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Effect of planting pattern, plant density and integration of zeoponix and chemical fertilizer (urea) on sunflower yield and yield components

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Key words: Planting pattern, Plant density, Zeoponix, Sunflower, yield and yield components.

Abstract

An experiment was conducted to evaluate the effect of planting pattern, plant density and integration of zeoponix and chemical N fertilizer (urea) on sunflower yield and yield components. The experimental design was analyzed as factorial based on randomized complete block with three replications. Treatments consisted of 3 factors which are different crop densities, including 2 levels. The population of plants was including 5 plants m^{-2} (d1) and 8 plants m^{-2} (d2). The second factor was planting patterns which were included twin rectangular rows (A1) and twin zigzag rows (A2). Different fertilizing treatments were selected as third factor consisted of the sole application of zeoponix (f1) and chemical fertilizer urea (f3), and integration of 50%zeoponix +50% chemical fertilizer urea (f2), that were at 3 levels. Results showed that there were significant differences in interaction of planting pattern, plant density and fertilizing system on plant height, stalk diameter, biologic yield, seed yield, number of seeds per head, 1000 seed weight, seed oil content and oil yield, protein content and protein yield and harvest index. LSD test for means of these traits showed that zigzag arrangement × plant population of 8 plants m^{-2} × 100% zeoponix (a2d2f1) treatment had the best performance and could be recommended to farmers for sunflower cultivation.

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Introduction

Sunflower (*Helianthus annuus* L.) is one of the most widely edible oilseed crops in the world. It was reported that, approximately around 80% of oilseed for human food is imported in Iran (Zarea *et al.*, 2005), so increasing sunflower production is a priority option to reduce this deficit. Adequate plant density and a planting pattern with optimum spatial arrangement (equidistant is superior) are important cultural factors that increase radiation interception and yield production. Changing planting patterns from rectangular into zigzag arrangement decreases plant-to-plant competition for radiation interception and biomass production (Bullock *et al.*, 1988; Andrade *et al.*, 2002). Sunflower yield (Andrade *et al.*, 2002) and soybean yield (Duncan, 1986; Ikeda and Sato, 1992) increased in response to sowing distance between and on the rows. When row spacing is reduced, light interception increases. There are times during the crop cycle that are most critical for yield determination. These times comprise the period bracketing flowering in sunflower (Chimenti and Hall, 1992, Connor and Sadras, 1992; Cantagallo *et al.*, 1997). Therefore, the response of grain yield to narrow rows can be analyzed in terms of the effect on the amount of radiation interception at the critical periods for kernel set. Higher crop growth rates during these periods may not be achieved with wide rows (Andrade *et al.*, 2002). Increase in light interception by reducing row spacing has been reported for corn (Egharevba, 1975; Flenet *et al.*, 1996; Andrade *et al.*, 2002), sorghum (Clegg *et al.*, 1974; Graham *et al.*, 1988; Muchow *et al.*, 1990; Flenet *et al.*, 1996), soybean (Mason *et al.*, 1980; Boared *et al.*, 1990; Andrade *et al.*, 2002) and sunflower (Flenet *et al.*, 1996; Andrade *et al.*, 2002).

In recent times, concerns about unbalanced use of fertilizers leading to environmental pollution which have been globally expressed. As a result, studies on how to use efficient methods to reduce nutrient applications at the same time increasing or maintaining crop yield, reducing nutrient losses and improving nutrient use efficiency are imperative (Oosterhuis and Howard, 2008). In this regard, inclusion of zeolites in fertilizers management for agriculture is essential as besides serving as soil conditioner (including soil fertility improvement), zeolites have the potential to increase crop yield (Valente *et al.*, 1982; Noori *et al.*, 2006).

Zeolite has been used in agriculture for decades around the world. Farmers in Japan have been using zeolite since 1965 as a dietary supplement for livestock and as a soil amendment for sandy, clay poor soils. Zeolite is an amazing natural mineral because of its extraordinary ability to absorb, hold, release, and exchange different chemicals, nutrients and ions according to need. Zeolite is a naturally occurring hydrated sodium potassium calcium alumino silicate (of the subtype clinoptilolite) which was formed from the glass component of volcanic ash millions of years ago. Zeolite is a mineral with infinite, three-dimensional, honeycomb like channels that allow it to lose and gain water reversibly.

