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Note on the effects of winter and spring waterlogging on growth, chemical composition and yield of rapeseed

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Abstract

In regions where climatic conditions are adequate for rapeseed production soils may suffer waterlogging of varying duration. A pot trial was conducted to determine the effects of waterlogging on the growth, nutrient absorption and yield of rapeseed. As the effect of anoxia is known to depend on temperature the study was carried with winter or spring floods of 3, 7 or 14 days duration compared with a control without flooding. Seed yield was affected by 3 or more days of waterlogging. Winter waterlogging decreased the number of seed per plant, due to fewer branches, siliques and seeds per silique. Spring waterlogging, by contrast, reduced individual seed weight and seed oil content. The uptake of N, P, K and Ca decreased significantly with flooding but that of Na increased with spring waterlogging. Yield decline was greater with winter than with spring flooding. Temperature during the flooded period was not the only factor determining the effects of waterlogging: the stage of development, when waterlogging occurred, is also an important factor.

Keywords: *Brassica napus* L.; Rapeseed; Waterlogging; Yield components; Nutrient uptake

1. Introduction

A number of studies have considered the effect of waterlogging on rapeseed (*Brassica napus* L.). Findings have varied, some authors observed negative effects of waterlogging when it occurred during the first stages of development of rapeseed (Anderson, 1980; Boiffin et al., 1981). Cannell and Belford (1980) observed that yield of rapeseed was unaffected by waterlogging of 10 to 42 days during the vegetative stage, with very low temperatures. In a preliminary experiment, however, we observed that with 28 days of waterlogging, 66% of the plants died (Gutierrez Boem and Lavado, unpublished data)

In most crops, O_2 used in root respiration is supplied from the soil (Drew, 1983). Diffusion is the main mechanism of O_2 movement through soil. Because O_2 has a very small diffusion rate in water, O_2 flow almost stops when the soil is saturated with water. The duration of the O_2 pool when the soil is flooded depends on temperature. Higher temperatures cause higher respiration rates in roots and soil microorganisms and therefore soil O_2 is consumed more quickly. Lack of O_2 then may limit crop growth due to alterations in metabolism (Drew, 1983, 1992). One alteration is a decline in nutrient uptake, as has been found for N, P, K and other nutrients in

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many crops (Drew, 1988). Some authors have suggested that nutrient uptake is more affected than growth (Glinski and Stepniewski, 1985). The effects depend on duration of waterlogging and the stage of development of the crop as well as other factors (Jackson and Drew, 1984). Mineral nutrition of rapeseed has been studied mainly in normal conditions (e.g., Urricariet et al., 1995).

In Argentina, rapeseed could be cropped in a wide area with large climatic and edaphic variations (Murphy and Pascale, 1989). In the Pampean region, where it is now grown on several thousand hectares, many soils suffer periodic floods of varying duration, especially during winter. Although the rainfall has no seasonal distribution, the water balance is positive during the winter due to less evapotranspiration. During winter and spring, lengthy storms can cause in considerable flooding. This is exacerbated by the poor surface drainage of the region and the slow percolation because of the presence of very clayey B horizons (Soriano, 1991).

The objective of this research was to determine the effects of winter or spring waterlogging on growth, nutrient uptake, yield and its components, of rapeseed at the growth stages found in the field at those times of the year.

2. Materials and methods

The experiment was carried out in plastic pots (17 cm diameter by 18 cm deep), filled with 4 kg of sieved (5 mm) dry Ah horizon of a Typic Natraquoll (US Soil Taxonomy). The main properties of this soil are: loamy texture, with 23% clay, 46% silt and 31% sand; 3.1% organic carbon; and pH (in paste) 6.6. More details about soil characteristics were published in Gutierrez Boem et al. (1994). Twenty-five seeds were sown in each pot on 22 May 1992. The cultivar was the hybrid Iciola 41. The emerged plantlets were thinned to leave only one plant per pot.

