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Influence of lodging and nitrogen rate on the yield and yield attributes of oilseed rape (*Brassica napus* L.)

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Abstract The effects of lodging and nitrogen rate were studied in a field trial of oilseed rape *Brassica napus* L. Lodging decreased seed yield (16%) compared with a frame-raised crop. Yield decreased because of a significant reduction in each of the yield components coupled with a reduced plant population caused by stem breakage at the ground level. Lodging also reduced the final crop dry weight and harvest index. Seed yield was also lower when 200 kg ha^{-1} nitrogen was applied than with 400 kg ha^{-1}. A general decrease in pod number m^{-2}, seed nuber pod^{-1} and seed weight caused the lower yields. The use of 400 kg ha^{-1} of nitrogen changed the contribution of the terminal raceme and individual branches with respect to seed yield. Seed nitrogn content and nitrogen yield increased at the 400 kg ha^{-1}, lowering both seed oil content and oil yield.

Key words Oilseed rape · Lodging · Raceme · Branches · Nitrogen rate

Introduction

Lodging, the collapse of the crop or pods falling below the cutter level at harvest, is a serious problem in oilseed rape. The occurrence of lodging is often a seasonal phenomenon, but should lodging occur early in the crop season during flowering or pod development, a high yield loss can be expected (Bremner 1969). Most growers in the UK apply at least 200 kg ha^{-1} nitrogen (N) to optimize oilseed rape yields (Ellsemere 1985). While the effects of lodging in oilseed rape have been reported (Holmes 1980; Scarisbrick et al. 1982; Daniels et al. 1986), its consequences have not been examined on a morpho-physiological basis. Bremner (1969) and Pinthus (1973) suggested that in cereals lodging is promoted by an over-supply of nitrogen because of the effects of increased nitrogen on basal internode elongation. A similar relationship seems to exist in oilseed rape between higher rates of nitrogen and lodging. The objective of the experiment presented here was to évaluate the nature of yield losses caused by lodging, especially in relation to higher rates of nitrogen application. The study emphasizes the morpho-physiological characteristics of individual plants at harvest.

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Materials and methods

Rapeseed variety 'Bienvenu' (*Brassica napus* L.) was Norsden drilled on August 23, 1984, on a Boulder clay soil at the Cockle Park Experimental site of Newcastle University, England. Seven kilograms of seeds per hectare was used in 12-cm rows, and the plants were singled by hand in March to restore a target population of 100 plants m^{-2}. Pre-sowing soil analysis indicated that the soil contained high levels of both Mg and S, and the P and K status were also satisfactory (Table 1). Therefore, N, P and K fertilizers were applied at a basal level of 50 kg ha^{-1}.

The treatment included a lodged crop that was compared with a control crop grown within a wire-frame under two levels of spring nitrogen (200 and 400 kg ha^{-1}). The basis for selection of these two treatments of nitrogen rate was to compare lodging effects with respect to the currently recommended rate (200 kg ha^{-1}) used in the UK and a very high rate (400 kg ha^{-1}), which is sometimes used by the farmers. The crop was maintained upright by constructing a rigid frame around the growing crop at the early flowering stage on May 9, 1985. Natural lodging was allowed in the other treatment. Lodging occurred on June 16 following a heavy and prolonged rainfall that coincided with the end of flowering. Each nitrogen rate was applied in two equal splits on February 28 and March 20. The factorially combined experiment was replicated four times within a randomized block design. Individual plots measured 1.8 m × 8 m, and treatment plots were separated by a similar area of untreated crop to minimize interplot interference.

Crops were desiccated at maturity and harvested using a Class Compact Combine. A sub-sample of seeds off combine was retained for moisture, oil and nitrogen determinations, and seed yields expressed at 9% moisture content. A quadart comprising ten 0.5-

Table 1 Results of pre-sowing soll analysis

Sampling date	pH	ADAS[a] Fertility index P	K	Mg	S
August 16, 1984	6.3	3	2	4	4

[a] According to the ADAS (Agricultural Development and Advisory Service, UK) index, the fertility level of each nutrient is marked from 0 to 5, with 0 indicating nil and 5 a very high level of the nutrient concerned

m-long rows within each plot was harvested separately before combining. On the basis of sample fresh weight and plant number, a representative sub-sample of 30 plants was selected and air dried in an unheated greenhouse. These sub-samples were later dissected on a branch-by-branch basis, e.g. Terminal raceme (TR), Branch 1 (B1), Branch 2 (B2) ... Branch n (Bn). Pods were counted, crushed by hand and cleaned in an aspirator to separate the seeds, which were then weighed and counted. Data were analysed statistically and means presented with LSD or standard errors of differences of means (SED).

