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Response of rapeseed to nitrogen fertilisation in a Mediterranean environment

Response of rapeseed to nitrogen fertilisation in a Mediterranean environment

M. Ângelo Rodrigues, Arlindo Almeida, Jorge Ferreira, Tiago Ribeiro, Margarida Arrobas

Mountain Research Centre, Polytechnic Institute of Bragança
Phone number +351 273303237, e-mail: angelor@ipb.pt

1. Introduction – Portugal needs urgently to increase the production of vegetable oils to be able to meet the mandatory 10% minimum target to be achieved by all EU member states for the proportion of biofuels in petrol and diesel consumption by 2020 (Directive 2009/28/EC).
Rapeseed oil is the main raw material used in Europe for the manufacture of biofuels. Portugal, however, does not produce rapeseed oil, in spite of some studies having indicated that there are favourable ecological conditions to do this throughout the country [1, 2].
Nitrogen (N) is one of the most significant ecological factors promoting crop yields [3, 4]. Rapeseed is considered to be a high demand crop for N [4, 5, 6, 7, 8, 9], showing also low N use efficiency [5, 8, 10]. Excessive N fertilisation represents additional energy consumption and may cause the contamination of ground waters through nitrate leaching and lead to the emission of environmentally relevant nitrogenous gases to the atmosphere [11]. Splitting of N fertilisation into two different applications is one of the best strategies to improve crop N use efficiency [12, 13]. In Mediterranean climate, the growing cycle of the winter crops begin in early autumn and continue throughout the winter. The low temperatures and high precipitation rates of this period slow crop growth and cause nitrate leaching and denitrification. Nitrogen applied at pre-plant may be particularly inefficient due to the poor crop demand and the high leaching potential of the autumn/winter period. On the other hand, farmers like to apply N at pre-plant to promote the growth of the early vegetative phase, since this can be important to produce a good final yield.
In this work, results of a N fertilisation field trial are reported, where several N rates were applied as pre-plant and top-dress, to establish the best recommendation programme for this crop.

2. Experimental - The field trial took place in Bragança (NE Portugal) in the winter-spring growing season of 2009/2010. The region benefits from a Mediterranean climate with some Atlantic influence. Mean annual temperature and accumulated precipitation are 11.9 °C and 741 mm, respectively. The soil is loamy textured, 1.0% organic matter, pH 5.1, and presents mean and high phosphorus and potassium levels, respectively. Rapeseed had never been cultivated before in this soil. It was included in a wheat-fallow rotation, taking the place of wheat. The soil was limed before the trial started with 1000 kg lime ha^{-1}. A basal fertilization with phosphorus (superphosphate 18% P_2O_5) and potassium (potassium chloride 60% K_2O) were also carried out by using 220 and 65 kg ha^{-1}, respectively. Both lime and basal fertilisers were incorporated by soil tillage. A combination of ten N fertilisation treatments (pre-plant plus top-dress) with three replications were established. Ammonium nitrate was used as a fertiliser in pre-plant and also in top-dress applications. At pre-plant, the fertiliser was incorporated in the soil before sowing. At top-dress, the fertiliser was spread on the soil surface on March 13th. A Napropamide based herbicide was incorporated in the soil with a field cultivator shortly before sowing. The cultivar *Es Hydromel* was mechanically sown on September 21th, at a rate of 4.3 kg seed ha^{-1}.
Soil inorganic N (NO_3^-, NH_4^+) levels were monitored on November 26th and March 11th. Soil extracts were prepared from 20 g of soil and 40 mL 2 *M* KCl. The suspension was shaken for 1 hour and filtered in Watmann #42 filter paper. Nitrate and ammonium concentrations in the extracts were analyzed in a UV-VIS spectrophotometer. Plant N nutritional status (tissue NO_3^-, and total N as N nutritional indicators) and dry matter yield were also determined on November 26th and March 11th. Plant extracts for nitrate analysis were taken by adding 50 ml of distilled water to 1.0 g of dry sample. Total N was determined by a Kjeldahl procedure in a Kjeltec Auto 1030 Analyzer. Above-ground dry matter yields were estimated from nine (three per plot) random samples of a square metre. Total N in plant tissues was determined on April 17th, 36 days after the top-dress N application, to evaluate the effect of top-dress N treatments. At harvest, July 5th, dry matter yield was determined from field samples of a square metre and straw was separated from seed after threshing. Apparent N recovery (ANR) was estimated as: ANR (%) = 100 x (N recovered in the fertilised treatments - N recovered in the control)/N applied as fertiliser.

