Phyton (Horn Austria) Special issue: "Sulfur-Metabolism"	Vol. 32	Fasc. 3	(9)-(13)	18. 12. 1992

The Effect of Site and Foliar Sulfur on Oilseed Rape: Comparison of Sulfur Responsive and Non-responsive Seasons

By

E. J. BOOTH & K. C. WALKER[1)]

Key words: *Brassica napus*, foliar sulfur, glucosinolates, yield.

Summary

BOOTH E. J. & WALKER K. C. 1992. The effect of site and foliar sulfur on oilseed rape: comparison of sulfur responsive and non-responsive seasons. - Phyton (Horn, Austria) 32 (3): (9)-(13).

The effect of foliar sulfur application on the glucosinolate content and yield of a high glucosinolate and a low glucosinolate variety of winter oilseed rape was determined on both high and low sulfur sites. Results from two seasons were compared. At the low sulfur site, sulfur application had no effect on yield in the first, non sulfur responsive season, whereas in the second, sulfur responsive season, sulfur application more than doubled yield of both varieties. Yield at the high sulfur site was not influenced by sulfur application in either season. It is suggested that variations in yield response may be due to differences in the extent of root growth. In many cases glucosinolate content was increased by sulfur application, even when yield was not affected. The glucosinolate content of the high glucosinolate variety responded more to sulfur application than that of the low glucosinolate variety. The implications of these findings are discussed.

Introduction

Oilseed rape, now Scotland's most important non-cereal crop (WALKER & BOOTH 1992) has a higher sulfur requirement than most arable crops. The amount of sulfur received through atmospheric deposition in the UK declined by 34 % from 1970 to 1985 (UNSWORTH & FOWLER 1985) and continues to decline due to a reduction in the burning of fossil fuels. Coupled with this is a trend away from

[1)] The Scotish Agriculturul College (Aberdeen), 581 King Street, Aberdeen, AB9 1UD, Scotland.

using sulfur containing fertilisers. As a consequence, sulfur deficiency is becoming an increasingly common problem within northern Europe and there is a growing interest in the need to apply sulfur to achieve optimum yields.

EC policy has changed with regard to glucosinolates and there is now no encouragement for oilseed rape producers to seek to reduce glucosinolates by agronomic means. Never-the-less, glucosinolates remain important anti-nutritive factors and with the increased attractiveness of rapeseed as an animal feedstuff under the new EC regime, pig producers in particular require low glucosinolate rapeseed to allow maximum inclusion in feed rations.

It has been noted that sulfur deficiencies in crops appear greater in certain seasons than in others and that the effect of sulfur application on yield of oilseed rape varies from season to season (WETTER & al. 1970). The aim of this study was to compare the effect of sulfur application not only on yields but also on glucosinolates in sulfur responsive and non-responsive seasons at both high and low sulfur sites.

Materials and Methods

In each of the seasons that the trials took place, 1988 - 1989 and 1989 - 1990, sites were chosen to represent soils associated with sulfur deficient crops and non-sulfur deficient crops. In order to minimise any climatic and sulfur deposition differences, the sites were located in the same area in both seasons, but the same sites were not used consecutively in order to maintain good agronomic practice. Two varieties of winter sown oilseed rape (*Brassica napus*) were compared; Rafal, a high glucosinolate variety and Cobra, a low glucosinolate variety. In the first season, the trials were sown on 31 August 1988 and in the second season the trials were sown on 5 September 1989. Plot size used was 20 x 2.13 m. Standard husbandry practices (ANON 1985) with regard to fertiliser and agrochemical applications were employed in both seasons.

Sulfur treatments were applied as elemental sulfur (Thiovit - 80 % sulfur) on 14 March 1989 and on 27 March 1990, at the beginning of stem extension in each case. In the first season, the effects of 4 levels of sulfur fertiliser were investigated (0, 8, 16 and 32 kg ha^{-1} sulfur) and in the second season an additional treatment of 64 kg ha^{-1} was included. Treatments were randomised and 3 replicates for each sulfur treatment were included.

In order to confirm visual sulfur deficiency symptoms in 1990, leaf samples consisting of the uppermost fully differentiated 2 - 3 leaves per plant, were taken from plots of both varieties which had not received sulfur at the high and the low sulfur sites. The samples were assessed for total sulfur using the method of SCHNUG 1984.

Plots were desiccated on 20 July 1988 and on 25 July 1989 in the first and second seasons respectively, and harvested approximately 2 weeks later.

Yields were recorded and the total glucosinolate content was determined for a sample from each plot. For the samples harvested in 1989, glucosinolate content was assessed using the Unilever Colworth glucose release method (SMITH & DACOMBE 1987) and for samples harvested in 1990, the X-ray Fluorescence method was used (SCHNUG & HANNEKLAUS 1988).

As a result of the differences in the number of sulfur treatments assessed between the seasons, data for each season were statistically analysed separately. The trials also contained 2 different nitrogen treatments of 150 and 250 kg ha^{-1} in both years. In the work reported here, data from plots receiving the different nitrogen treatments were meaned. Analysis of variance was used for data analysis.

Results and Discussion.

