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The Effects of Irrigation Regimes and Nitrogen Rates on some Agronomic Traits of two Rapeseed Cultivars

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Introduction

Water is not the only limiting factor in arid and semiarid ecosystems. Plants often suffer from nutrient (especially N and P) deficiencies, which could be exacerbated by climate and environment changes, especially increased water stress (Wu et al., 2009) due to the close relationships between water and nutrient availabilities. Nitrogen (N) fertilizer plays a crucial role in enhancing canola yield. A high rate of N application increases leaf area development, improves leaf area duration (LAD) after flowering, number of branches per plant, the number of silique per plant and increases overall crop assimilation, thus contributing to increased seed yield (Rose et al., 2008). Amounts of N fertilizer required for maximum yield of oilseed species vary, depending on environmental conditions (Gan et al., 2007).

Material and Methods

The study was conducted at Agricultural Research Station of Karaj, Tehran province, Iran. The local climate is semi-arid with an average rainfall of 243 mm concentrated over the months of December–April. In this study, two rapeseed cultivars, Zarfam and Modena, were used. As cultivar Zarfam is more drought-resistant than Modena. The study (a randomized complete block design with four replicates) was conducted at two years and consisted of a factorial combination of two rapeseed cultivars, four irrigation regimes and four nitrogen rates. The irrigation regimes consisted of irrigation scheduling based on maximum allowable depletion (MAD) of the total available soil water (ASW). Each irrigation regime was based on a predefined level of MAD, which was a fixed percent of the total ASW. Irrigation water was applied whenever the threshold value of MAD for the particular irrigation treatment was attained. The irrigation treatments signed by I_1 to I_4 as 30, 45, 60 and 75% MAD of ASW. More much water was applied in the first year compared with the second year because of different rainfall of 230 mm versus 260 mm. Nitrogen (urea) was splited as half with sowing (incorporated) and the remaining half at the beginning of stem elongation (hand broadcasted) (N45+45, N90+90, and N135+135). All plots received phosphorus at 60 kg ha^{-1} as triple super phosphate and 50 kg K_2O ha^{-1} from potassium sulphate at sowing in both years. The target plant density was 95 plants per m^2. The area of each plot was 1.8×5.3 m (9.6 m^2) consisting of 6 rows, 5.3 m long and 30 cm apart, Maintaining a buffer of 2m between adjacent plots. The relationship between irrigation regimes and N fertilizer rates was investigated by regressing seed yield against N fertilizer rates using a segmented linear-plateau model as Eq.1.

$y = a + bN$ if $N<N_{critical}$ (linear part) (1)

$y = a + b N_{critical}$ if $N\geq N_{critical}$ (plateau part)

Where y is the yield (kg ha^{-1}), N is fertilizer rates (kg N ha^{-1}), $N_{critical}$ is the critical point or the N fertilizer rate at which the plateau begins, a and b are model coefficients. The plateau of the regression estimated the maximum yield, and the critical point of the regression estimated the N fertilizer rate at which the maximum seed yield was achieved. These nonlinear regression coefficients were estimated using iterative optimization method by the Solver Add-ins tool (Microsoft Excell, 2003).

Results and Discussion

Zarfam had higher seed yield than Modena (Table 1). The variation in seed yield from I_1 to I_2 was found to be almost similar during two crop experiments (Table 1). The reduction in seed yield from I_1 to I_2 was little due to marginal effect of moisture level variation between I_1 and I_2, which is 30–45% MAD. However, the decline in seed yield was more prominent beyond the depletion level of 45% MAD (I_3 and I_4). Similar trends were observed during the two experiments. As rainfall during the growth stages in the first year was less than that in the second year; the seed yield was less in the first year than that in the second year. The crop experienced no stress during the critical stages of the first year due to timely occurrence of rainfall.

The yield reductions in rapeseed at I_3 and I_4 MAD of ASW can be explained by fewer silique per plant and lower 1000-seed weight (Table 1). The water stress usually causes a decline in growth, leaf area, and a hasten maturation (Sinaki et al., 2007), thus decreasing seed yield.

Seed yield responded to N fertilizer rates in a curvilinear manner, and the responses were consistent among the irrigation regimes and cultivars (Fig. 1). The segmented linear-plateau model revealed that seed yield increased sharply with increasing N fertilizer rates up to $N_{critical}$ (Fig. 1 and Table 2). Beyond $N_{critical}$, the yield response to N fertilizer rates was generally leveled off or the rate of increase in yield declined. The rate of $N_{critical}$ was greater than the current recommendation of 130 kg N ha^{-1} (the vertical solid line in Fig. 1). The intercept of the regressed line indicated the minimum yield, which in most cases occurred when no N fertilizer was applied. The critical point of the segmented lines estimated the N fertilizer rate at which the maximum seed yield was achieved, while the plateau of the regression estimated the maximum yield. The I_1 and I_2 were the most responsive irrigation levels to added N fertilizer (highest b value) in terms of seed yield. The critical point for seed yield was the lowest for I_4 and highest for the I_2. Nitrogen rate recommendations are site-specific and affected by environmental conditions. Therefore, knowledge of the residual soil N, rate, and amount of N mineralized from soil organic sources, and individual crop needs are all required to optimize N fertilizer recommendations.

