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Optimization of Irrigation and Nitrogen Regimes for Rapeseed Production Under Drought Stress

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Abstract: In order to optimization of irrigation and nitrogen management for rapeseed (*Brassica napus* L. cv. Hyola 401) production at terminal drought stress, an experiment was conducted in a split plot at base of RCB design with four replications in experimental field of Agricultural and Natural Resource University of Ramin during 2005-2007. Irrigation management at three levels: without stress, moderate and severe water stress established as main plots and four N fertilizer rates: 90, 140, 190 and 240 kg N ha^{-1} were consider as sub plots. The results showed that rapeseed oil and grain yield was affected by terminal drought stress severely. Moderate and severe drought stress reduced grain yield by 14.5 and 32% compared to no stress condition, respectively. With increasing of N rate the number of branches, pod m^{-2} and 1000-seed weight and consequently seed yield was increased significantly. Seed oil content adverse to seed protein content with increasing the severity of drought stress was decreased. Increase in nitrogen led to increase in protein content, but oil content was decreased. Highest seed and oil yield (3996.3 and 1803.9 kg ha^{-1}, respectively) with 190 kg N ha^{-1} at no stress condition was obtained. According to these results for maximize production of rapeseed in this region and probably in similar conditions full irrigation and application of 190 kg N ha^{-1} (with respect to soil analyze) was recommended.

Key words: *Brassica napus*, seed quality, yield and yield components

INTRODUCTION

Rapeseed (*Brassica napus* L.) is the third most important source of plant oil in the world after soybean (*Glycine max* L.) and palm oil (Sovero, 1993). Presently, over than 85-90% of vegetable oil consumed in Iran is imported from abroad (Pourdad and Beg, 2007). There are agricultural opportunities to increase rapeseed (*Brassica napus* L.) production and the expansion of rapeseed (*Brassica napus* L.) in Iran has been dramatic. It has the potential to grow in Khuzestan Province (Southwestern of Iran) (Danesh-Shahraki *et al*., 2007). However, the reproductive growth of rapeseed is exposed to low rainfall and drought stress in this region. Water stress during the flowering stage has a severe impact both in seed yield and seed oil content (Champolivier and Merrien, 1996; Hashem *et al*., 1998; Ghobadi *et al*., 2006). Therefore, in seasons, with low or no rainfall at all, the crop needs to be supported by irrigation. However, the availability of water for irrigation is becoming scarce due to low rainfall as well as an increase in the demand of water for all industrial, domestic, municipal and other activities. So, any good irrigation management is required to get promising yield with good water use efficiency. The aim of irrigation water management is to know how much and when to apply water to the crop. Veihmeyer and Hendrickson (1927) forwarded the concept that soil water, which is held in the range of field capacity to permanent wilting point, is equally available to plants. However, Richards and Wadleigh (1952) showed that the availability of soil water to plants decreases with decreasing soil water content ahead of the soils permanent wilting point and at the same time, this can result in water stress and growth hindrance to a greater or lesser extent. This variability of the availability of soil water with variation in the soil water content shows the necessity for irrigation water management, to make the best use of water to attain an optimal yield. The presence of sufficient soil water enhances root growth and leaf area. It helps plants keep their leaves for a longer time, lengthen the flowering

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period and improves the proliferation of branches for each plant and at the same time it increases the number of flower forming pods, seeds per pod, seed mass and seed yield (Mondul and Paul, 1995; Banuelos *et al*., 2002).

Soil fertility improves the water use efficiency of plants (Caviglia and Sadras, 2001; Buttar *et al*., 2006). Plants grown on fertile soils use water efficiently and as a result they produce a deep and large root system (Caviglia and Sadras, 2001). Gabrielle *et al*. (1998) elaborated on the effect of nitrogen fertilizer application timing and amount for rapeseed (*Brassica napus* L.) as follows: rapeseed has a long growth cycle with large fertilizer requirements, compared to other winter crops such as winter wheat (*Triticum aestivum* L.). This long growth cycle exposes the available N in the soil profile to a greater risk of loss, if applied only at planting. Rapeseed production management including nitrogen application rate, might be different under various moisture conditions. According to Andersen *et al*. (1996) optimal rapeseed seed yield could be harvested if sufficient water is accompanied by proper nitrogen fertilization. The objective of this study was optimization of irrigation and nitrogen management for production of rapeseed in arid and semiarid regions of Khuzestan where the reproductive growth of plant is exposed to drought stress.

