Comparison of Sole and Combined Nutrient Application on Yield and Biochemical Composition of Sunflower under Water Stress

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Abstract

This experiment was conducted to find the influence of organic manure sources and chemical fertilizers alone or in combination on the quality and yield of sunflower and also on the macro nutrients content of seeds under water stress. Three levels of water stress (S_1: full irrigation, S_2: withholding irrigation at flowering stage, and S_3: withholding irrigation at seed filling stage) were randomized to the main plot units and 8 fertilizer treatments (F_1: control, F_2: cattle manure, F_3: sheep manure, F_4: poultry manure, F_5: chemical fertilizer, F_6: 50% cattle manure+50% chemical fertilizer, F_7: 50% sheep manure+50% chemical fertilizer, and F_8: 50% poultry manure+50% chemical fertilizer) were randomized to the subplot units. Obtained results revealed that seed yield decreased significantly due to water stress when imposed at either of the growth stages. Assessment of the qualitative parameters of sunflower seeds showed that water stress caused a marked decrease in oil content and unsaturated fatty acids of oil, however this negative effect was greater in water stress at seed filling stage with respect to water stress at flowering stage. While, protein content increased due to water stress at flowering stage. Results also indicated that drought stress at seed filling stage significantly decreased nutrient content of the seeds, whereas drought stress at flowering stage caused to increase of nutrient uptake. Sunflower plants significantly responded to fertilizer treatments. The seed yield was highest in case of application of manure alone or in combination with chemical fertilizer than in control. Protein and oil percentage were significantly higher in F_3 (sheep manure) and F_6 (50% cattle manure+50% chemical fertilizer), respectively. Compared to control, all fertilization methods generally increased nutrient concentration of sunflower. The highest N content was observed in F_4 and F_6 treatment. Combination of poultry manure and chemical fertilizer (F_8) led to the highest P content and sheep manure application (F_3) resulted to the highest K content than control.

Keywords: Manure, fertilizer, Seed quality, Nutrient uptake, Sunflower.

1. Introduction

Sunflower (*Helianthus annuus* L.) is the fifth most important source of edible oil after soybean, rapeseed, cotton, and peanut, and due to high content of edible oil (38-50%) and protein (40-44%) and its high content of unsaturated fatty acids as well as to the lack of cholesterol has a desirable quality (Razi and Assad, 1998; Abdel-Motagally and Osman, 2010).

The vital role of the sunflower crop depends mainly on the characteristics of the oil produced, which can be used directly or after processing in food and non-food industries (Vermeercsh, 1996). Sunflower is practically free of significant toxic compounds and contains four important fatty acids, namely palmitic (16:0), stearic (18:0), oleic (18:1), and linoleic (18:2) acids that linoleic acid has a relatively high concentration than other fatty acids (Baydar and Erbas, 2005; Seiler, 2007). Environmental factors during the seed-filling period and even during flowering stage can widely affect seed yield and seed quality of oilseed crops (Ali et al., 2009; Monotti, 2003; Petcu et al., 2001a). Between all these environmental factors, drought stress during all growth stages and development is an important limiting factor for plant growth and yield and can influence the quality of sunflower (Flagella et al., 2002).

It has been reported that drought also reduced water absorption and nutrient uptake of plants. Soleimanzadeh et al. (2010) investigated the response of sunflower to drought stress and reported that seed yield and oil yield of this plant significantly decreased due to drought stress. Results of an experiment conducted by Baldini et al. (2000) revealed that drought stress caused a significant reduction of about 15% in the concentration of oleic acid in standard hybrid. Petcu et al. (2001a) examined the response of sunflower hybrids to water stress and reported that drought stress had a significant negative effect on oleic acid concentration so that the reduction was 4 to 14% between sunflower hybrids, In contrast, the linoleic acid concentration increased due to drought stress treatment. Ensiye and Khorshid (2010) studied the response of safflower to irrigation regimes and reported that the oil content and oleic and linoleic acid percentage were reduced by drought stress, significantly. Whereas, Flagella et al. (2000) concluded that stopping irrigation from flowering to physiological maturity increased the percentage of oleic acid in sunflower seeds compared to those irrigated at all growth stages. Ali et al. (2009) stated that the increase or decrease in oil oleic and linoleic acid contents due to water stress when applied at different growth stages could be variety specific. The protein content of crops may be affected by irrigation water availability. Amir et al. (2005) observed that peanut plants received adequate moisture has given highest kernels and total proteins content of seed. Foroud et al. (1993) also reported a decrease in protein content of soybean under moisture stress.

