446.81d	708.07d	431.00d	19.16b	54.03c	3.38a	2.84b	2.81a	0.42a	0.63a	0.77a
M2	1895.41c	917.24c	506.88bc	19.27b	58.75bc	3.09ab	3.03b	2.79a	0.43a	0.60a	0.79a
M3	2060.08b	1012.96b	486.25c	20.07ab	65.46a	2.90bc	3.03b	2.95a	0.47a	0.62a	0.78a
M4	2302.66a	1140.95a	543.65ab	21.00a	65.72a	2.68c	3.46a	3.01a	0.47a	0.62a	0.79a
M5	2323.71a	1143.30a	558.38a	21.10a	63.87ab	2.63c	3.52a	2.93a	0.48a	0.60a	0.79a

For a given means within each column of each section followed by the same letter are not significantly differences ($p < 0.05$).

I1: Irrigation after using 35% available water; I2: irrigation after using 70% available water (water deficit).

M1: 130 kg ha^{-1} N by urea; M2: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure; M3: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 5% weight of cattle manure, zeolite; M4: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 10% weight of cattle manure, zeolite; M5: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 15% weight of cattle manure, zeolite.

SY, seed yield (kg ha^{-1}); OY, oil yield (kg ha^{-1}); SH, seed number in capitulum; P, percentage seed protein; SW, 1000-seed weight (gr); LN, leaf nitrogen content (%); SN, seed nitrogen content (%); LK, leaf potassium content (%); SK, seed potassium content (%); LP, leaf phosphorous content (%); SP, seed phosphorus content (%).

flowering stage and different irrigation regimes were applied after this stage. Perhaps the water deficit in the second irrigation regime (I2) was not enough and therefore the difference was not significant in respect of leaf nitrogen content. Moreover, seed N content was not significantly affected by irrigation regimes; however, seed N content was somewhat more in I2 regimes. This increase is rationalized by the explanation that water deficit leads to an increase in N compound transport from sources to the seeds. In the case of K and P content of leaf and seed, irrigation had no significant effect on the content of these elements although, I1 showed a little more preference than I2 (Table 5). According to Table 1, the amount of K and P was enough in the soil therefore, the K and P content of leaf and seed were not affected by the different irrigation regimes.

Amongst the assayed elements, only N content of leaf and seed was affected by manure treatment (Table 5). Insignificant differences among the different manure treatments on K and P content of leaf and seed were due to the availability of these elements in the soil, though Domadar Reddy et al. (2000) reported that manure application increased K and P absorption. It seems that when these elements are available in the soil, plants will not show response to excessive increases of elements. The highest leaf N content (3.38%) was found in plants treated with the M1 treatment while the lowest related to M4 and M5 (2.68% and 2.63%), respectively (Table 5). The combination of cattle manure with the highest proportions of zeolite (M4 and M5) amplifies microbial activity and also decreases NH_4^+ mobility and absorption. Dwairi (1998a) evaluated zeolite tuff as a controlled slow-release fertilizer for NH_4. The seed N content was increased in M4 and M5 treatments compared to the M1 treatment, since N was slowly released by manure (Pang and Letey 2000) or zeolite (Dwairi 1998b) in due course. Regarding the M4 and M5 treatments, N availability and absorption were highest at the seed filling period, and therefore N content increased. Kramer et al. (2002) found out that although in organic systems total N absorbed is less than conventional systems, continuous releasing of N from organic sources increased N absorption by plants, therefore simultaneously occurred between absorption rate and available N.

The results showed that the interaction effects were significant on sunflower capitulum diameter. The highest (17.75 cm) and the lowest (9.87 cm) capitulum diameters were obtained from I1-M4 and I2-M1 treatments, respectively (Figure 1). The M4 treatment may have improved water retention and nutrition conditions and subsequently increased capitulum diameter, while in the I2-M1 treatment, N leaching was more due to low cation exchange capacity of soil (Table 1) and low water retention due to low organic matter in soil. Decreasing of capitulum diameter in this treatment leads to reduced seed numbers and final yield.

Percentage oil had the lowest variation in response to irrigation and different manure levels. There was no significant difference among treatments on oil percentage but interaction effect was significant (Figure 2).

Changes in chlorophyll content by irrigation and manure are given in Figure 3. The least chlorophyll content was observed in the I2-M1 treatment, and the most chlorophyll content was related to I1-M4 and I1-M5 treatments, vice versa. The N level has a direct effect on chlorophyll content as it is usual to use chlorophyll content to determine the N status of the plant (Eghball and Power 1999). The M4 and M5 treatments act as N pool during growth period and supplied plants at critical times, whereas in chemical treatment (M1) nitrogen leaching leads to a decrease in chlorophyll content.