MATERIALS AND METHODS

A 2 year field experiment was conducted at the Agronomic Research Area, College of Agricultural and Natural Resource University of Ramin (31°36' N, 48°53 'E), Mollasani, Ahvaz, Iran during 2005-2007. This area is situated at an elevation of 50 m above see level. Temperature and rainfall data during the crop-growing period was collected from a weather station that was 0.5 km from the experimental site and presented in Table 1. The soil at the experimental site (0-30 cm soil layer) was silty clay. Summary of soil characteristics of experimental field is presented in Table 2. The earlier crop in 2005-6 and 2006-7 was wheat. The experiment, split plot at base of randomized complete block design (RCB) with four replications, was conducted at two years. Irrigation regimes at three levels: without stress (S_1), moderate (S_2) and severe (S_3) water stress (irrigation after depletion of 25, 50 and 75% field capacity (FC) established as main-plots and four N fertilizer rates: 90, 140, 190 and 240 kg N ha^{-1} were considered as sub-plots. FC was measured by pressure plate (Tan, 2005). Drought stress treatment was implement from flowering stage and continued after maturity (Ghobadi *et al*., 2006). The area of each sub-plot was 10 m^2 consisting of 8 rows, 4 m long and 30 cm apart. Two and 1 m alleys were left around each main and sub plots, respectively to avoid plot to plot water and N contamination during irrigations. Nitrogen was applied as split in two applications; one third with sowing (on 22 Nov. 2005 and 20 Nov. 2006) and the remaining at the beginning of stem elongation (on 5 Jan. 2005 and 7 Jan. 2006). N fertilizer applied as urea form. All plots received P: K fertilizers in the rates of 60:50 kg ha^{-1} at sowing. Cultivar (*Brassica napus* L var. Hyola 401) was sowing at a 20 mm seeding depth on 22 November 2005 and 20 November 2006. Plots were thinned to final plant density of about 100 plants m^2 at seedling stage. Weeds were controlled by hand or mechanically as needed. Seed yields were taken at maturity by harvesting the 1.8 m^2 area of the two inner rows of each plot at the end of April. Seed yield was adjusted to a 10.0% moisture basis. Ten plants were collected randomly from the central two rows and the following growth and yield component variables were recorded for each plot; plant height, number of branches per plant, pod number per plant and 1000-seed weight. Seed oil content was determined with the Soxholet apparatus and seed N concentration by micro-Kjeldahl method (Gupta, 2004). All data were analyzed with the GLM procedure using the SAS statistical software package. Means were compared using Duncan's Multiple Range test at 5% probability level (Mead *et al*., 2003).

Table 1: Monthly agrometeorological data of the experimental site during the growing season*

Year and month	$T_{min.}$ (°C)	$T_{max.}$ (°C)	Rainfall (mm)	Evaporation (mm)
2005-6				
Nov.	8.0	28.4	15.2	153.4
Dec.	6.3	25.0	26.8	71.2
Jan.	5.3	18.2	55.3	61.7
Feb.	7.8	18.8	140.1	51.2
Mar.	7.1	24.8	2.0	101.9
Apr.	12.3	29.4	14.3	155.3
2006-7				
Nov.	14.0	29.2	24.9	127.9
Dec.	5.2	18.0	66.0	62.8
Jan.	3.0	13.7	31.3	31.7
Feb.	6.7	19.4	31.2	64.1
Mar.	9.5	22.8	6.8	73.5
Apr.	14.1	27.3	54.7	127.7

*Source: Climatic reports of climatology station of Agricultural and Natural Resource University of Ramin, Mollasani, Ahvaz, Iran

Table 2: Summary of soil characteristics of experimental field*

Year	Depth (cm)	pH	EC (dS m^{-1})	Total N (%)	Available P (mg kg^{-1})	Available K (mg kg^{-1})	Bulk density (Mg m^{-3})
2005	0-30	7.7	2.1	0.07	9.1	181	1.34
	30-60	7.8	1.3	0.03	6.8	125	1.37
2006	0-30	7.0	2.6	0.05	9.2	183	1.31
	30-60	7.5	1.8	0.03	6.7	120	1.38

*pH (saturated paste), EC (saturated extract), Total N (Kjeldahl), Available P (Olsen), Available K (exchangeable) according to Tan (2005)