Zeolite is a natural super porous mineral. It carries a negative charge balanced by freely moving cations with positive charges. This provides an ideal trap for positive cations like nitrogen rich ammonium and potassium which are then released when demanded by plants. Thus, zeolite could be used as fertilizers, stabilizers and chelators (Kapetanios and Loizidou, 1992; Perez-Caballero *et al.,* 2008). A study showed that zeolites enable both inorganic and organic fertilizers to slowly release their nutrients (Perez-Caballero *et al.,* 2008).

Zeoponix is zeolite, which is used in poultry bed because of water, urea, NH_4 and ion absorption. After the end of chicken breeding, zeoponix can be collected and be used as biological manure in agriculture. The objective of this study was to investigate if the use of inorganic fertilizers together with zeolite changing planting pattern and plant density will improve nutrient uptake and consequently yield and yield components of sunflower.

Materials and methods

Field experiment

An experiment was conducted to evaluate the effect of planting pattern, plant density and integration of zeoponix and chemical N fertilizer (urea) on sunflower yield and yield components at the Experimental Farm of 'Tarbiat Modares University in 2010, Tehran, Iran.

Hybrid belizar sunflower seeds were handplanted on 27 June 2010 on sandy soil. The zone was located in 16th Km of Tehran – Karaj highway and lies between 35° 44′ N latitude and 51° 10′ E longitude and 1352 m above sea levels. The region is characterized as semi-arid, with mean annual precipitation of 250 mm, which mostly falls during the autumn and winter months. Daily meteorological data on precipitation and air temperature were obtained from the nearest weather station (500 m from the experimental site) (Fig. 1). The means of the temperature and relative humidity during the experimental period were close to the mean of the same long period. Before planting, several soil samples were taken at depths of 0–30 and 30–60 cm, composite samples were collected, air-dried, crushed, and tested for physical and chemical properties (Table 1).

The experimental design was analysed as factorial based on randomized complete block with three replications. Sunflower was sown with 50000 and 80000 plant per hectare density on 27 June, 2010. The seeds were sown at a rate of three to four seeds in shallow holes at a depth of 5 cm and firmly covered. Prior to V4 [V (number) Vegetative Stages (i.e. V-1, V-2, V-3, etc.). These are determined by counting the number of true leaves at least 4 cm in length, beginning as V-1, V-2, V-3, V-4, etc. (Schneiter and Miller, 1981)] they were thinned to one stand (25 d after emergence). The experimental treatments consisted of 3 factors which are different crop densities including 2 levels. The population of plants was including 5 plants m^{-2} (d1) and 8 plants m^{-2} (d2). The second factor was planting patterns which were including twin rectangular rows with 75 cm between the rows (A1) and twin zigzag rows (A2) with 75 cm between the rows. (Table 3 and Fig. 1). Different integrated fertilizing treatments were selected as third factor consisted of the sole application of zeoponix (5752 Kg/ha) (f1) and chemical fertilizer, urea (283 Kg/ha) (100%) (f3) based on as sunflower pure nitrogen need in accordance with the results of soil analyses (130 Kg/ha nitrogen), and integration of 50%zeoponix (2876Kg/ha)+50% chemical fertilizer urea (142 Kg/ha) (f2), that were in 3 levels. Zeoponix was applied before planting prior to zeoponix analysis. Chemical fertilizer urea was applied in 2 times; half amount of it applied before planting and the remained half at the beginning of reproductive stage R1 (Schneiter and Miller, 1981)] during the irrigation.

Weeds were removed by hoeing as needed and no problems with diseases or insects occurred. Plots were flood-irrigated according to sunflower need. Sunflower seeds were sown in plots with 4 rows which were 4 meters in both sides of 75 cm furrows.

Laboratorial experiment

To determine sunflower seed yield and yield components, 5 plants were selected randomly with regard of marginal effect during seed physiological ripening. Parameters including plant height, stalk diameter, head diameter, number of seed per head, 1000 seed weight, seed yield, biologic yield and harvest index were measured. Sunflower seed oil was extracted with petroleum ether using Soxhlet instrument (AOAC, 1990). The seed protein content was estimated using the Kjeldahl method described in AOAC (1984). This method involves protein digestion, distillation and determination of % nitrogen content of the distillate by titration and then multiplying the % nitrogen by a factor of 6.25 to obtain the corresponding protein content in %. Statistical analyses were carried out using SAS software (Statistical Software, SAS institute, 2002), and the mean values were classified by LSD test.