Table 2 Summary-results of F-statistics showing the effect of treatments on different parameters (*ns* Not significant, * $P \leq 0.05$, ** $P \leq 0.01$)

Parameter	Lodging	N-rate	Lodging × N-rate
Yield:			
Seed yield (t ha^{-1})	**	*	ns
Seed N content (%)	ns	**	ns
Seed N uptake (kg ha^{-1})	**	ns	ns
Oil content (%)	ns	**	ns
Oil yield (t ha^{-1})	**	**	ns
Yield parameters:			
Pod number (m^{-2})	**	ns	ns
Seed number pod^{-1}	**	ns	ns
Seed weight (mg)	**	ns	ns
Plant number m^{-2}	**	ns	ns
Crop dry weight (gm^{-2})	**	*	ns
Harvest index (%)	**	ns	ns
Branch-wise (per plant) study:			
Branch number	ns	ns	ns
Branch dry weight (g)	ns	ns	ns
Pod number	ns	ns	ns
Seed number pod^{-1}	**	**	ns
Seed number branch^{-1}	**	**	ns
Seed dry weight (g)	**	**	ns

Results and discussion

A summary of the results of the effects of treatments as obtained after the analysis of variance (ANOVA) are shown in Table 2. The effects of lodging and N rate were significant, while no interaction between main treatments was apparent. This was because lodging occurred with all of the plots (irrespective of N treatments) following a particularly heavy rainstorm.

Lodging

Seed yield and yield components

Lodging caused a significant reduction of 0.75 t ha^{-1} (16.2%) in seed yield compared with the control (frame-raised crop) (Table 3). Yield components show that seed yield loss from lodging was due to a significantly low contribution from each of the yield components. Pod number m^{-2} was reduced by 19.9%, and seed number pod^{-1} and seed weight were reduced 17.5% and 11%, respectively.

The harvest index was significantly lower in the lodged crop than in the control because total crop dry weight and seed yield m^{-2} were significantly reduced in the lodged crop. Number of plants at harvest was significantly lower in the lodged crop; 70 plants m^{-2} compared with 83 in the control. Field observations revealed that the higher plant mortality in the lodged crop was caused by stem breakage at the ground level. This might have been greatly responsible for making the difference in pod number m^{-2}. Similar occurrences of stem breakage have been reported by Kimber (1985) and Mendham et al. (1981), particularly from the early lodging of oilseed rape.

Yield component analysis on a branch-by-branch basis showed that branch development, branch dry weight and pod number plant^{-1} were determined before the occurrence of lodging and therefore not influenced by the treatment. Lodging strongly influenced seed number from both individual pods and branches, and in turn, seed yield (Fig. 1A–C). Overall lodging caused a

Table 3 Effect of lodging on seed yield and other parameters. (Means with different letters along the line differed significantly ($P \leq 0.01$))

	Treatment: Lodged crop	Treatment: Framed crop	LSD$_{.01}$	% Reduction over control
Seed yield (t ha^{-1})	3.87b	4.62a	0.39	16.2
Plant number m^{-2}	70.0b	83.0a	8.75	15.7
Pod number (m^{-2})	8260.1b	10307.3a	1422.10	19.9
Seed number pod^{-1}	8.18b	9.91a	1.199	17.5
Seed weight (mg)	3.97b	4.48a	0.14	11.0
Crop dry weight (gm^{-2})	1118.9b	1477.7a	184.77	24.3
Seed yield (gm^{-2})	268.0b	401.3a	64.4	33.2
Harvest index (%)	23.7b	27.0a	2.73	3.3