RESULTS AND DISCUSSION

Monthly temperature and precipitation values during the study period were given in Table 1. The 2005-2006 growing season was warmer and wetter than 2006-2007, so, the effect of year on some characters such as number of pod m^{-2}, seed and oil yield was significant (Table 3). The study showed that all of the characters were affected by different levels of irrigation regimes and nitrogen rates. Highest seed yield (3563.2 kg ha^{-1}) was taken from the treatments with no water stress. Moderate and severe drought stress, compared to no stress conditions, reduced the grain yield by 14.5 and 32%, respectively. Water stress during the flowering stage resulted in the decline of LAI and LAD (due to wilting and rapid senescing of leaves) followed by abortion and dropping of flowers, as well as pods (Gunasekara *et al*., 2003). Therefore, it is of great importance to supply the plant with sufficient water during the sensitive stages of growth (mainly flowering and to some extent seed filling). In this study, lower seed yield in treatments with stress during the flowering stage was due to significant reduction in number of branches, seed weight and especially number of pods m^{-2} (Table 4). Number of pods is commonly a major determinant of rapeseed yield (Ozer, 2003). Reduction of these two yield component (1000-seed weight and No. of pods m^{-2}) followed by increasing the No. of seeds per pod as third yield component. This negative correlation is consistent with those reported by Angadi *et al*. (2003). Reduction of harvest index (HI) with increasing the severity of drought stress (Table 4) showed that limiting effect of terminal drought stress on seed yield compared to biological yield was greater. These results are consistent with those reported by Setter (1990) and Wright *et al*. (1995).

the seed yield increased with increasing the N rate up to 190 kg N ha^{-1} (N_3), significantly (Table 4). The next highest rate (N_4) had no significant increasing effect

Table 3: Results of the analysis of variance for seed yield (SY), harvest index (HI), number of branches (NB), number of pods per m^2 (NP), number of seeds per pod (SP), 1000-seed weight (SW), oil yield (OY), oil content (OC) and protein content (PC)

Source of variation	df[a]	SY	HI	NB	NP	SP	SW	OY	OC	PC
Year (Y)	1	*	ns	ns	**	ns	ns	**	ns	**
Error 1	6	-	-	-	-	-	-	-	-	-
Drought stress (S)	2	**	**	**	**	*	**	**	**	*
Y*S	2	ns	ns	ns	ns	ns	ns	ns	ns	ns
Error 2	12	-	-	-	-	-	-	-	-	-
Nitrogen (N)	3	**	**	**	**	*	**	**	**	**
Y*N	3	ns	ns	ns	ns	ns	ns	ns	ns	ns
S*N	6	**	**	*	**	*	**	**	n.s	*
Y*S*N	6	ns	ns	ns	ns	ns	ns	ns	ns	ns
Error 3	54	-	-	-	-	-	-	-	-	-

*, ** and [ns]significant at the 5 and 1% and non-significant, respectively [a]Degree of freedom

Table 4: Mean value comparisons of the seed yield (SY), harvest index (HI), number of branches (NB), number of pods m^{-2} (NP), number of seeds per pod (SP), 1000-seed weight (SW), oil yield (OY), oil content (OC) and protein content (PC)

Treatments	SY (kg ha^{-1})	HI (%)	NB	NP	SP	SW (g)	OY (kg ha^{-1})	OC (%)	PC (%)
Irrigation management									
S_1	3563.2a	30.7a	9.16a	4746.8a	22.9b	3.27a	1621.1a	45.6a	21.8b
S_2	3045.8b	29.1b	8.18ab	4194.3b	23.9ab	3.06ab	1366.4b	45.0ab	22.5ab
S_3	2418.5c	27.8c	6.55b	3425.6c	24.3a	2.90b	1058.2c	43.8b	22.7a
Nitrogen rate									
N_1	2432.2c	27.5d	5.12c	3430.8c	24.7a	2.88c	1126.8c	46.2a	20.3c
N_2	2920.4b	29.4c	7.94b	3986.1b	24.1ab	3.05b	1314.8b	44.9b	22.3b
N_3	3331.9a	30.3a	9.24a	4497.1a	23.4ab	3.18a	1478.8a	44.3c	23.2a
N_4	3352.2a	29.7b	9.55a	4574.9a	22.7b	3.19a	1473.9a	43.9c	23.6a
Interactions									
S_1N_1	2906.0f	28.9g	6.67d	4137.3e	23.4cde	3.01d	1372.6e	47.2	20.0h
S_1N_2	3485.1d	30.9c	8.69b	4764.4c	23.0de	3.18b	1590.3c	45.7	21.5f
S_1N_3	3996.3a	32.0a	10.82a	5111.8a	22.8e	3.45a	1804.0a	45.1	22.7de
S_1N_4	3865.3b	31.1b	10.45a	4973.7b	22.6e	3.43a	1717.6b	44.5	23.0c
S_2N_1	2367.1i	27.4i	4.79e	3296.7h	25.0ab	2.91e	1096.0h	46.3	20.4g
S_2N_2	2884.9f	29.2f	8.55bc	3869.3f	24.4bc	3.08c	1304.0f	45.2	22.4e
S_2N_3	3308.5e	30.0d	8.88b	4605.2d	23.3de	3.09c	1462.6d	44.2	23.4b
S_2N_4	3622.9c	29.8e	10.50a	5005.9ab	23.0de	3.17b	1603.0c	44.3	23.9a
S_3N_1	2023.4j	26.2j	3.90f	2858.4i	26.0a	2.73f	911.8j	45.0	20.6g
S_3N_2	2391.3i	28.1h	6.58d	3324.5h	25.0ab	2.90e	1050.1i	43.9	23.0cd
S_3N_3	2691.1g	28.9g	8.03bc	3774.4fg	24.0bcd	2.99d	1169.9g	46.5	23.5b
S_3N_4	2568.4h	28.1h	7.70c	3745.1g	22.3e	2.96de	1101.0h	42.9	23.8a