Result and discussion

Vegetative growth

Sunflower plant height, stalk diameter and biologic yield were the parameters measured to show vegetative growth. Result showed that there was no significant difference in plant arrangement and plant density on sunflower height and plant arrangement on biologic yield. however, there was significant difference in interaction of planting pattern, plant density and fertilizing system on plant height, stalk diameter and biologic yield ($P < 0.05$) (Tab. 4).

Maximum plant height and stalk diameter were achieved at a zigzag arrangement × plant population of 8 plants m^{-2} × 100% zeoponix (a2d2f1) treatment (Tab. 4). However, maximum biologic yield was observed in twin rectangular arrangement × plant population of 5 plants m^{-2} × 50% zeoponix+50% chemical fertilizer (a1d1f2) and zigzag arrangement × plant population of 5 plants m^{-2} × 100% zeoponix (a2d1f1).

Table 1. Physical soil properties of experimental research farm.

Depth (cm)	Sand (%)	Lime (%)	Clay (%)	Texture	Field Capacity(%)	Available Water(%)	(g/cm3)	PH
0 - 30	69	20	11	Sandy loam	21	12	1.45	7.5

Table 2. Chemical properties of zeoponix.

N (%)	P (%)	K (%)	Fe P.P.M.	Zn P.P.M.	Cu P.P.M.	Mn P.P.M.	B P.P.M.
2.26	1.05	0.9	850	160.8	40.05	225.2	19.45

This finding might be explained by decreasing the plant-to-plant competition for available water, nutrient and light in zigzag arrangement, more plant production by having more plant density and more frequent nitrogen ion decomposition and release from organic fertilizer can cause better plant performance. From several plant population studies (Goubbels and Dedio, 1990), it was shown that a population of 7.4 plants m^{-2} produced higher yield in sunflower than 5.5 plants m^{-2}. Other researchers demonstrated that as plant population of sunflower is increased from low to high, the flowering stage was delayed, plant height increased, the plants lodged more, and seed size, head and stalk diameter decreased (Vranceanu *et al.*, 1982; Fick *et al.*, 1985).

Table 3. Treatments of planting patterns, number of rows sowing, planting densities (plants m−2), distance between of plant on rows sowing (cm) and between rows (cm).

Between rows (cm)	Distance between plants in rows (cm)	Planting densities (plants m−2)	Number of Rows sowing	Planting patterns
75	44	5	2	Twin rectangular row
75	33	8	2	Twin rectangular row
75	44	5	2	Twin zigzag row
75	33	8	2	Twin zigzag row

Reproductive growth

Seed yield and yield components

There was significant difference in main factors and interaction of planting pattern, plant density and fertilizing system on sunflower seed yield ($P < 0.05$) (Tab. 5). Maximum seed yield was achieved at a zigzag arrangement × plant population of 8 plants m^{-2} × 100% zeoponix (a2d2f1) treatment (Tab. 5). Zarea *et al.* (2005) reported that plant densities, planting patterns and plant densities × planting pattern had a significant effect on sunflower yield. They mentioned that yield tended to increase in twin zigzag rows at the rate of 8 plants m^{-2}. The periods bracketing flowering in sunflower (Chimenti and Hall, 1992; Connor and Sadras, 1992; Cantagallo *et al.*, 1997) are times during the crop cycle that the assimilates which are most critical in yield determination. Sunflower yield increase in response to narrow rows is closely related to the improvement in light interception during the critical period for grain set (Andrade *et al.*, 2002).

Table 4. Means comparison of defined characters by LSD test at the 5% level.

Treatment	Height(cm)	Stalk diameter(cm)	Biologic yield(Kg/ha)
Planting arrangement			
A_1	152.25a	2.47b	17328a
A_2	156.72a	2.88a	17849a
Planting density			
D_1	152.250a	2.47b	24084a
D_2	156.722a	2.88a	11093b
Fertilizing system			
F1	157.333ab	2.89a	19575a
F2	158.250a	2.84a	21880a
F3	147.875b	2.29b	11311b
C.V.(%)	7.64	18.1	29.3
Interaction			
A1D1F1	156.167bcd	2.5bcd	21150bc
A1D1F2	154.833bcd	2.33cd	39029a
A1D1F3	150.167bcd	2.04d	13854cd
A1D2F1	157bc	2.72bcd	10985d
A1D2F2	153.667bcd	3.09abc	10648d
A1D2F3	141.667cd	2.16d	8303d
A2D1F1	136.500d	2.5bcd	33333a
A2D1F2	156.5bc	2.76bcd	24367b
A2D1F3	151.667bcd	2.58bcd	12772cd
A2D2F1	179.667a	3.66a	12833cd
A2D2F2	168ab	3.18ab	13475cd
A2D2F3	148cd	2.4bcd	10313d

Different letter indicate the significant difference ($p \leq 0.05$) among treatments.

