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Nitrogen fertilization and head rot in broccoli

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Abstract

An increase in the amount of nitrogen supplied to broccoli (*Brassica oleracea* var. *italica*) led to an increased incidence of head rot, which resulted in a decrease of the amount of marketable produce. Indications were found that head weight and head dry matter content are, probably indirectly, involved in limiting head rot at low nitrogen supply. The harvest index was not influenced by treatment. Identification of the mechanisms which resulted in limited head rot at low nitrogen levels, could help to identify breeding characteristics to screen for in agronomic evaluation programs for broccoli cultivars under normal nitrogen supply.

Keywords: broccoli, calabrese, *Brassica oleracea* var. *italica*, head rot, spear rot, bacterial soft rot, nitrogen fertilization

Introduction

Head rot, or spear rot, is a serious disease of broccoli (*Brassica oleracea* L. var. *italica* Plenck). Head rot may result in downgrading of the head or render it completely unmarketable. Yield losses may run up to 100 per cent. Head rot occurs mainly when heads mature during prolonged periods of damp, wet conditions. Various *Pseudomonas* (Brokenshire & Robertson, 1986; Wimalajeewa et al., 1987; Hildebrand, 1989; Canaday et al., 1991) and *Erwinia* (Brokenshire & Robertson, 1986; Canaday et al., 1987) species have been reported as the cause of the disease. Control of head rot with fungicides or bactericides is generally not successful (Canaday et al., 1987) and currently there are no recommendations for chemical control. There are, however, differences between broccoli cultivars in susceptibility to head rot (Canaday et al., 1991).

Broccoli responds with yield increases to rather high amounts of nitrogen (Greenwood et al., 1980; Dufault & Waters, 1985; Kowalenko & Hall, 1987). Canaday & Wyatt (1992) reported that increased nitrogen rates increased disease incidence and severity of head rot in a susceptible cultivar. The increased disease incidence decreased the marketable yield.

In the framework of research on nitrogen fertilizer application in broccoli, it was found that nitrogen applied influenced the incidence of head rot. This paper de-

scribes effects of the amount of nitrogen on head rot incidence, yield and plant dry matter content of broccoli.

Materials and methods

General

In 1990 an experiment was carried out in which the effect of the amount and method of application of nitrogen (N) on yield and quality of broccoli was studied. The experiment was conducted at Lelystad, on a marine loam soil. Modular raised transplants of cv. Emperor were planted on 13 July at a planting distance of 0.50 × 0.45 m (44.400 plants ha^{-1}). Net plots measured 3.0 × 3.6 m comprising 56 plants. Four successive harvests were carried out on 4, 6, 8, and 10 September. Because of wet weather towards harvest time head rot developed in the experiment, based on natural infection.

Experimental design

The experiment had a randomized complete block design with four replications. Treatments were: 0, 49, 98, 147 and 196 kg N ha^{-1} applied at planting. Each amount of fertilizer was applied in two ways: (i) broadcast and (ii) row applied. There was one extra treatment that consisted of a split application: 98 kg N ha^{-1} was applied at planting, both broadcast and row applied, and 49 kg N ha^{-1} was applied broadcast four weeks after planting. Broadcast applied N at planting was lightly raked in. Row applied N was placed in a hand-drawn furrow next to the row. At 0 N, plots were lightly raked or furrows were drawn. N was applied as calcium ammonium nitrate. Soil available N at planting (0–0.60 m) was 54 kg ha^{-1}.

Grading of heads

At harvest all heads were trimmed to 16 cm in length, weighed, and graded in four quality groups, (i) no head rot, (ii) little head rot, but still marketable, (iii) unmarketable because of head rot and (iv) unmarketable because of other reasons. Size of marketable heads only was recorded in three diameter classes, 4–8 cm, 8–12 cm and >12 cm.

Sampling of plant material

At 6 September five randomly chosen plants in each plot were cut at soil level and separated in head, stem, shoots, leaf-stalks and leaf-blades. Fresh and dry weights (after drying at 70 °C) of this material were measured. The five heads were graded as described above and included in the harvest data of 6 September.