Nowadays increase in the prices of chemical fertilizers, lack of consistency in feeding the soil and endangering human health caused to the increase of the use of manure for soil fertility (Mokhtariniya and Siadat, 2011). Manure can improves soil fertility, increase water-holding capacity, decrease soil erosion, improves amount of oxygen, and promotes beneficial organisms and productivity (Cassman et al., 1995; Hamza and Abd-Elhady, 2010). Aowad et al (2009) investigated the effects of organic and inorganic fertilization on seed and oil yield of sunflower and found that the highest values of seed oil content and oil yield were produced from sunflower plants received the nitrogen fertilizer at the recommended rate (30 kg N/fed) alone or in combination with 20 and 30 m^3 farm yard manure. Organic sources such as animal manure can be an benifical source of major nutrients when applied at optimum rates and can influence the temporal dynamics of nutrient availability (Paul and Beauchamp, 1993) through their effects on physical and chemical properties of the soil. Zamil et al. (2004) compared the effect of different sources of manure with chemical fertilizer on seed yield and nutrient concentration of mustard and concluded that the highest seed yield was obtained from poultry manure and cow manure than control. Also, the highest concentration of nutrients especially N and P was obtained from application of poultry manure.

Adeniyan et al. (2011) investigated the effects of different organic manures and NPK fertilizer for improvement of soil chemical properties and maize traits in two different soils and concluded that application of organic manures enhanced soil organic carbon, total N, available P and exchangeable K better than NPK fertilizer in both soils, however the application of chemical fertilizer achieved the highest amounts of dray mater and yield of maize. The aim of this research was to investigate the effects of different sources of organic manure and chemical fertilizer alone or in combination on yield and seed quality of sunflower as affected by water stress in eastern region of Iran.

2. Materials and methods

This research was conducted out for determining the effects of drought stress with manures and chemical fertilizer on the quantity and quality features of sunflower plants during 2009 cropping season in Gonabad where is the southeast city of Khorasan Razavi Province, Iran on latitude 34^o 21N′ and longitude 58^{o}42′E at an elevation of 1150 meters above sea level with mean annual rainfall of 145 mm. The experiment was laid out in randomized complete plot design with split arrangement with three replications.

Main plot composed of three levels included: S_1 (full irrigation), S_2(withholding irrigation in flowering stage), and S_3(withholding irrigation in seed filling stage) and sub plot composed of eight levels included: F_1 (control), F_2 (cattle manure), F3 (sheep manure), F_4 (poultry manure), F_5 (chemical fertilizer), F_6 (50% cattle manure+50% chemical fertilizer), F_7 (50% sheep manure+50% chemical fertilizer), and F_8 (50% poultry manure+50% chemical fertilizer). Before sowing, a mixed soil sample composed of different locations of the field prepared and transferred to the laboratory for physical and chemical analysis. The soil characteristics of the experimental field are given in Table 1. Based on soil test, nitrogen (as urea), phosphorus (as triple super phosphate) and potassium (as potassium sulfate) at the rate of 220, 150 and 100 kg ha^{-1} were applied in recommended chemical fertilizer treatment, respectively. All organic manures (cattle manure, sheep manure, and poultry manure at the rate of 30, 20 and 10 ton ha^{-1}, respectively) were added before sowing, while PK and 1/2 N fertilizer also applied as at the time of sowing and remaining N as top dressing was applied At 6 leaf stage. Seeds were sown in 10^{th} May, 2009 and the planting density was approximately 77000 plant ha^{-1} in rows 65 cm apart. Planting was done by dibbling and placing 3 seeds per hill at 20 cm distance from each other.

At 3-4 leaf stage, one plant per hill was maintained through thinning in order to achieve proper plant population. During growing season, two hoeing were done for weeds control. Irrigation in full irrigation treatment was regularly carried out at 7 days interval. In water stress treatments, sunflower plants were not irrigated temporary for seven days interval.

At harvesting time (16^{th} September, 2009), heads of the two inner ridges of each plot were harvested and left 10 days until fully air dried by sunshine and then, seed yield was estimated. Seed protein content was determined by measuring the nitrogen content with the Micro-kjeldhal method and multiplying it by 6.25 to express to total protein content (Bremner, 1996). Seed oil content was determined according to A.O.A.C. (1990) using soxhlet apparatus and diethyl ether as a solvent. The composition of fatty acids was determined using gas chromatography according to A.O.A.C. (1990) and expressed as a percentage of the total fatty acid content. Also, phosphorus content was determined by colorimetric method (A.O.A.C, 1990) and potassium content was analyzed by Flame-photometer (Chapman and Pratt, 1978).