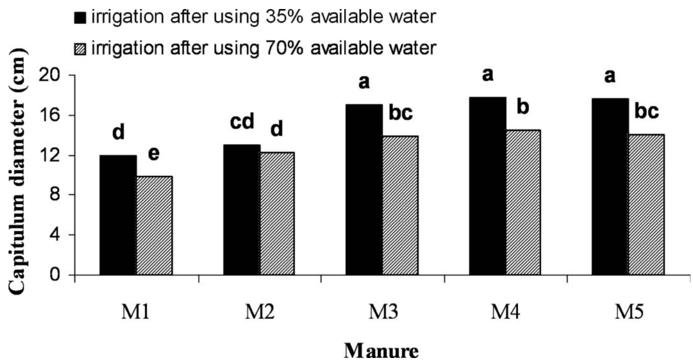

Figure 1. Changes in sunflower capitulum diameter due to interaction between different irrigation regimes and different compound of manure and zeolite. M1: 130 kg ha^{-1} N by urea; M2: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure; M3: kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 5% weight of cattle manure, zeolite; M4: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 10% weight of cattle manure, zeolite; M5: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 15% weight of cattle manure, zeolite.

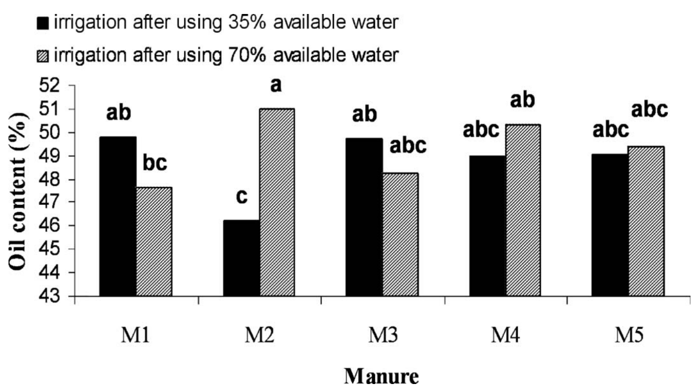

Figure 2. Changes in sunflower percentage oil due to interaction between different irrigation regimes and different compound of manure and zeolite. M1: 130 kg ha^{-1} N by urea; M2: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure; M3: kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 5% weight of cattle manure, zeolite; M4: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 10% weight of cattle manure, zeolite; M5: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 15% weight of cattle manure, zeolite.

The highest final dry matter as a growth index was obtained in the I1-M5 treatment while I2-M1 produced the lowest dry matter among treatments (Figure 4). It is obvious that water deficit (I2), low water retention capacity (Table 1) and also absence of curative materials such as manure or zeolite (I2M1) have an affect on stomatal closure, CO_2 exchange rate, photosynthesis and finally plant growth. In addition, low cation exchange capacity causes N leaching increscent. In summary, water and N deficit decreased dry matter. In I1-M3, I1-M4 and especially I1-M5 treatments, the increasing of water retention capacity due to cattle manure

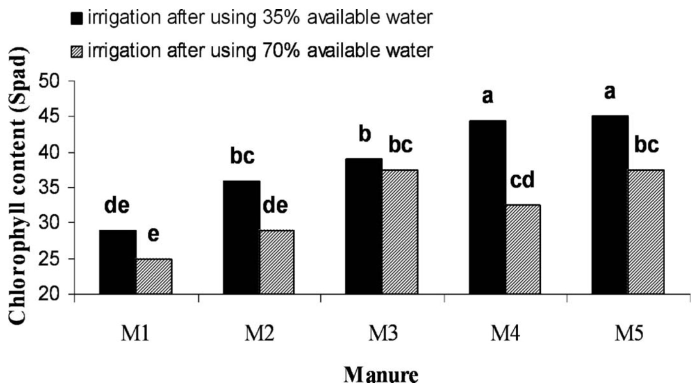

Figure 3. Changes in sunflower chlorophyll content due to interaction between different irrigation regimes and different compound of manure and zeolite. M1: 130 kg ha^{-1} N by urea; M2: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure; M3: kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 5% weight of cattle manure, zeolite; M4: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 10% weight of cattle manure, zeolite; M5: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 15% weight of cattle manure, zeolite.

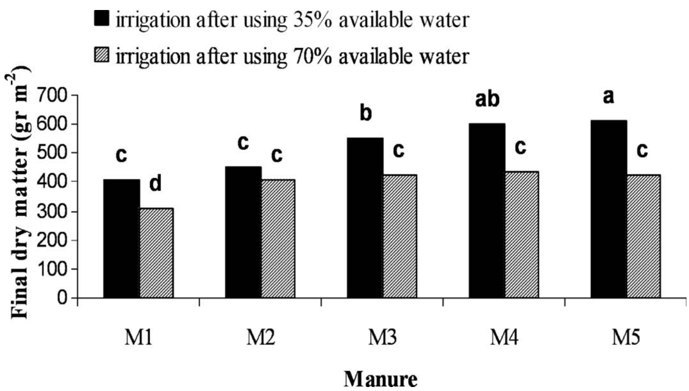

Figure 4. Changes in sunflower final dry matter due to interaction between different irrigation regimes and different compound of manure and zeolite. M1: 130 kg ha^{-1} N by urea; M2: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure; M3: kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 5% weight of cattle manure, zeolite; M4: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 10% weight of cattle manure, zeolite; M5: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 15% weight of cattle manure, zeolite.

