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Effects of water deficit and nitrogen levels on grain yield and oil and protein contents of maize

Kazem Ghassemi-Golezani[1*], Nasrin Raei[1] and Yaegoob Raei[1]

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ABSTRACT

This research was conducted in 2014, to evaluate the effects of water deficit and nitrogen fertilizer on grain yield, oil and protein contents of maize (cv. double Cross 303). The experiment was arranged as split-plot based on Randomized Complete Block design (RCB) with three replications. Irrigation treatments (irrigation after 60, 90, 120 and 150 mm evaporation) and nitrogen levels (0, 46 and 92 kg N/ha) were located in the main and sub plots, respectively. Mean grain yield per unit area decreased with decreasing water availability, but it was improved with increasing nitrogen fertilizer. Grain oil percentage significantly decreased, but protein percentage slightly increased as a result of water deficit. In general, oil and protein yields significantly decreased under moderate and severe water stress, mainly because of decreasing grain yield under these conditions. Nitrogen application decreased oil percentage, but increased protein percentage significantly. Nevertheless, nitrogen fertilizer enhanced oil and protein yields per unit area, with no significant difference between nitrogen rates. These results were positively related with grain yield per unit area in maize.

INTRODUCTION

Water and nitrogen are the most limiting factors in agricultural production in most parts of the world, especially in arid and semiarid areas (Cassman and Sheehy 2001). Water deficiency occurs when water potentials are sufficiently negative to reduce water availability to sub-optimal levels for plant growth and development (Boyer 1982). When the full crop requirements are not met, water deficit in the plant can develop to a point where crop growth and yield are affected. Water stress during vegetative stages has the greatest impact on plant height and biomass (Ghassemi-Golezani et al. 2008). Water limitation may lead to physiological disorders such as reductions in photosynthesis and transpiration (Sarker et al. 2005; Petropoulos et al. 2008).

Drought stress severely limits growth and development of plants by affecting different metabolic processes such as CO_2 assimilation and oil and protein synthesis (Nasirkhan et al. 2007). Esmaeilian et al. (2012) reported that water stress at grain filling stage of sunflower caused a decrease in oil content. The decrease in seed oil content of oilseed crops under water stress is a common phenomenon (Ali et al. 2009). Henry and MacDonald (1978) showed that severe drought decreased oil and increased protein contents of rapeseed. Hobbs and Muendel (1983) also reported that drought stress increases protein content in soybean.

Plant nutrition is one of the most important factors that increases plant production. Nitrogen is most recognized in plants for its presence in the structure of the proteins (Fretz 1976). Jackson (2000) found that the relationship between total plant yield and N reflects the tendency of canola to exhibit an indeterminate growth habit when nutrients and water were essentially unlimited. He obtained optimal oil yield in the same range as seed yield, even though a negative relationship exists between oil content and increased N levels. Under dry land conditions, soil moisture often limits yield. Increasing moisture supply increases the yield potential of the crop and enhances the amount of N required for optimum yield (Grant and Bailey 1993).

[1-] Department of Plant Eco-physiology, Faculty of Agriculture, University of Tabriz, Tabriz, Iran.
*Email: golezani@gmail.com

Water deficit can reduce the yield of maize in the field (Ghassemi-Golezani et al. 1997). In a study on the effect of drought stress at different growth stages of maize, Abdelmula and Ebrahim-sabile (2007) found that the stress at reproductive stage had the most decreasing effect on yield. It is also known that without N, the maize kernel cannot develop properly (Uhart and Andrade 1995). The protein content and the grain yield increases as the N uptake by maize grain enhances (Gallais and Hirel 2004). However, the interaction of water and nitrogen supply on oil and protein yield of maize is not well documented, so this research was aimed to investigate that subject properly.

MATERIALS AND METHODS

A field experiment was conducted in 2014 at the Research Farm of the Faculty of Agriculture, University of Tabriz, Iran (38°5N, 46°E). The area is located at an altitude of 1360 m with the mean annual rainfall of 285 mm. Seeds of maize (*Zea mays* L., cv. Double-Cross 303) were hand sown in about 4 cm depth of a sandy-loam soil with a density of 10 seeds/m^2 on 3rd may 2014. Each plot consisted of 9 rows with 2.5 m length, spaced 25 cm apart. The experiment was arranged as split plot on the basis of randomized complete block design with three replicates. The factors were irrigation at four levels (irrigation after 60 (I_1), 90 (I_2), 120 (I_3) and 150 (I_4) mm evaporation from class A pan) in main plots and N fertilizer (urea) at three levels of 0, 46 and 92 kg N/ha in sub-plots. Weeds were controlled by hand during crop growth and development.

At maturity, plants in 1 m^2 of each plot were harvested and grain yield per unit area was determined. Percentages of protein and oil for each sample were measured, using a seed analyzer (model: Zeltex ZX-50) and then protein and oil yields per unit area was calculated.

The data were analyzed by MSTAT-C soft-ware and the figures were drawn by the Excel software. Means of the traits were compared by Duncan multiple range test at $p \leq 0.05$.

RESULTS AND DISCUSSION

Analyses of variance of the data showed significant effects of irrigation ($p \leq 0.01$) and nitrogen ($p \leq 0.05$) levels on grain yield, oil percentage and yield. Protein percentage was only affected by nitrogen levels, but protein yield was significantly influenced by both irrigation treatments and nitrogen fertilizer ($p \leq 0.01$). The interaction of irrigation × nitrogen was not significant for grain yield and oil and protein percentages and yields ($p \leq 0.05$).