Using organic fertilizers provide phosphorus and nitrogen and along with micronutrients for plants. Also, applying the organic manure increase soil organic matter and improve soil conditions for plant growth (Gholamhosseini *et al.*, 2013). Khodami Abasiyeh (2003) showed that use of organic fertilizer increased available phosphorus, potassium, magnesium and sulfur for plant. Moreover, organic fertilizers with improving soil physical properties provided suitable conditions for root development (Oue'draogo *et al.*, 2001). Many researchers have reported that manure application has positive effects on the physicochemical properties of soil and improves crop yields (Basso and Ritchie, 2005; Herenica *et al.*, 2007; Bhattacharyya *et al.*, 2008;). Additionally, it seems that adding zeolite to fresh manure prevents the N loss from the soil due to absorption and subsequent release of the N by the zeolite. In this way, zeoponix can act as a slow-release fertilizer to supply N to the crop gradually.

Gholamhosseini *et al.* (2013) showed that integrated treatments with zeolite increased sunflower yield. It appears the sunflower yield increase for zeoponix treatments resulted from a proper balance between available soil and plant N requirements. In early growth stages, during which the crop nutrition requirements are low, soil N concentrations in the 100% zeoponix and 50%zeoponix+50%chemical fertilizer treatments were lower than in 100% chemical fertilizer treatments, but due to the gradual release of N from zeoponix, N availability lasted longer in those treatments and resulted in higher N availability during the reproductive stage. Reductions in soil bulk density, increased in soil water retention capacity (Gholamhosseini *et al.*, 2013) and enhanced of soil microbial activities (Daryaei *et al.,* 2010) due to application of zeoponix can also account for yield increases.

Number of seed per head and 1000 seed weight

There was significant difference in interaction of planting pattern, plant density and fertilizing system on number of seed per head and 1000 seed weight ($P < 0.05$) (Tab. 5).

Table 5. Means comparison of defined characters by LSD test at the 5% level.

Treatment	Head diameter(cm)	Number of seeds per head	1000 seed weight(g)	Seed yield(Kg/ha)	HI(%)
Planting arrangement					
A_1	18.9b	978.43b	76.354b	3283.6b	24b
A_2	20.3a	1084.59a	90.155a	4193.1a	28a
Planting density					
D_1	17.7000b	980.43b	70.213b	3510.4b	17b
D_2	21.5069a	1082.59a	96.296a	3966.2a	35a
Fertilizing system					
F1	20.5146a	1088.59a	97.220a	4146.9a	26.4a
F2	19.7125ab	1096.38a	78.969b	3841.2a	23.6b
F3	18.5833b	909.57b	73.575b	3226.9b	29a
C.V.(%)	9.77	13.15	9.13	9.99	12.17
Interaction					
A1D1F1	17.767cd	1042.7b	62.620f	3131.0de	14.74d
A1D1F2	17.067d	1052.8b	67.447ef	3372.3de	10.39d
A1D1F3	17.833cd	966.7b	69.667ef	3483.3cde	25.97c
A1D2F1	22.167ab	1041.5b	113.975b	4018.7c	36.58b
A1D2F2	20.583bc	1038.8b	78.810de	3579.0cde	33.71b
A1D2F3	18cd	728.1c	65.607f	2117.0f	25.53c
A2D1F1	17.583cd	860.3bc	79.230de	3961.5cd	11.93d
A2D1F2	17.867cd	1009.4b	71.953ef	3597.7cde	14.72d
A2D1F3	18.083cd	950.7bc	70.362ef	3516.7cde	28.03c
A2D2F1	24.542a	1409.8a	133.053a	5476.3a	42.69a
A2D2F2	23.333ab	1284.6a	97.667c	4815.7b	35.73b
A2D2F3	20.417bc	992.8b	88.667cd	3790.7cd	36.74b

Different letter indicate the significant difference ($p \leq 0.05$) among treatments.