Statistical analysis

Data were subjected to an analysis of variance to test treatment effects on head rot incidence, yield and plant characteristics. Main effects of nitrogen are presented. Effects of the way of application are discussed only where relevant.

Results and discussion

Harvest period

Most of the heads were harvested at the first two harvest dates. Except for 0 N, most of the marketable heads were harvested at the first harvest date (Table 1). Head rot may have advanced harvest. Heads already infected but still marketable, were harvested to prevent further deterioration of the head.

There have been no substantial differences between the different treatments in environmental conditions shortly preceding and during harvest, as most of the heads were harvested within the first three days of the harvest period.

Head rot incidence

The percentage of head rot infected heads and heads that were unmarketable due to head rot doubled or increased sixfold respectively from 0 to 196 kg N ha^{-1} (Table 2). The same trend was found for head rot infection of marketable heads. Head rot infection in one size class (8–12 cm head diameter) of the marketable heads also showed an increase with an increase in N supply (Table 2). Canaday & Wyatt (1992) found that head rot incidence was influenced by the size of the head, larger heads being more infected. An analysis of disease incidence with heads of similar size, however, still showed an increase in disease incidence with an increase in N supply. Our data on head rot infection in one size class are in agreement with the observations of Canaday & Wyatt (1992).

The relation between head rot incidence and average head weight was described by an exponential curve (Figure 1). A similar relation described head rot incidence

Table 1. Total number of heads and number of marketable heads (between brackets) harvested on the successive harvest dates (number per 10.8 m^2).

Harvest date	Nitrogen (kg ha^{-1})									
	0		49		98		147		196	
04–09	20	(19)	29	(27)	20	(13)	24	(15)	25	(15)
06–09	29	(25)	24	(6)	30	(6)	28	(4)	28	(3)
08–09	1	(1)	1	(0)	2	(1)	1	(0)	0	(0)
10–09	4	(4)	2	(1)	3	(2)	2	(1)	2	(1)

Table 2. The effect of nitrogen on headrot incidence.

Nitrogen (kg ha^{-1})	All heads		Marketable heads			
	head rot infected (%)	unmarketable due to head rot (%)	total		heads 8–12 cm diam.	
			number per 10.8 m^2	infected (%)	number per 10.8 m^2	infected (%)
0	39	10	48	33	41	31
49	72	38	34	56	25	62
98	88	60	21	70	16	78
147	90	62	20	76	12	85
196	88	65	19	67	11	72
Significance	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001
LSD (α=0.05)	8	11	5	13	5	11

within the size class 8–12 cm marketable head diameter and average head weight (Figure 2).

No significant effect on head rot incidence was found for the method of application, i.e. broadcast versus row application. Split application of nitrogen also did not influence head rot incidence. Significant interactions between method of application and amount of nitrogen were found for percentage head rot infected heads (P = 0.028), percentage infected marketable heads (P = 0.009) and percentage infected