The experiment was conducted outdoors and the pots were covered with transparent plastic during rainy days. Soil water content was adjusted daily to maintain it between 75 and 100% of pot capacity, by weighing the freely drained pots. Waterlogging was carried out at two different times: one set of pots was flooded in winter and another set in spring. Pots of waterlogging treatments were flooded, with a 2-cm water layer over the soil surface. After the period of flooding, the pots were allowed to drain and return to the previous watering regime. Winter waterlogging was started on 14 July when the plants had four unrolled leaves (B4 stage; Centre Technique Interprofessionel des Oleagineux Métropolitains, 1978) and flooding lasted 3, 7 or 14 days. The mean ambient air temperature during each winter flooding period was 5.5, 6.8 and 7.3°C, respectively. Spring waterlogging was started on 15 September, at the ending seed filling in main branches, and beginning of filling in lateral ones (G4 stage; Centre Technique Interprofessionel des Oleagineux Métropolitains, 1978), and lasted 3, 7 or 14 days. The mean ambient air temperature of each flooding period was 16.8, 16.8 and 14.9°C, respectively. A no-flooding control was included. The experimental design was completely random with five replications. On 25 October, main and lateral branches were harvested separately. Plants were oven-dried at 60°C and weighed. Plant height, number of branches, aboveground biomass, as well as silique number, seed number and weight of main and lateral branches were recorded. With these parameters, average seed number per silique and average individual seed weight and seed yield could be assessed. Oil content in seeds was determined by extraction in a soxhlet apparatus. Samples of shoot material and seeds (after oil extraction) from each pot were analyzed for various nutrients. Nitrogen was determined by the Kjeldahl method. Another subsample was digested in concentrated HNO_3 and then $HClO_4$ (70%). P content of this digest was determined by vanado–molybdate colorimetry and Na, Ca and K were determined by atomic-absorption spectrophotometry.

Collected data were analyzed statistically by ANOVA. Whenever the hypothesis of equal means was rejected ($P < 0.05$), the means were compared using the Duncan test.

3. Results and discussion

As observed with this species (Cannell and Belford, 1980) and in *Brassica rapa* (Daugherty and Musgrave, 1994), the older leaves turned purple.

Senescence of these leaves, a common symptom of many species when they are subjected to waterlogging (Jackson and Drew, 1984), was hastened during waterlogging. Waterlogging had no significant effects on development, but affected growth and yield depending on the time it occurred. Winter waterlogging coincided with an early stage of crop development (B4), and plant height was significantly reduced when winter waterlogging lasted more than 7 days, while branch number decreased with 3 days or more of flooding (Fig. 1). Silique number was not affected on the main branch, but on lateral branches it was decreased significantly by 3 days or more of winter or spring waterlogging. This drop was more important with the winter waterlogging, due to the decrease in branch number (Fig. 1). The number of seeds per silique was lower when winter waterlogging lasted more than 3 days, both in the main and lateral branches. This component was not affected by spring waterlogging.

Seed number was affected more by winter than spring waterlogging, in main as well as lateral branches. Seed number on the main branch decreased when the winter waterlogging lasted more than 7 days. On lateral branches, seed number decreased with 3 days or more of winter waterlogging,

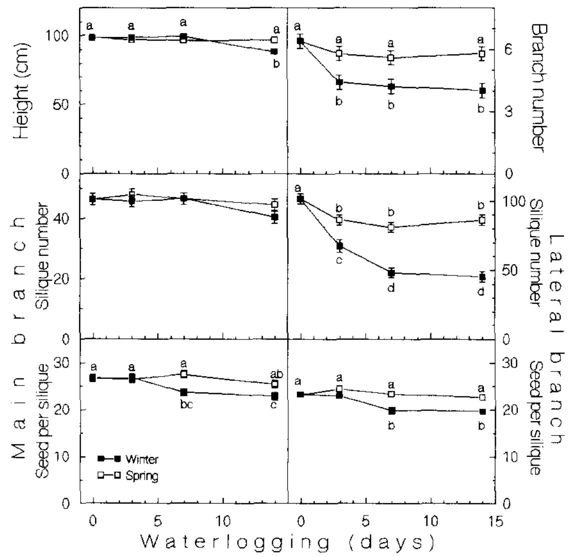

Fig. 1. Effect of waterlogging on rapeseed height and silique number and seeds per silique in main and secondary branches. Different letters denote significant differences ($P < 0.05$).

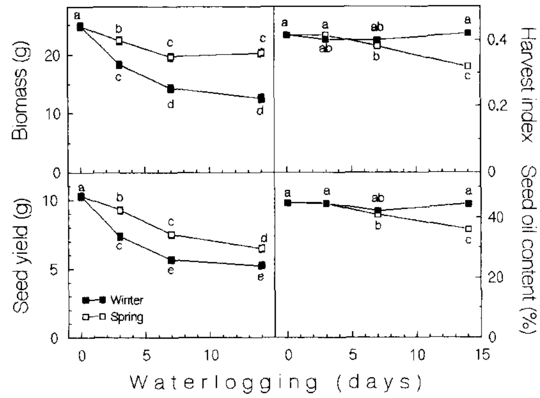

Fig. 2. Effect of waterlogging on plant biomass, harvest index, seed yield and oil content. Different letters denote significant differences ($P < 0.05$).