Maximum number of seed per head and 1000 seed weight were achieved at a zigzag arrangement × plant population of 8 plants m^{-2} × 100% zeoponix (a2d2f1) treatment (Tab. 5).

Zarea *et al.* (2005) showed that maximum thousand sunflower seed weight was achieved at a plant population of 6 plants m^{-2} and planting at the higher rate (8 and 10 plants m^{-2}) resulted in reducing thousand seed weight. This result is in inconformity with ur research. It may probably that in plant density more than 8 plant per m^{-2} competition during grain filling is more severe which is caused lighter seeds in comparison to lower plant density. It could be concluded that 8 plant density per m^{-2} is the most appropriate in sunflower cultivation. In our study, decreasing the plant-to-plant competition for available water, nutrient and light increases seed weight and seed number per head in zigzag arrangement, are probably caused this result.

Seed oil and protein yield

There were significant difference in main factors and interaction of planting pattern, plant density and fertilizing system on seed oil content and oil yield, protein content and protein yield ($P < 0.05$) (Tab. 6). Maximum seed oil content and seed oil yield were found in the a2d2f2 and a2d2f1 treatments. These results showed that mixing natural zeolite, with chicken manure carries a negative charge balanced by freely moving cations with positive charges. This provides an ideal trap for cations such as $NH4^{+}$, which are then released when required by plants. Natural zeolite has a very open framework with a network of pores that provide a large surface area for trapping and exchanging valuable nutrients. Therefore, greater frequent N availability appears to have caused an increase in photosynthetic products and consequently seed oil yield. The founding is supported by the result of Gholamhosseini *et al.* (2013). In the other hand, zigzag arrangement and 8 plants m^{-2} cause higher seed oil yield (Tab. 6).

Table 6. Means comparison of defined characters by LSD test at the 5% level.

Treatment	Seed oil content(%)	Seed protein content(%)	Seed oil yield(Kg/ha)	Seed protein yield(Kg/ha)
Planting arrangement				
A_1	47.1974b	18.5978a	1512.78b	615.18b
A_2	47.1974a	18.2100a	1984.62a	762.71a
Planting density				
D_1	45.6900b	16.4206b	1606.30a	577.59b
D_2	47.5413a	20.3872a	1891.10a	800.30a
Fertilizing system				
F1	46.4411ab	17.1308b	1923.26a	726.53a
F2	47.2892a	21.1092a	1825.94a	653.69a
F3	46.1167b	16.9717b	1496.90b	686.61a
C.V.(%)	2.7	10.09	7.69	13.15
Interaction				
A1D1F1	43.063d	1341.0d	13.153d	417.42f
A1D1F2	45.38c	1538.4cd	15.430cd	522.75ef
A1D1F3	46bc	1602.3cd	20.333b	708.33cd
A1D2F1	47.483abc	1907.9b	20.957b	844.68bc
A1D2F2	47.246bc	1691bc	21.523b	770.23bc
A1D2F3	47.031bc	996.1e	20.190bc	427.63f
A2D1F1	46.220bc	1832.2bc	13.503d	531.14ef
A2D1F2	47.010bc	1688.9bc	16.337c	590.88de
A2D1F3	46.467bc	1635bcd	19.767b	695cd
A2D2F1	47.7ab	2612a	20.273b	1112.89a
A2D2F2	49.521a	2385.5a	15.233cd	730.90cd
A2D2F3	46.267bc	1754.2bc	24.147a	915.46b

Different letter indicate the significant difference ($p \leq 0.05$) among treatments.

Robinson *et al.* (1980) reported that equidistant planting patterns cause higher yield and seed oil yield in sunflower. Gubbels and Dedio (1990) reported that with increased planting density, seed oil yield was increased.