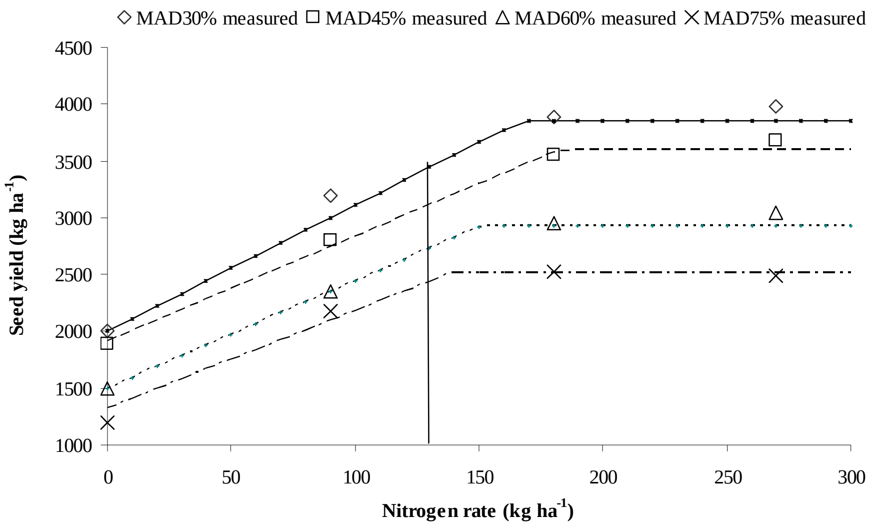

Fig. 1. Nonlinear regression output for seed yield produced under different irrigation regimes, averaged data for two experiments, the vertical solid line indicates the recommended rate of N fertilizer (130 kg N ha^{-1}) for rapeseed production under normal growing conditions.

Table 1. Mean comparison some agronomic traits of rapeseed under irrigation regimes, cultivars, and nitrogen rates.

	Silique number (no. plant^{-1})	Seed number (no. silique^{-1})	1000-Seed weight (gr)	Seed yield (kg ha^{-1})	Water use efficiency (kg m-3)
year1					
I_1	191 a	25 a	3.7 a	3872 a	0.54 b
I_2	188 a	24 a	3.6 a	3850 a	0.61 a
I_3	119 b	20 b	3.21 b	3135 b	0.53 b
I_4	83 c	18 c	3.2 b	2654 c	0.47 c
N_1	73 d	20 c	3.26 c	2312 c	0.37 c
N_2	105 c	22 b	3.33 b	3124 b	0.41 b
N_3	170 b	25 a	3.44 a	3800 a	0.51 a
N_4	190 a	25 a	3.5 a	3700 a	0.5 a
Zarfam	130 a	23 a	3.51a	3250 a	0.56 a
Modena	128 b	20 b	3.2 b	3157 b	0.5 b
year2					
I_1	210 a	28 a	3.74a	4190 a	0.63 b
I_2	207 a	27 a	3.65 a	4134 a	0.79 a
I_3	131 b	24 b	3.5 b	3264 b	0.56 c
I_4	91 c	23 b	3.47 b	2740 c	0.5 d
N_1	80.3 d	22 d	3.53 b	2464 d	0.4 d
N_2	115 c	24 c	3.59 b	3231 c	0.63 c
N_3	196 b	26 b	3.76 a	3830 b	0.73 b
N_4	210 a	27 a	3.75 a	3991 a	0.88 a
Zarfam	144 a	26 a	3.8 a	3499 a	0.6 a
Modena	141 b	24 b	3.75 b	3389 b	5.5 b

* Mean values on the same columns with the same letters are not significantly different ($P < 0.05$) according to the LSD.

Table 2. Summary of the nonlinear regression coefficients (a, intercept; b, linear slope coefficient; critical point, N fertilizer rate at which the plateau begins) for seed yield. Average data for two experiments (Eq. 1).

Irrigation regimes	R^2	a	b	$N_{critical}$
I_1	0.97	1999	11.11	166.5
I_2	0.97	1850	9.4	189.8
I_3	0.97	1500	9.2	150
I_4	0.98	1200	7.7	147

Conclusions

In the present study, the responses of the irrigation levels/cultivars to N fertilization was assessed under two scenarios: (i) at the rate typically recommended (130 kg N ha^{-1}), and (ii) at rates increasing from 0 to 270 kg N ha^{-1}. At the typical rate of recommendation, the seed yield of I_4 and I_3 were 2200 and 2600 kg ha^{-1}, respectively, which was less than seed yield produced by I_2 and I_1. The seed yield in I_3 and I_4 was less responsive than other irrigation levels to various rates of N fertilizer, while the I_1 had the greatest response in seed yield to increased N fertilization. These results indicate that I_3 and I_4 are grown with a yield penalty under the typical N recommendation (i.e., 130 kg N ha^{-1}), and that this penalty is not alleviated with an adjustment of the N fertilizer rate. It is feasible that improvement of irrigation schemes can help enhancing the yield potential for rate typically recommended. Overall, seed yield responded to N fertilizer rates in a curvilinear manner for all the irrigation levels/cultivars studied. Seed yield increased sharply with increasing N fertilizer rates up to $N_{critical}$. The rate of increase in seed yield peaked as fertilizer N rates approaching 147 kg ha^{-1}, which was higher than the current recommendation of 130 kg N ha^{-1}. The magnitude of the responses to N rates varied among the irrigation levels. More N fertilizer was required to maximize seed yield in I_2 relative to I_1. It is speculative that the I_2 has a more structured physiological response to N fertilizer rates compared with a more flexible response in I_1. Structured physiological responses to growth resources limit the ability of crop plants to convert extra photosynthetic biomass associated with additional N fertilization into seed yield (Angadi et al., 2000). The Zarfam cultivar has improved some key phenological traits such as earlier flowering, longer duration of flowering and maturity, and improved drought tolerance during the reproductive growth period. These improved phenological characteristics help us to improve the adaptation of this cultivar to the drought-prone region (e.g. Karaj). Compared with the high-yielding I_1 and I_2 with (I_3 and I_4), the seed yield of (I_3 and I_4) had a weaker response to increased rates of N fertilizer, suggesting that N use efficiency of (I_3 and I_4) is low.

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