and from 7 days or more of spring flooding. Individual seed weight decreased in both main and lateral branches when the spring waterlogging was longer than 3 days but winter waterlogging did not affect this component (Fig. 2). Aboveground biomass and total seed yield declined with a waterlogging of 3 days. Both reductions were larger during winter (Fig. 2) but harvest index decreased only with spring waterloggings. In both seasons, seed yield of the main branch decreased with a waterlogging of 7 days. In the lateral branches, seed yield decreased with 3 days of waterlogging, but this was more important with the winter treatment. Spring waterlogging took place during seed filling and the main yield component affected was individual seed weight. Seed number was almost determined when the stress occurred, and it was only affected in the lateral branches, which were less developed when waterlogging started.

It is known that the higher temperature during waterlogging, the lower plant growth. This effect of temperature is seen when the impact of waterlogging in our winter experiment is compared with the results of Cannell and Belford (1980). The stress occurred at the same stage of development (B4), but the effect of winter waterlogging in our experiment was larger than with their observations. This difference might be explained by the lower temperature during the waterlogging period of their experiment (1–2°C), contrasted with ours (5.5–7.3°C), and with base growth temperature for rapeseed (5°C) (Morri-

Table 1
Effect of waterlogging on quantities of N, P, K, Ca and Na absorbed by rapeseed plants (mmol in dry weight of aboveground biomass plus seeds)

Treatment	Nutrient				
	N	P	K	Ca	Na
Control	46.8	2.2	16.2	7.7	1.2
Winter waterlogging – 7 days	22.8	1.4	9.1	6.1	0.7
Winter waterlogging – 14 days	22.7	1.2	8.5	4.4	0.8
Spring waterlogging – 7 days	33.8	1.4	12.6	4.4	8.4
Spring waterlogging – 14 days	26.6	1.5	12.1	4.9	8.1
Standard error	1.4	0.1	0.6	0.3	0.4

son et al., 1989). In our experiment, however, winter waterlogging caused a more significant reduction of yield than spring waterlogging. It reveals that temperature is not an absolute determinant: the stage of development and, consequently, the component of the yield affected, also determined the effects of waterlogging on crop yield.

Winter waterlogging did not affect oil content, whereas it declined with 7 days of waterlogging in spring (Fig. 2). The effect of waterlogging on nutrient concentration revealed the following: in aboveground biomass, nitrogen concentration decreased but the concentration of other nutrients was not affected whereas nutrient concentration of the seed did not change (data not shown). Sodium concentration increased with spring waterlogging. The absorbed quantities of N, P, K, Na and Ca in the aboveground biomass plus seeds are presented in Table 1. Waterlogging caused, except for Na, a decrease in nutrient uptake. As with the differences in biomass production, the uptake of some nutrients (N, K and Ca) was less with winter waterlogging than with spring treatment. The smaller nutrient uptake found in this experiment is quite common in plants subjected to waterlogging, and is due to the inhibition of the mechanisms of uptake and active transport of nutrients caused by the lack of O_2. Roots cannot produce the energy necessary to maintain these processes (Drew, 1988; Pezeshki, 1994). It seems that the plants did not become deficient, despite the restricted rooting volume. The nutrient concentrations in our flooded plants were similar to those in rapeseed grown in a field experiment at the same site and similar soil, but in non-flooded conditions (Urricariet et al., 1995). Comparing both conditions, there was no difference between plant and seeds in nutrient partitioning. In the case of sodium, waterlogging inhibits the mechanism that excludes it from roots (Drew, 1988) allowing an inflow of Na with transpirational water flow. This could explain why this effect was observed only during spring waterlogging, when the temperature was higher and the plants larger than during the winter period, and transpiration flow was presumably larger. The increase in Na concentration reduced the K/Na and Ca/Na ratios, which approximated but did not reach the threshold of Na toxicity for rapeseed (Porcelli et al., 1995). Na toxicity may therefore be discarded as cause of yield decline, even in the spring-waterlogged plants.

4. Conclusions

In these experimental and climatic conditions, rapeseed proved quite susceptible to waterlogging: yield was reduced with a waterlogging of only 3 days. Nutrient absorption was also reduced. Yield decline was due to the reduction of different yield components, depending on the developmental stage and time when the waterlogging occurred. In winter, it mainly decreased the number of seeds per plant, while in spring it decreased the individual seed weight. Yield reduction was greater with winter than spring waterlogging, although temperature was lower in winter. This result indicates that in field conditions, where crops are subjected to environmental changes as the season advances, the temperature during the flooded period is not the only factor determining the effects of waterlogging. The stage of development, when waterlogging occurred also needs to be considered.

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