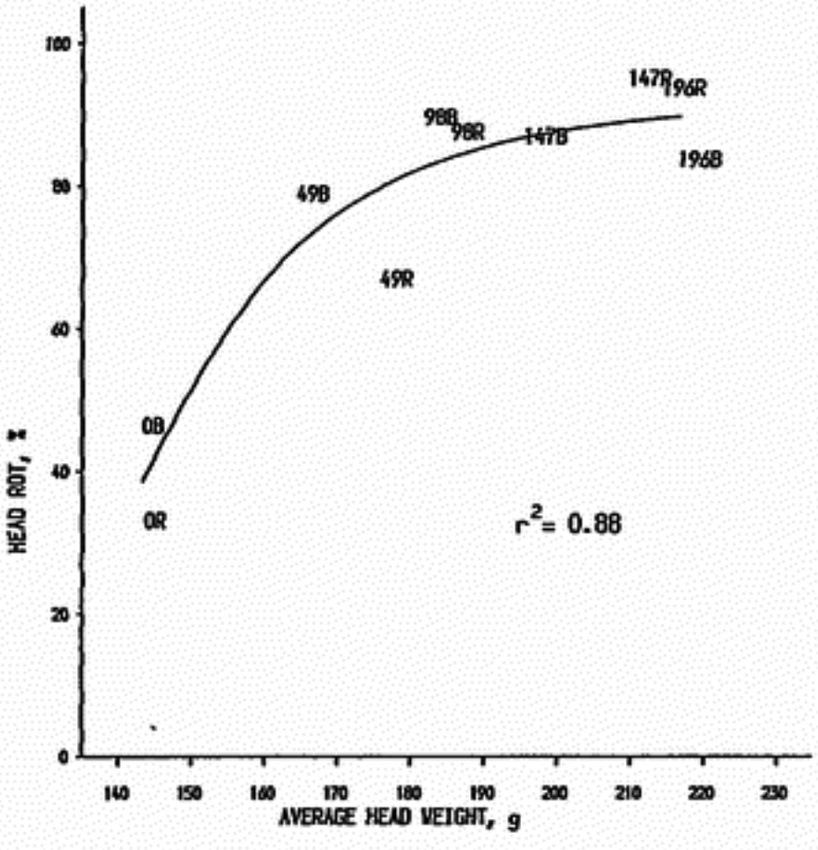

Figure 1. Relation between head rot incidence and average head weight (numbers indicate N application in kg ha^{-1}; B = broadcast; R = row application).

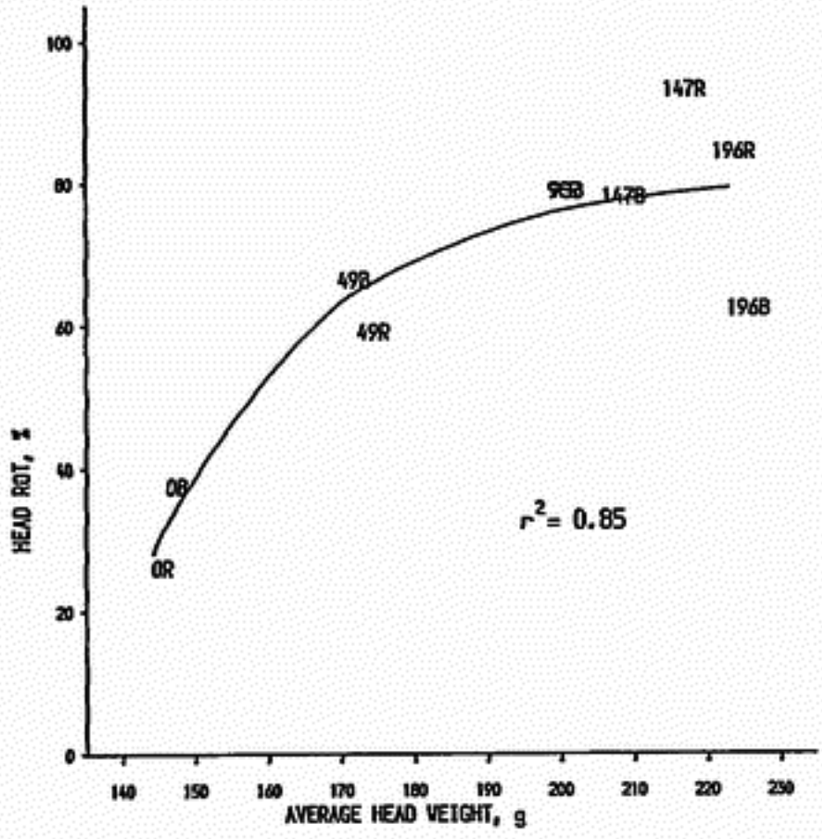

Figure 2. Relation between head rot incidence and average weight of marketable heads 8 –12 cm diameter (numbers indicate N application in kg ha^{-1}; B = broadcast; R = row application).

marketable heads 8–12 cm diameter ($P = 0.029$). The percentage head rot infected heads at 0 N broadcast was higher than at 0 N row application. The percentage infected marketable heads at 147 and 196 kg N ha^{-1}, and the percentage infected marketable heads 8–12 cm diameter at 196 kg N ha^{-1}, were higher with row application of nitrogen than with broadcast application. These significant interactions between amount of nitrogen and method of application are difficult to explain. With the treatments concerned no differences were observed between average head weight or head dry matter percentage.