(Adediran et al. 2004) and the increasing of cation exchange capacity by zeolite (Shaw and Andrews 2001) lead to an enhancement of final dry matter.

The LAI significantly responded to irrigation and manure treatment. The highest and the lowest LAI were observed in the I1-M5 and I2-M1 treatments, respectively (Figure 5). Horst (1995) reported that if N be available, NH_4 assimilation causes leaf expansion. In addition, the effect of moisture availability on leaf extension is affirmed (Denmead and Shaw 1960). So in the I1-M5 treatment, the increased water and N availability is a reason of leaf expansion. It is considered that there is a direct correlation between LAI and photosynthetic potential, so an increase of LAI is equal with an increase of dry matter and yield.

Total consumed water was 7250 $\pm$ 100 m^3 ha^{-1}; 56% was allocated to the first irrigation (I1) and 44% to the second irrigation (I2). The field was irrigated 13 and eight times in the first and second irrigation regimes, respectively. The highest WUE was obtained in I1-M4 and I1-M5 treatments (Figure 6). Cattle manure application causes an improvement of water retention capacity (data are not shown) also zeolite via prevention of N leaching is the reason for increasing the long availability of N for plants. In summary, these two matters led to the enhancement of WUE, although in

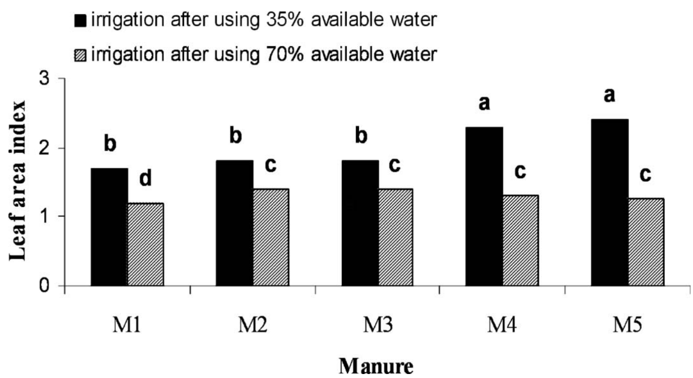

Figure 5. Changes in sunflower leaf area index due to interaction between different irrigation regimes and different compound of manure and zeolite. M1: 130 kg ha^{-1} N by urea; M2: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure; M3: kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 5% weight of cattle manure, zeolite; M4: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 10% weight of cattle manure, zeolite; M5: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 15% weight of cattle manure, zeolite.

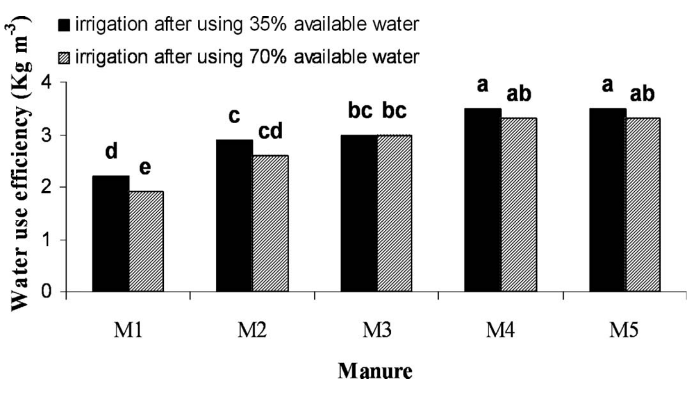

Figure 6. Changes in sunflower water use efficiency due to interaction between different irrigation regimes and different compound of manure and zeolite. M1: 130 kg ha^{-1} N by urea; M2: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure; M3: kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 5% weight of cattle manure, zeolite; M4: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 10% weight of cattle manure, zeolite; M5: 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by cattle manure in combination with 15% weight of cattle manure, zeolite.

the second irrigation regime (I2) a noticeable amount of water (750 m^3 ha^{-1}) was protected; nonetheless, negative effect water deficit and unfavorable physico-chemical properties of the soil beside the lowest WUE was obtained in the I2-M1 treatment.

Conclusion

According to the above-mentioned results, hypothesizes were accepted as adding zeolite to cattle manure prevented the nitrogen leaching and increased sunflower yield. In this experiment the best treatments were irrigation after consuming 35% of available soil moisture and providing 80 kg ha^{-1} N by urea and 50 kg ha^{-1} N by manure compost in combination with 15% of total manure weight added zeolite.

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