Finally, all data were subjected to analysis of variance using SAS program (SAS Institute, 2002) and wherever appropriate, the mean values were compared according to Duncan's multiple range test at 5% probability level.

3. *Results and discussion*

3.1. Seed yield

There was a significant negative effect of water stress on the seed yield of sunflower at the 1% level of probability (Table 2). Means comparison of obtained date revealed that the highest amount (3872 kg ha^{-1}) was observed in plants normally irrigated at whole growing season, while the lowest values were obtained in plants that were not received enough irrigation water at flowering stage (3391 kg ha^{-1}) and seed filling stage (3375 kg ha^{-1}), so that least treatments did not differ significantly from each other with respect to this parameter (Table 2). Data presented in Table 2 show that the difference between different fertilizer treatments in respect to seed yield of sunflower was statically significant. Results of the comparison of treatments' means presented in Table 3 show that application of cattle manure alone (F_2 treatment) resulted to maximum seed yield (3752 kg ha^{-1}) which was statistically equal to that of F_4 (poultry manure alone) and F_6 (50% cattle manure+50% chemical fertilizer) treatments giving seed yields of 3744 kg ha^{-1} and 3738 kg ha^{-1}, respectively. The lowest seed yield (2942 kg ha^{-1}) was related to sunflower plants was not received manure and chemical fertilizer (control). Similarly, Saeed et al. (2002) reported that fertilization with organic manure alone or in combination with chemical fertilizers significantly increased the seed yield of sunflower as compared to no fertilization.

3.2. Seed protein content

Highly significant differences ($P \leq 0.01$) were observed among water stress treatments with respect to seed protein content (Table 2). The comparison of treatments' means (Figure 1) indicates that irrigation missing at flowering stage significantly enhanced protein percentage of sunflower than other treatments, so that plants treated with this treatment had the highest value (21.9%). Our results are in agreement with the findings of Ahmad et al. (2009) who reported that seed protein content of sunflower was significantly higher in irrigation missing at flowering stage than in control, when crop was given normal irrigations.Results obtained from the variance analysis show that fertilizer treatments have a significant effect in the case of protein content (Table 2).

Among all treatments, the maximum value (22.7%) related to F_3 treatment (100% sheep manure) and the minimum amount (19%) related to control (Figure 2). Results are in line with the findings of Nanjundappa et al. (2001) who reported an increase in seed protein content of sunflower due to application of organic sources.

3.3. Seed oil content

Data (Table 2) showed that water stress and different organic and inorganic fertilizers had significant effects on the oil content of sunflower. There was a significant negative effect of drought stress at seed filling stage on this trait. The highest oil content (39.2%) was recorded in plants that not exposed to drought stress which was statistically at par with plants that exposed to drought at flowering stage (38.7%). The lowest oil content (37.4%) was related to water stress at seed filling stage (Figure 1). The low oil content may be due to the short seed filling stage caused by the temporary irrigation missing during this period. Iqbal et al. (2005) examined the effect of water stress on sunflower lines and concluded that drought stress in reproductive stage reduced 4 and 7% achene oil content of Suncross and Gulshan-98 lines compared to control, respectively.

As shown in Figure 2, seed oil differed among fertilizer treatments. Sunflower plants which fertilized with 50% cattle manure and 50% chemical fertilizer had the highest oil content (39.7%) and plants fertilized with chemical fertilizer alone had the lowest value (37.2%). Such results may be due to the adverse effect of nitrogen on oil content, is offset by an increase in protein content (Munir et al., 2007). The physiological reason for this negative correlation is related to the competition for carbon skeletons during carbohydrate metabolism (Rathke et al., 2005). Bakht et al. (2010) reported that seed oil of sunflower decreased with an increase in the rate of NP fertilizers.

3.4. Unsaturated fatty acids

Analysis of variance (ANOVA) for fatty acid composition showed a significant effect of water stress treatments on linoleic acid of sunflower seeds (Table 2). As shown in Table 3, water stress significantly decreased the content of linoleic, so that the highest value was observed in unstressed plants and the lowest amount was recorded from plants stressed at seed filling stage (S_3 treatment). Petcu et al. (2001a) investigated the effect of water stress on sunflower hybrids in Romania and concluded that water stress at flowering stage negatively affected the content of linoleic acid of seeds compared to control.