Grain yield

Grain yield is the main target of crop production. Mean grain yield per unit area under I_1 was higher than that under limited irrigation conditions. Grain yield decreased as water availability decreased (Table 1). Water deficit affects every aspect of plant growth and modifying the anatomy, morphology, physiology, biochemistry and finally the productivity of crop (Jones et al. 2003; Hafiz et al. 2004). Grant et al. (1989) stated that water deficit severely decreased yield through abnormal development of embryo sac and grain sterility and finally it decreased fertile grain number in canola. Hammad et al. (2011) found that N deficiency decreased grain yield of maize by decreasing seed number per ear and seed weight.

Grain yield per unit area increased with increasing nitrogen supply (Table 1). Similarly, Bundy and Carter (1988) reported that grain yield of maize increased as nitrogen supply enhanced. Qayyum et al. (1998) found that canola grain yield increased significantly when N rate was increased from 0 to 180 kg/ha. Moreover, Cheema et al. (2001) reported that the seed yield of canola increased as N application rate increased from 0 to 90 kg/ha.

Oil percentage and yield

Oil percentage decreased as water stress increased. Maximum percentage of oil was obtained under well watering (I_1). Seed oil percentage under severe water limitation (I_4) was considerably lower than that under other irrigation treatments. Percentages of oil in grains produced under I_2 and I_3 were statistically similar. Oil percentage slightly decreased by application of nitrogen, due to increasing grain yield (Table 1). The low oil percentage due to water deficit may be resulted from the short grain filling duration (Ghassemi-Golezani and Lotfi 2013).

Oil yield per unit area considerably decreased under moderate and severe water stress (I_3 and I_4), mainly because of decreasing grain yield under these conditions. However, oil yield increased with increasing nitrogen rates. This was also closely related with improving grain yield per unit area due to nitrogen supply (Table 1). It was also reported that water limitation significantly decreases seed and oil yields of sunflower (Soleimanzadeh et al. 2010) and maize (Ghassemi-Golezani et al. 2011).

Protein percentage and yield

Although protein percentage slightly increased under limited irrigations, the difference was not statistically significant. Nitrogen supply enhanced protein percentage, with no significant difference between nitrogen rates (Table 1). Nelson et al. (2009) observed that the protein content in maize

Table 1. Means of grain yield and oil and protein contents of maize under different irrigation and nitrogen levels

Treatments	Grain yield (g/m^2)	Oil (%)	Oil yield (g/m^2)	Protein (%)	Protein yield (g/m^2)
Irrigation					
I_1	609.40 a	6.04 a	36.81 a	7.83 a	47.72 a
I_2	578.32 a	5.39 b	31.17 a	8.14 a	47.08 a
I_3	279.83 b	5.45 b	15.28 b	8.47 a	23.70 b
I_4	188.30 b	5.11 c	9.62 b	8.31 a	16.33 b
Nitrogen					
N_1	319.60 b	5.80 a	18.54 b	7.53 b	24.07 b
N_2	416.64 ab	5.49 b	22.87 ab	8.37 a	34.87 a
N_3	505.82 a	5.19 b	26.25 a	8.67 a	43.85 a

I_1, I_2, I_3 and I_4: Irrigation after 60, 90, 120 and 150 mm evaporation, respectively. N_1, N_2 and N_3: 0, 46 and 92 Kg/ha N, respectively.

grain ranged from 6% to 9%. Thompson (1978) also found little effect of water stress on seed protein content in soybean. As nitrogen is the major constituent of protein, increasing N application frequently led to an increase in protein content of oilseed crops (Brennan and Bolland 2007; Malhi and Gill 2007). The nitrogen application to sesame has been also reported to increase protein content (Malik et al. 1990; Sharar et al. 2000). It was suggested that the high N rate increases the amino acids synthesis in the leaves and this stimulate the accumulation of protein in the seeds (Patil et al. 1997).

Protein yield per unit area under I_1 and I_2 was significantly higher than that under I_3 and I_4. The highest protein yield was recorded for the highest nitrogen supply. These results strongly related with grain yield per unit area. In other words, protein yield increased with increasing grain yield per unit area (Table 1). Reduction in protein and oil yields per unit area with increasing the severity of water stress could be attributed to sharp decline in grain yield per unit area under stressful condition (Ghassemi-Golezani and Lotfi 2013). Therefore, sufficient nitrogen supply can considerably enhance protein yield via improving protein percentage and grain yield of maize under full and limited irrigation conditions.

CONCLUSION

Mean grain yield of maize improved with increasing nitrogen application, but it was decreased with decreasing water supply. Water stress caused a significant reduction in oil percentage and a slight enhancement in protein percentage of grains. Decreasing grain yield per unit area due to moderate and severe water deficit led to significant reduction in oil and protein yields under these conditions. Oil percentage decreased, but oil yield per unit area increased as a result of nitrogen fertilizer. Nitrogen application also enhanced protein percentage and yield, with no significant difference between nitrogen rates. Therefore, sufficient nitrogen supply can considerably improve oil and protein yields via increasing grain yield of maize under full and limited irrigation conditions.

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