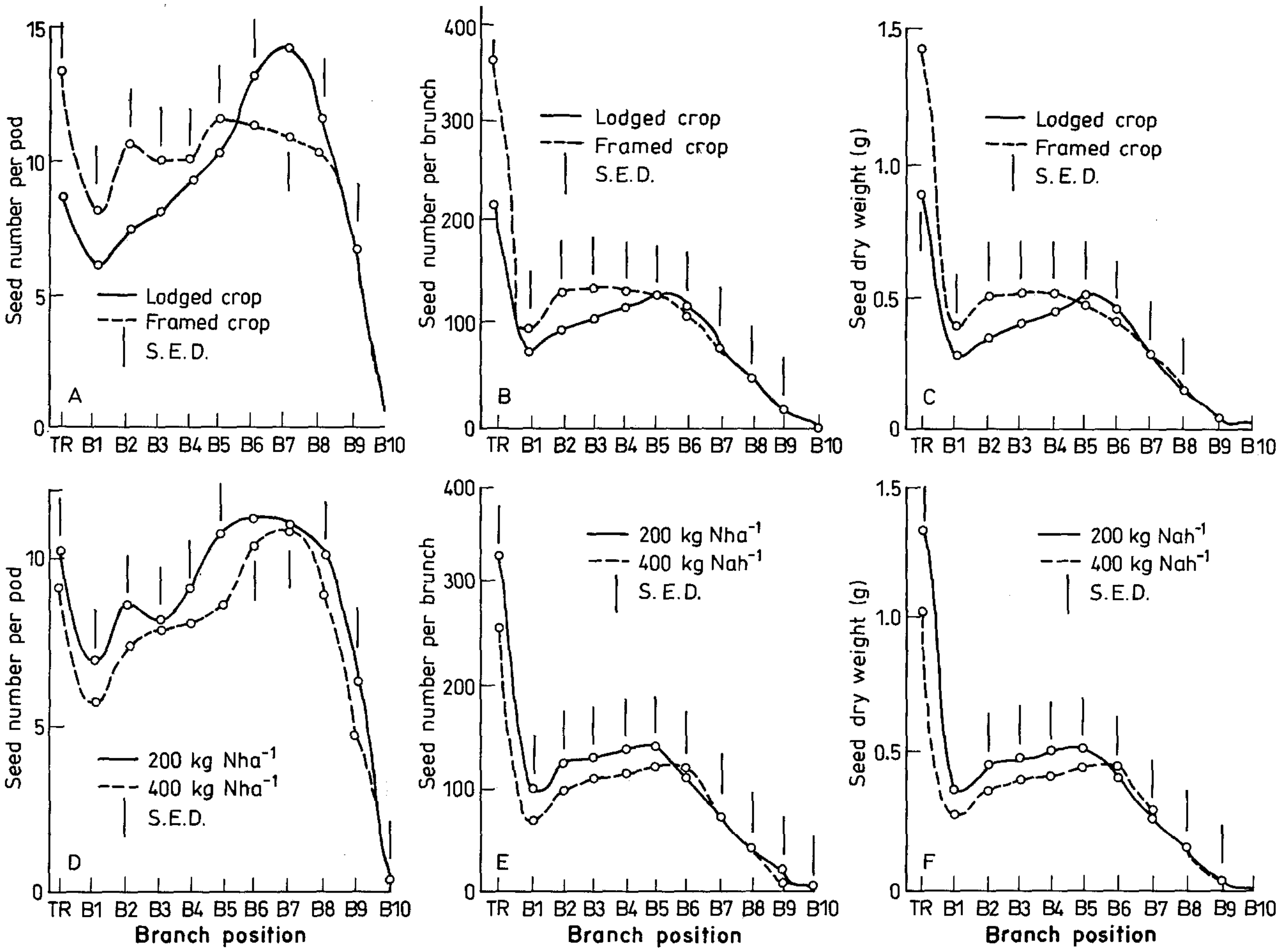

Fig. 1 Effects of lodging (**A**, **B**, **C**) and nitrogen rate (**D**, **E**, **F**) on the yield parameters on a branch-by-branch basis

reduction of 1.7 seeds pod^{-1}, attributable largely to the decreased in seed number per pod within the terminal raceme and higher-order branches. A small amount of compensatory growth was observed in the lower-order branches of the lodged crop. A decline in seed number per branch for the terminal raceme and branches one to three caused a significant reduction (25%) in seed number plant^{-1} compared with the control. Seed dry weight over branches declined significantly with the terminal raceme and higher-order branches in the lodged crop (Fig. 1C). The contribution of the terminal raceme and upper four branches accounted for 61% of the seed yield plant^{-1} in the lodged crop compared to 71% in the control. These differences may be due to a higher level of pod shading in the lodged crop, as has been reported by Thomas (1982) in winter wheat.

Seed nitrogen and oil yield

Lodging did not influence seed nitrogen content, but lodging did cause a significantly lower (18%) seed nitrogen uptake (Table 4). Seed oil content was not influenced by lodging, although oil yield was reduced 16% due to decreased seed yield in the lodged crop.