Data (Table 2) showed that different organic and inorganic fertilizers had a significant effect on linoleic acid of sunflower. Data on Table 3 illustrate that application of organic manure increased the content of linoleic acid where the maximum value was found in F_4 (100% poultry manure) and minimum value was observed in no fertilization treatment. Munir et al. (2007) observed that the highest amount of linoleic acid in sunflower was recorded from combination of poultry manure and NPK fertilizer.

An analysis of variance showed that Table 2). Oleic acid decreased significantly due to the imposition of water stress and highest decrease drought stress imposed at reproductive stage had a significant effect on oleic acid content (in this fatty acid was observed when water stress was applied at seed filling stage. Petcu et al. (2001b) investigated the effects of drought stress on some characteristics of five Romanian sunflower hybrids and found a significant negative effect of drought on the oleic acid concentration in all tested sunflower hybrids.

In this investigation, it could be concluded that oleic acid content significantly responded to organic and inorganic fertilizers as well as their combination (Table 2). Means comparison showed that among all treatments, the best result was obtained when F_2 treatment (cattle manure) was applied. The lowest amount also was obtained from without fertilizer (Table 3). Akbari et al. (2011) reported that oleic acid content of sunflower seeds was higher due to application of manure alone than its combination with chemical fertilizer or control.

3.5. Nutrient uptake

Results obtained from the variance analysis showed that nitrogen concentration of sunflower seeds influenced by water stress significantly at 0.01 level of probability (Table 2). Data presented in Table 3 reveal that sunflower plants that was not stressed and those stressed at flowering stage had the higher seed nitrogen content than plants stressed at seed filling stage. This event may be due to faster translocation of N-compounds to seeds due to water deficit condition in flowering stage (Gholamhoseini et al., 2008). As shown in Table 2, application of different manures and chemical fertilizer had significant effects on N contents of the seeds. Comparison of means clarify that F_4 and F_6 treatments increased nitrogen content more than other treatments compared to control (Table 3).

According to the analysis of variance results (Table 2) seed phosphorus content significantly influenced by drought, in such a manner means comparisons showed that sunflower plants stressed at flowering stage had more P content than other treatments (Table 3). Higher P content of corn seeds due to drought stress than normal irrigation has been reported by Rafiee et al. (2004).

The result showed that different methods of soil fertility had a significant effect on seed phosphorus content of sunflower seeds (Table 2). Means comparisons specified that combined application of poultry manure and chemical fertilizer resulted to the highest P concentration in the seeds and no fertilization achieved the lowest value (Table 3). Superior effect of combined fertilization in balanced nutrient supply and improved soil fertility and nutrient uptake over application of inorganic or organic source alone have been reported by Ayeni and Adetunji (2010).

There was a significant effect of water stress treatments on potassium content of the seeds (Table 2). Obtained results showed that drought stress in flowering stage induced an increase of K concentration of seeds than other treatments, however, the difference between it and full irrigation was not statically significant (Table 3). Potassium accumulation could be caused to increase the tolerance to water stress in plant (Kidambi et al., 1990). Zhao (2000) stated that by increasing drought stress the potassium concentration on shoot increased. He suggested that the reason of increase of potassium concentration may be due to its important role in osmotic adjustment in plant organs.

Table 2 indicates that potassium concentration of seeds influenced by manure and fertilizer application significantly ($P \leq 0.05$). Plots amended with sheep manure had significantly highest seed potassium content than plots without fertilizer application (Table 3).

Table 1. Mechanical and chemical properties of soil in the experimental field.

Depth (cm)	Soil texture	ECe (dS/m)	pH	O.C (%)	N (%)	P (mg/kg)	K (mg/kg)
0-30	Clay loam	3.4	7.8	0.6	0.05	3.5	147

Table 2. Effects of water stress and fertilizer on quantitative and qualitative traits of sunflower

Source of variance	df	Seed yield	Protein content	Oil content	Linoleic acid	Oleic acid	N content	P content	K content
Block	2	7945.09**	8.01ns	2.86ns	8.21ns	1.56ns	0.12ns	7312.3ns	1073.0ns
Water Stress	2	1258317.0**	22.93**	20.22**	58.04**	8.75**	0.87**	26045.9**	38141**
Error a	4	64812.8	20.22	7.54	10.74	1.88	0.63	4801.2	11580
Fertilizer	7	641319.0**	9.45*	4.62*	10.51*	2.78*	0.16*	8064.9*	4220.1*
Interaction	14	74272.6ns	3.40ns	6.15ns	5.10ns	1.32ns	0.12ns	3660.5ns	3078.9ns
Error b	42	78808.6	4.30	2.10	188.5	0.95	0.07	3630.3	1929.5
CV (%)		7.98	9.86	3.75	3.20	8.06	12.19	8.07	7.39

Ns= Non significant; * and ** = Significant at 5% and 1% probability, respectively.