Among all treatments, maximum seed protein content were obtained with a2d2f3 (24.147 kg ha^{-1}). However, seed protein yield was higher in a2d2f2 and a2d2f1 treatments. (Tab. 6). Chemical fertilizer urea which was applied during flowering stage, is used for grain filling. Whereas, organic fertilizer decomposition provides nutrients gradually and frequently during plant growth. Absence of soil amendments in sandy soil cause nitrate leaching (Gholamhosseini *et al.*, 2013). In this regard, effect of organic fertilizer application on nitrate leaching has been evaluated by several researchers, Gholamhosseini *et al.* (2013) demonstrated that composted manure+zeolite reduced nitrate leaching. These nutrients is using in plant biomass instruction such as roots, stems and leaves and thus, seed protein content of those sunflowers which was received organic fertilizer and integration of chemical and organic fertilizers, were significantly less than those received sole chemical fertilizer urea. In general, ready to absorb nitrate ions in urea fertilizer are freely mobile in phloem sap and uptake during grain filling and supply as seed protein content. Consequently, it seems that the application of sole chemical fertilizer increased seed protein content because of ready to absorb nitrate ions in urea fertilizer. However, higher number of seed per head and 1000 seed weight of zigzag arrangement × plant population of 8 plants m^{-2} × 100% zeoponix (a2d2f1) treatment compensated the lower protein content in these treatments and therefore protein yield was increased. High protein content in sunflower is negative trait because it causes difficulties in seed oil extraction.

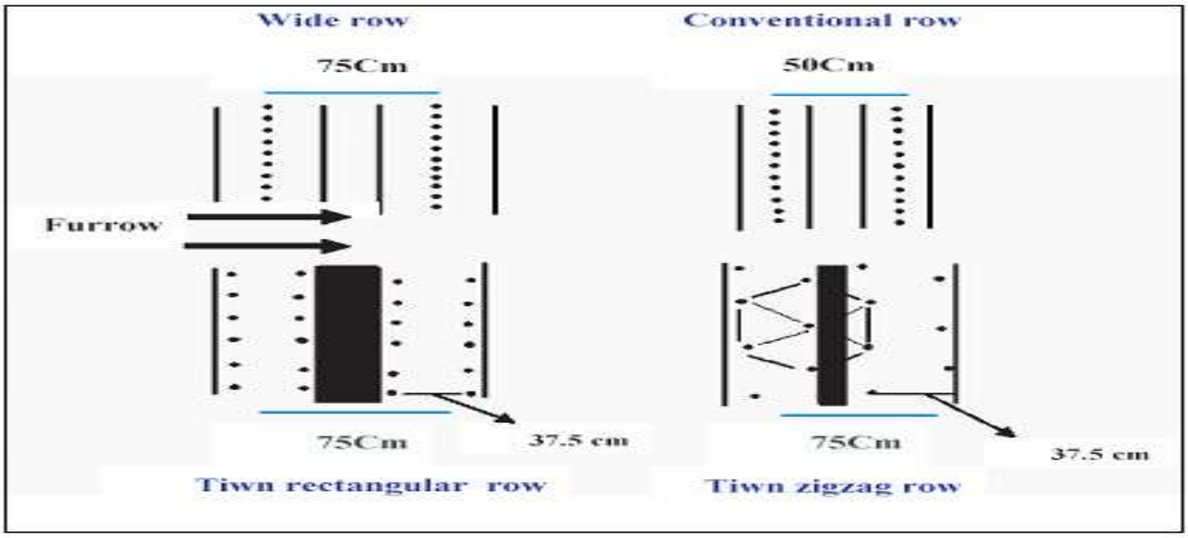

Fig. 1. Schematic shapes of planting patterns which used in experimental treatments**.**

Harvest index

Harvest index (HI) was significantly affected by the main factors and interaction of plant arrangement, plant density and fertilizing system (Table 5). LSD test for means showed that zigzag arrangement × plant population of 8 plants m^{-2} × 100% zeoponix (a2d2f1) treatment had the highest HI (Tab. 5). Reduction of N leaching in the presence of natural zeolite, increases plant-available N and consequently increases N use efficiency. Higher N use efficiency can not only alleviate environmental pollution but also enhance crop yield and harvest index. In addition, in commercial sunflower production, higher plant populations are recommended for sunflower when the grower wants to achieve optimum seed yield performance and harvest index (Sitzer, 2010). In general, the factors increasing the crop productivity, will inhance HI.

Conclusion

On the basis of present findings it is concluded that for obtaining a higher sunflower yield and yield components and oil yield should be sown in zigzag arrangement × plant population of 8 plants m^{-2} × 100% zeoponix (a2d2f1) treatment. The greater light interception and more frequent availability of nutrients in zeolite-based fertilizing treatments led to greater suppression of late-emerging weeds and well-grown sunflowers; therefore, selection of appropriate planting patterns and plant densities along with organic fertilization could be an option for farmers to produce a higher sunflower yield in sustainable agriculture and reduction of chemical fertilizer application which decrease environmental problems.

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