Nitrogen rate

Seed yield and yield components

Seed yield decreased significantly by 0.40 t ha^{-1} when the level of nitrogen application increased from 200 to 400 kg ha^{-1} (Table 5). The high rainfall and exceptionally cloudy weather during the period from June through August may have contributed to the lower yield with greater nitrogen application, but Scott et al. (1973) reported that a dressing of 300 kg N per hectare reduced seed yield to a greater extent than did 200 kg ha^{-1}. This yield decrease that results from higher nitrogen levels has been described by Scott et al. (1973) as being due to a reduction in pod and seed number plant^{-1}. In the present experiment, increasing the nitrogen rate from 200 to 400 kg ha^{-1} reduced fertile pod number m^{-2} and seed number pod^{-1} by 11% and 9%, respectively. The combined effect of yield components was also apparent from crop dry weight and seed yield m^{-2} at harvest, while harvest index was reduced only marginally in the higher nitrogen treatment.

Branch-wise analysis of individual plants indicated that the nitrogen rate did not markedly influence either branch number or the branch dry weight distribution. However, the terminal raceme produced significantly fewer pods with a general decrease in this parameter from branches one to four, resulting in an overall reduced pod number at the higher nitrogen rate. Seed number pod^{-1} was lower at the higher nitrogen rate, occurring on all branches including the terminal raceme (Fig. 1D). Similarly, a significant reduction in pod number was obtained in both the terminal raceme and primary branches one to four, and this significantly affected seed number plant^{-1} (Fig. 1E). The lower-order branches, on the other hand, were little affected by nitrogen treatment. Seed yield from individual branches was consistently lower at the higher nitrogen rate on both the terminal raceme and higher-order branches. The difference between treatments was significant ($P \leq 0.01$) for the terminal raceme and the first two branches only (Fig. 1F). The mean seed yield obtained from the lower-order branches was similar between treatments, but because of the yield reduction from the upper branches, including the terminal raceme, the lower-order branches (B5-B10) at the 400 kg N ha^{-1} treatment contributed 36% of the total per plant seed yield compared to 32% at the 200 kg ha^{-1} rate. Daniels et al. (1986) also reported that an increased rate of nitrogen application decreased the contribution of terminal raceme.

Table 4 Effect of lodging on seed yield and other parameters. (Means with different letters along the line differed significantly ($P \leq 0.01$))

	Treatment		$LSD_{.01}$
	Lodged crop	Framed crop	
Nitrogen (%)	3.47	3.54	–
Nitrogen uptake (kg ha^{-1})	134.1b	163.3a	12.22
Oil content (%)	36.8	36.9	–
Oil yield (t ha^{-1})	1.43b	1.70a	0.14

Table 5 Effect of nitrogen rate on seed yield and other yield parameters (Means with different letters along the line differed significantly ($P \leq 0.05$))

	Nitrogen rate (kg ha^{-1})		$LSD_{.05}$
	200	400	
Seed yield (t ha^{-1})	4.44a	4.04b	0.29
Pod number (m^{-2})	9802.0	8762.0	–
Seed number per pod	9.48	8.62	–
Seed weight (mg)	4.10	4.06	–
Crop dry weight (gm^{-2})	1389.8a	1206.9b	125.11
Seed yield (gm^{-2})	373.52a	295.77b	43.54
Harvest index (%)	26.5	24.2	–

Table 6 Effect of nitrogen rate on the seed nitrogen and oil yields (Means with different letters along the line differed significantly ($P \leq 0.01$))

	Nitrogen rate (kg N ha^{-1})		$LSD_{.01}$
	200	400	
Nitrogen (%)	3.40b	3.62	0.13
Nitrogen uptake (kg ha^{-1})	151.0	146.0	–
Oil (%)	37.4a	36.4b	0.46
Oil yield (t ha^{-1})	1.66a	1.47b	0.14

Seed nitrogen and oil yield

Seed nitrogen content was significantly greater at the higher nitrogen rate, but seed nitrogen uptake remained similar between treatments because of lower seed yield at the 400 kg ha^{-1} nitrogen level (Table 6). Oil content of the seed was decreased by 1.0% at the higher nitrogen level. The difference between treatments in the oil yield was also significant with a 11.5% lower yield of oil being found at the higher nitrogen rate.

Our results confirm that lodging in oilseed rape is a damaging phenomenon that reduces post-lodging dry matter production and seed yield. Therefore, attempts should be taken to check the lodging occurrence in oilseed rape. These may be conveniently done either by changing the plant type or by improving management practices. The use of plant growth retardants in oilseed rape should be considered as they have been shown to be effective in the control of lodging (Addoquaye et al. 1985; Almond and Dawkins 1985; Child 1985; Daniels et al. 1982).

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