Table 3. Effect of water stress and fertilization on measured parameters of sunflower.

Treatment	Levels	Seed yield (kg/ha)	Linoleic acid (%)	Oleic acid (%)	N content (mg/100 g)	P content (mg/100 g)	K content (mg/100 g)
	S_1	3872a	67.31a	12.53a	2.29a	757.9ab	614.3a
Water stress	S_2	3391b	66.62ab	12.36ab	2.32a	771.5a	619.6a
	S_3	3375b	64.34b	11.41b	1.98b	708.9b	548.1b
	F_1	2942c	64.33c	10.98c	1.97c	694.7c	558.3c
	F_2	3752a	66.30abc	12.96a	2.16abc	731.3bc	585.2bc
	F_3	3446b	66.55ab	12.26ab	2.27ab	782.7ab	629.7a
	F_4	3744a	67.78a	12.17ab	2.33a	738.8abc	603.5ab
Fertilization	F_5	3486ab	65.00c	12.08ab	2.20abc	750.5abc	613.6ab
	F_6	3738a	65.77abc	12.07ab	2.40a	740.1abc	588.5abc
	F_7	3523ab	66.12abc	11.87bc	2.07bc	740.5abc	582.4bc
	F_8	3495ab	66.90ab	12.41ab	2.18abc	790.1a	590.5abc

Means within a column for each variable followed by the same letter are not significantly different (P =0.05).

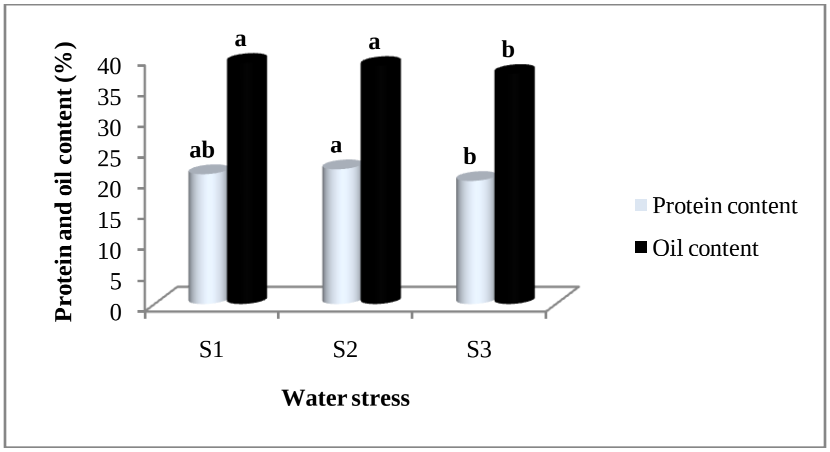

Figure 1. Effect of water stress on protein and oil content of sunflower seed.

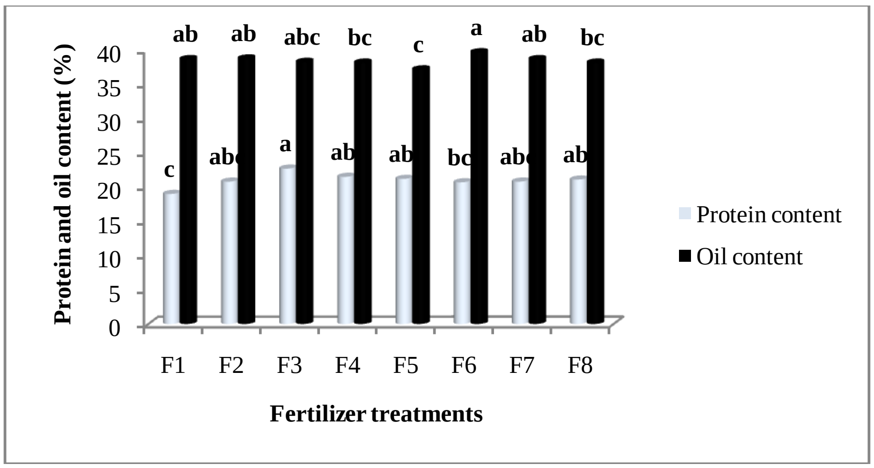

Figure 1. Effect of manure and chemical fertilizer on protein and oil content of sunflower seed.

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