3. Results and Discussion – On November 26th, soil inorganic N levels were significantly higher in the plots where 50 kg N ha^{-1} were applied in comparison with the control (table 1). Nitrate was a more significant contributor than ammonium to the higher soil inorganic N levels recorded in most fertilised plots. In March, at the end of the winter, no significant differences were found in soil inorganic levels between pre-plant N treatments. The end result of N applied as pre-plant fertiliser was in crop uptake, but also in nitrate leaching and denitrification due to the autumn-winter rains. In an excess of precipitation, nitrate is readily mobile, being leached out from the soil [14]. The winter rains reduce soil aeration which also promotes biological nitrification [15].

Table 1. Soil inorganic N (NO_3-N, NH_4-N, NO_3-N + NH_4-N) during the autumn-winter period as a function of N applied as pre-plant.

	November, 26th			March, 11th		
N applied	NO_3-N	NH_4-N	Inorg.-N	NO_3-N	NH_4-N	Inorg.-N
kg/ha	mg kg^{-1}					
0	9.0 b	3.6 a	12.6 c	2.7 a	3.6 a	6.3 a
25	9.4 b	3.8 a	13.2 b	2.4 a	3.6 a	6.0 a
50	11.4 a	3.9 a	15.3 a	2.7 a	4.7 a	7.4 a

Mean separation within columns by Tukey's test, $P < 0.05$.

Nitrate concentration and total N in plant tissues on November 26th were significantly higher in the treatment where the higher N rate was applied in comparison with the control (table 2). Dry matter yields were higher in the fertilised plots in comparison to the control. Nitrogen uptake, which reflects total plant N and dry matter yield, showed significant differences among the three pre-plant treatments, being the higher values recorded in most fertilised plots.
The effect of pre-plant treatments was less evident on March 11th after the winter rains (table 2). Nitrogen uptake and dry matter yields were not statistically different among treatments. This result provides the first evidence of the poor efficacy of N applied at pre-plant on crop growth and development. Thus, the effect of pre-plant N on the increase of foliage growth was only evident for the early growth phase in the autumn.

Table 2. Tissues' nitrate-N (NO_3-N), total-N (Total-N), dry matter yield (DMY) and N uptake of rapeseed young plants during the autumn-winter growing period as a function of N applied as pre-plant.

	November, 26th				March, 11th			
N applied	NO_3-N	Total-N	DMY	N uptake	NO_3-N	Total-N	DM	N uptake
kg/ha	mg kg^{-1}	g kg^{-1}	kg/ha	kg/ha	mg kg^{-1}	g kg^{-1}	kg/ha	kg/ha
0	205.9 b	32.1 b	718.4 b	23.1 c	32.2 a	19.2 b	1960.3 a	37.7 a
25	192.2 b	32.1 b	808.7 a	25.9 b	37.2 a	20.7 ab	2243.3 a	46.3 a
50	316.9 a	34.6 a	808.0 a	28.0 a	41.5 a	21.3 a	2096.6 a	44.6 a

Mean separation within columns by Tukey's test, $P < 0.05$.

On April 17th, after the application of N in the top-dress treatments, the N nutritional status of plants was closely related to the rate of N applied. There were found to be significant differences in total N in stems and leaves among the top-dress N treatments independently of the pre-plant N rate (table 3). In spring the temperature rises, enhancing crop growth and increasing crop demand for N. On the other hand, in this period, the precipitation rate reduces, increasing the opportunity for N uptake by roots.
At harvest, on July 5th, dry matter accumulated in straw and seeds was significantly different among top-dress N treatments (table 4). The more highly fertilised plots produced higher dry matter yields of stems and seeds. The dry matter accumulated in seeds was 4534 kg ha^{-1} when 150 kg N ha^{-1} was applied at pre-plant (0:150 treatment). Other highly productive plots were those where high N rates were applied at pre-plant, such as 50:150 kg N ha^{-1} and 25:125 kg N ha^{-1}.
The N concentrations in straw and seeds were significantly higher in the treatments corresponding to the higher N rates applied as top-dress (table 5). Nitrogen uptake by straw, seeds and total was also significantly different among top-dress N treatments, as the result of the cumulative effect of the higher N concentrations in plant tissues and dry matter yields. A spring rapeseed crop accumulates 50-60 kg N for every tonne of seed produced. The equivalent for winter rapeseed is about 70 kg N [5]. In the present study, the rapeseed crop accumulated between 25 to 35 kg N for every tonne of seed, values significantly lower than the afore-mentioned, even compared to a spring rapeseed crop. This result suggests a higher

internal N use efficiency, which may be due either to the warmer growing conditions of the Mediterranean region or a characteristic of the cultivar *Es Hidromel* used in this study. It is well documented that both of these factors may affect the optimal N demand [8]. In addition, Rodrigues et al. [2] have also reported good rapeseed yields obtained with moderate N doses in similar agro-ecological conditions.