No sulfur deficiency was seen at the low sulfur site in 1989. In 1990, symptoms - interveinal chlorosis of the leaves, stunting of the plant, pale flowers - were confirmed by leaf analysis as being due to sulfur deficiency. Total sulfur concentrations of Rafal and Cobra leaves were 2.57 mg g^{-1} DM and 2.11 mg g^{-1} DM respectively. In 1989, sulfur application had no effect on yield at the low sulfur site, contrasting with the following season when the higher sulfur applications were associated with a highly significant effect, more than doubling yield of both varieties (Table 1). Glucosinolate content was increased (significantly for Rafal) by sulfur application at a level of 16 kg ha^{-1} and above in 1989 and (non-significantly) in 1990 for both varieties (Table 1). The glucosinolate content of Rafal was affected more than Cobra in both years. At the high sulfur site, no sulfur deficiency was noted in either season and total sulfur concentrations of leaves from Rafal and Cobra were 4.46 mg g^{-1} DM and 4.66 mg g^{-1} DM respectively. Yield was not influenced consistently by sulfur application at the high sulfur site in the 1988/89 or the 1989/90 season (Table 2). However, glucosinolates were increased significantly in 1989 for both varieties and particularly for Rafal. In 1990 the glucosinolate content of Rafal only was increased (non-significantly) by sulfur application. In both years and for both varieties, in particular Rafal, the glucosinolate levels at the high sulfur site were far higher than the glucosinolate levels in the corresponding trial at the low sulfur site (Table 2).

Table 1. The effect of sulfur application on yield and glucosinolate content at the low sulfur site, over 2 seasons. Each data point is a mean of 6 measurements (1 per plot).

Sulfur application (kg ha^{-1})	Yield (t ha^{-1})				Glucosinolate content (μmol g^{-1} seed)			
	Rafal		Cobra		Rafal		Cobra	
	1989	1990	1989	1990	1989	1990	1989	1990
0	4.0	1.7	3.8	1.7	39	16	12	5
8	4.2	2.6	3.7	2.6	36	16	12	5
16	3.9	3.0	3.8	2.8	48	18	14	6
32	4.1	3.6	3.8	3.5	55	28	13	8
64	-	3.6	-	3.9	-	38	-	9
LSD (p=0.05) (between sulfur application means)	0.26	0.35	0.26	0.35	4.2	12.4	4.2	12.4

Table 2. The effect of sulfur application on yield and glucosinolate content at the high sulfur site, over 2 seasons. Each data point is a mean of 6 measurements (1 per plot).

Sulfur application (kg ha^{-1})	Yield (t ha^{-1})				Glucosinolate content (μmol g^{-1} seed)			
	Rafal		Cobra		Rafal		Cobra	
	1989	1990	1989	1990	1989	1990	1989	1990
0	3.6	4.5	3.6	4.8	68	68	27	14
8	3.8	5.1	3.4	4.8	73	66	28	17
16	3.7	4.6	3.4	4.8	76	71	27	14
32	3.6	5.1	3.6	4.8	78	69	33	16
64	-	4.6	-	4.5	-	72	-	16
LSD (p=0.05) (between sulfur application means)	0.23	0.34	0.23	0.34	3.6	5.0	3.6	5.0

The differences in response to sulfur in the 2 seasons were reflected by the general level of sulfur deficiency observed throughout the north of Scotland (SUTHERLAND K.G. personal communication). In the 1989/90 season, sulfur deficiency was observed more frequently than in the 1988/89 season, corresponding to the lack of sulfur deficiency in the 1988/89 trials and the severe sulfur deficiency at the low sulfur site in the 1989/90 season. Any doubt about whether the 1989 low sulfur site was actually low in sulfur was dispelled by examining the glucosinolate figures which show far lower levels in both varieties in the low sulfur site.

Root growth is known to be an important factor affecting nutrient uptake of plants and the variation in sulfur deficiency between seasons in this trial may be due in part to the extent of root growth. In the 1988/89 season, the mean monthly soil temperature was higher than in the 1989/90 season over the winter months of December, January and February by 1 - 2°C. Soil temperature was regarded as frequently having the dominant influence on root growth in a review by PAYNE & GREGORY 1988. An experiment by WALKER 1969 on maize demonstrated the sensitivity of root systems to changes in temperature; even a 1 °C change in soil temperature induced significant effects on growth and nutrient uptake. It is suggested that the lower soil temperature in the 1989/90 season led to poorer root growth and is thus possibly a major factor in the occurrence of sulfur deficiency in that season.

It was of interest that in many cases glucosinolate content was increased by sulfur application even when yield was not affected. With the lack of encouragement for growers to actively attempt to produce low glucosinolate rapeseed, applications of sulfur as an insurance policy against yield penalties may become larger and more frequent. Increases in glucosinolate content will have further implications when rapeseed is used in feed, particularly whole rapeseed in pig diets (GILL 1991).

Results from the non sulfur deficient season confirm previous findings from a sulfur deficient season (BOOTH & al. 1991) which indicated that the glucosinolate content of double low varieties respond less to sulfur application than that of single low varieties. The present work also agrees with other studies (MILFORD & EVANS 1991), which show that site has a large effect on glucosinolate content.

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Zeitschrift/Journal: Phyton, Annales Rei Botanicae, Horn

Jahr/Year: 1992

Band/Volume: 32_3

Autor(en)/Author(s): Booth E. J., Walker K. C.

Artikel/Article: The Effects of Site and Foliar Sulfur on Oilseed Rape: Comparison of Sulfur Responsive and Nonresponsive Seasons. 9-13