Difference of means having similar letter in each column is not significantly different (Duncan) on seed yield. Higher seed yield as reported by Taylor *et al.* (1991) was largely due to higher pods per m^2 and seed weight (Table 4). Similar results were reported by Hocking *et al.* (1997), Cheema *et al.* (2001) and Angadi *et al.* (2003). An adequate application of fertilizer, especially N, enable the crop to produce rapid leaf growth to intercept more solar radiation and thus to produce and fill many pods. This is reflected in efficient partitioning of total dry matter (TDM) in to economic yield, as indicated by higher HI in the N_3 treatment compared to other rates of fertilizer applications (Diepenbrock, 2000; Cheema *et al.*, 2001).

Means comparison of interactions on seed yield indicated that there was significant difference among different treatments (Table 4). In second level of irrigation management (S_2) seed yield increased with increasing the N rate up to 240 kg N ha^{-1} (N_4). According to Pechan and Morgan (1985) and Wright *et al.* (1988), pod growth and yield are frequently source limited during seed filling. This problem can be solved to some extent by commencing the seed-filling period with a larger leaf area or by maintaining longer leaf area duration. In their conclusion, they mention the possibility of solving the source limitation partially by adding N during the seed-filling period. However, in no stress conditions (S_1) this rate (N_4) due to increasing the plant lodgging and in severe stress condition (S_3) reduced the seed yield, suggesting this fact that soil nitrogen absorption was affected by soil water status (Andersen *et al.*, 1996; Schittenhelm, 1999). Seed oil and protein content were affected by treatments too. Seed oil content adverse to seed protein content with increasing the severity of drought stress was decreased. Increase in nitrogen led to increase in protein content, but oil content was decreased. These results were not surprising, as similar effects have been reported by Cheema *et al.* (2001), Hocking and Stapper (2001) and Rathke *et al.* (2005). The negative correlation between oil content and protein content is well established (Asare and Scarisbrick, 1995; Andersen *et al.*, 1996; Brennan *et al.*, 2000; Hao *et al.*, 2004). The physiological reason for the negative correlation is related to the competition for carbon skeletons during carbohydrate metabolism (Bhatia and Rabson, 1976).

CONCLUSIONS

In conclusion, the results of this research showed that rapeseed (*Brassica napus* L.) is most sensitive to water deficit during the flowering stage. Moderate and severe terminal drought stress reduced grain yield by 14.5 and 32% compared to no stress condition, respectively. Lower seed yield in treatments with stress was due to significant reduction in number of pods m^{-2} and seed weight. With increasing of N rate up to 190 kg ha^{-1}, number of pods m^{-2}, seed weight and consequently seed yield was increased significantly. Altogether optimal seed and oil yield could be harvested if sufficient water is accompanied by proper nitrogen fertilization. Highest seed and oil yield (3996.3 kg ha^{-1} and 1803.9 kg ha^{-1}, respectively) with 190 kg N ha^{-1} at no stress condition (S_1N_3 treatment) was obtained. According to these results for maximize production of rapeseed in this region and probably in similar conditions full irrigation and application of 190 kg N ha^{-1} (with respect to soil analyze) was recommended. If irrigation, for any reason, done after depletion of 50% FC, application of higher levels of N (up to 240 kg N ha^{-1}) can be useful.

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