Table 3. Total N in plant tissues on 17 April (36 days after the application of top-dress N treatments) as a function of several N rates applied as pre-plant (pp), top-dress (td) and total N (tl).

N applied [pp:td (tl)] kg/ha	Total N, stem $g\ kg^{-1}$	Total N, leaf $g\ kg^{-1}$
0:0 (0)	6.5 d	24.2 d
0:50 (50)	7.4 c	30.6 c
0:100 (100)	8.4 b	33.5 b
0:150 (150)	8.9 a	44.6 a
25:25 (50)	6.5 c	25.0 c
25:75 (100)	7.7 b	29.8 b
25:125 (150)	9.1 a	40.7 a
50:0 (50)	7.8 b	27.1 b
50:50 (100)	8.4 a	34.8 a
50:100 (150)	8.4 a	34.1 a

Mean separation within columns of each pre-plant group of treatments by Tukey's test, $P < 0.05$.

Table 4. Dry matter (DM) yields of straw and seed at harvest as a function of several N rates applied as pre-plant (pp), top-dress (td) and total N (tl).

N applied [pp:td (tl)] kg/ha	DM straw Mg/ha	DM seed kg/ha
0:0 (0)	7.2 c	2059 c
0:50 (50)	10.1 b	2931 b
0:100 (100)	11.1 b	2868 b
0:150 (150)	12.5 a	4534 a
25:25 (50)	8.1 b	1744 c
25:75 (100)	9.1 b	3425 b
25:125 (150)	11.6 a	4026 a
50:0 (50)	7.3 c	2064 b
50:50 (100)	9.1 b	1883 b
50:100 (150)	12.5 a	4278 a

Mean separation within columns of each pre-plant group of treatments by Tukey's test, $P < 0.05$.

Table 5. Total N in straw and seed, N uptake (Nup) in straw and seed and apparent N recovery (ANR) as a function of several N rates applied as pre-plant (pp), top-dress (td) and total N (tl).

N applied [pp:td (tl)] kg/ha	N straw $g\ kg^{-1}$	N seed $g\ kg^{-1}$	NUp straw kg/ha	NUp seed kg/ha	NUp total kg/ha	ANR %
0:0 (0)	0.8 b	19.7 c	5.7 c	40.5 d	46.2 d	---
0:50 (50)	0.8 b	22.5 b	7.9 b	66.0 c	73.9 c	55.3
0:100 (100)	1.3 a	26.0 b	14.8 a	74.5 b	89.3 b	43.1
0:150 (150)	1.2 a	25.1 a	15.0 a	113.7 a	128.7 a	55.0
25:25 (50)	0.9 b	24.2 b	7.3 b	42.2 c	49.5 c	6.5
25:75 (100)	1.0 b	23.9 b	8.7 b	82.0 b	90.7 b	44.5
25:125 (150)	2.9 a	25.6 a	33.5 a	103.0 a	136.5 a	60.2
50:0 (50)	0.6 c	22.2 c	4.1c	45.8 b	49.9 c	7.4
50:50 (100)	1.5 b	25.6 b	13.2 b	48.3 b	61.5 b	15.2
50:100 (150)	2.2 a	27.6 a	27.4 a	117.9 a	145.3 a	66.1

Mean separation within columns of each pre-plant group of treatments by Tukey's test, $P < 0.05$.

Apparent N recovery varied from less than 10% if the N is applied at pre-plant, to values up to 50% if almost all the N is applied as top-dress (table 5). Apparent N recoveries found for rapeseed crop have been around or less than 50% [5, 10], a low value but not much dissimilar than that reported for other field crops [12]. Completely inacceptable were the particularly low apparent N recoveries found for the N applied as pre-plant.

4. Conclusions – Top-dress N fertilisation was unequivocally more effective in promoting seed yield than pre-plant N. Apparent N recovery was also completely different for the 0:50 N treatment (55.3%) when compared to the 50:0 treatment (7.4%). The application of N after the winter rains (as top-dress) is a more environmentally sound fertilisation strategy for this crop. In autumn and winter, the demand of rapeseed for N is poor due to de low temperatures. On the contrary, the risk is high for nitrate leaching and denitrification due to the heavy rains that usually occur. The application of N at pre-plant is usually recommended for increasing crop biomass at the early vegetative phase. The results of this experiment question this fertilisation strategy due to the poor performance of pre-plant N to improve the final yield. The internal N use efficiency was high in comparison to values recorded in the literature. Per each tonne of seed, N uptake was in the range of 25 to 35 kg N. Under the agro-ecological conditions of this experiment (growing season, cultivar, crop rotation, ...), it seems possible to get high rapeseed yields even with moderate N rates.

5. References

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