Yield

The total number of heads harvested was not significantly influenced by nitrogen application (Table 3). The average weight per head increased with increasing amounts of nitrogen, resulting in an increase in total head weight. Marketable yield and yield without any head rot, however, decreased with increase in nitrogen supply. The decrease in marketable yield with an increase in N supply, corroborate the observations of Canaday & Wyatt (1992), who reported a similar trend for a head rot susceptible cultivar.

Plant characteristics

Low average head dry weights because of low amounts of nitrogen were associated with high dry matter percentages (Table 4).

Table 3. The effect of nitrogen on the number of heads harvested, weight per head, total head weight and marketable yield.

Nitrogen (kg ha^{-1})	Number of heads harvested per 10.8 m^2	Head weight (g)	Total head weight (t ha^{-1})	Marketable yield (t ha^{-1})	
				total	without head rot
0	54	144	6.2	5.6	3.9
49	55	170	7.4	5.0	2.4
98	54	184	7.9	3.4	1.1
147	55	203	8.8	3.7	0.9
196	55	216	9.4	3.7	1.3
Significance	NS	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$
LSD (α=0.05)		9	0.4	0.9	0.7

Low head weights resulted from the low nitrogen applications and the high head weights from the higher N applications. Heads with a low weight had less head rot than heads with a high weight (Figure 1, 2). This relationship between head weight and head rot incidence is most likely an indirect relationship. High dry matter percentages were associated with low amounts of nitrogen. A similar relationship was observed by Kowalenko & Hall (1987). It is suggested that the higher dry matter percentage of the heads from low nitrogen treatments resulted in a tougher tissue, making the heads less susceptible to bacterial attack. Additionally, lower N rates may have resulted in lower tissue protein concentrations, limiting the growth rate of the bacteria involved.

The harvest index was not significantly influenced by the N treatment. The absence of an effect of treatments on the harvest index, indicates that it is unlikely that time of head initiation was influenced. This means that heads grew during the same period of time and differences in maturation time probably played no substantial role in the incidence of the disease.

Table 4. The effect of nitrogen on plant characteristics.

Nitrogen (kg ha^{-1})	Head dry weight (g)	Dry matter (%)			Harvest index (%)
		head	leaf-blade	stem	
0	13.5	9.5	13.9	11.8	14.2
49	15.0	9.4	12.9	11.5	14.2
98	17.2	8.8	11.7	9.8	14.3
147	17.7	8.6	11.5	9.4	14.5
196	18.2	8.2	11.0	8.9	14.7
Significance	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$	NS
LSD (α=0.05)	1.3	0.5	1.1	0.8	

Practical implications

An effect of nitrogen on the incidence of head rot in broccoli has been shown, although this observation was limited to one season. The higher nitrogen rates resulted in an increase in the incidence of head rot, which reduced the marketable yield. The highest marketable yield was obtained under conditions of low nitrogen. However, if conditions are not conducive to the occurrence of head rot, the level of nitrogen would not produce a commercially attractive yield. Identification of the mechanisms that resulted in limited incidence of head rot at low N level could identify characteristics to screen for in broccoli cultivar evaluation trials under normal N supply.

At present the recommended strategies to limit broccoli yield reduction due to head rot are restricted to: (i) chosing less susceptible cultivars for cultivation in late summer or autumn, when head rot conducive conditions are more likey to occur, and (ii) advancing harvest at the first signs of the disease.

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