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Biomass Accumulation and Absorption of Photosynthetic Active Radiation by Rapeseed Plants Depending on Sulphur Fertilization

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Abstract: In the year 2002 in the Chylice Experimental Station there was a field experiment with double-low spring rapeseed cv. Licosmos conducted. The aim of the study was to evaluate the effect of sulphur fertilization on seed yield and some indicators of plant productivity such as PAR (photosynthetic active radiation) absorption, LAI (leaf area index), RGR (relative growth rate), dry aboveground biomass as well as chlorophyll content and its fluorescence. Two fertilization rates: 0 and 40 kg S per ha were applied in pure sulphur form in autumn. The results proved that sulphur fertilization significantly increased dry aboveground biomass but it did not influence seed yield. Sulphur also modified some physiological traits of the plants, which means plants fertilized with sulphur had higher PAR absorption at the end of flowering and lower maximal chlorophyll fluorescence compared with plants grown with no sulphur fertilization. Relative growth rate of plants from plots fertilized with sulphur was maximal in earlier growth stages compared with plants from plots without such fertilization. Sulphur fertilization delayed the development of leaves and their chlorophyll content initially, but this effect was indistinct at the end of flowering.

Key words: Spring oilseed rape · sulphur fertilization · biomass increment · PAR absorption

INTRODUCTION

Recently observed lower sulphur emission to the atmosphere decreased the amount of sulphur in soil and caused worse sulphur nutrition of crop plants. The symptoms of sulphur shortage appeared especially in *Brassicaceae* crops, e.g. rapeseed, which have high sulphur demand [1, 2]. High content of glucosinolates and sulphur amino acids is characteristic of rapeseed and other plants from the same family and consequently their sulphur demand is higher. Average rapeseed demand for sulphur is above 50 kg per ha which is much more than that of crops from families *Fabaceae* and *Chenopodiaceae* -20-50 kg S per ha or cereals and potatoes (20 kg S per ha) [3]. Sulphur is a controversial chemical element. On the one hand its surplus has negative effect on natural environment and causes its acidification, but on the other hand sulphur as elemental and necessary component of amino acids e.g. methionine and cysteine is a requisite for protein synthesis necessary for biomass growth. It is also a component of ferrodixine which is responsible for transfer of electrons during the first phase of photosynthesis (light-dependent reactions). Sulphur has profound effect on creating assimilation area absorbing PAR and as a consequence on yield of crops [4].

Evaluation of the effects of sulphur on biomass accumulation is possible by using modern measurement instruments able to estimate the state of photosynthetic structures, e.g.: Area of leaves and other green organs, PAR absorption, chlorophyll content and fluorescence quantum yield of photosystems [3, 5]. Total effect of sulphur fertilization can be estimated by using RGR index, which presents relative biomass increment rate [6, 7].

The aim of this study was to evaluate the effect of sulphur fertilization on indices of rapeseed productivity such as PAR absorption, LAI, chlorophyll content and its fluorescence as well as RGR and biomass accumulation in the aboveground organs.

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MATERIAL AND METHODS

In the year 2002 a field experiment with double-low spring rapeseed cv. Licosmos was conducted in the Chylice Experimental Station in a randomized complete-block design with four replications. Soils in the experiment were classified as *Mollic Gleysols* [8] formed of loamy sand of glacial origin with pH_{KCl} equal to 6.5 and winter wheat was the preceding crop. Mineral fertilization was applied in the following rates: 80 kg K_2O, 60 kg P_2O_5 and 80 kg N per ha and pure sulphur in two rates: 0 and 40 kg S per ha. Sowing was carried out on 16 April and after germination, mean plant density was equal to 60 plants per $1m^2$. Herbicide Butisan 400 SC and insecticide Fastac 10EC were used after sowing.

Biomass measurements were taken five times during vegetation period:

- 3 May - 37 DAS (days after sowing) - rosette stage (GS 15)
- 6 June - 51 DAS - stem elongation (GS 35)
- 21 June - 66 DAS - full flowering (GS 65)
- 2 July - 77 DAS - end of pod formation(GS 79)
- 9 August - 112 DAS - full ripeness (GS 89)

Harvest was preceded by chemical desiccation conducted using Reglone, 8 days before harvesting, which was carried out on August 9, 115 days after sowing. RGR was calculated on the basis of dry biomass accumulation in the aboveground organs of the plants.

The following measurements were taken in the field: Chlorophyll content was evaluated four times (51, 58, 66 and 77 DAS) with SPAD 502 Minolta; LAI values were measured twice (58 and 77 DAS) with LAI-2000 plant canopy analyzer and PAR absorption also twice using Li-191SA line quantum sensor. During bud formation stage, 58 days after sowing chlorophyll fluorescence was evaluated with Handy Pea portable fluorescence measurement system (Hansatech, UK); and the following parameters were determined: F_o - fluorescence level when plastoquinone electron acceptor pool (*Qa*) is fully oxidised; F_m - fluorescence level when *Qa* is transiently fully reduced; F_v/F_m maximum quantum efficiency of photosystem II and P_i - fluorescence index.

Statistical analysis was calculated using one-way ANOVA and multiple comparisons procedure (Tukey's method) at α=0.05 level. The statistical package Statgraphics 4.1 was used.

RESULTS

Sulphur fertilization had no effect on chlorophyll content in rapeseed leaves, except for the first measurement taken during stem elongation stage, 51 days after sowing (Table 1). Chlorophyll content was significantly lower (by 2.3%) for plants from plots fertilized with sulphur compared with plants from plots with no sulphur fertilization.

Main fluorescence parameters obtained in the experiment during bud formation stage, 58 days after sowing did not prove differences between fluorescence indices: *Pi* and *Fv/Fm* for plants with and without sulphur fertilization. However, values of *Fm* and *Fo* were higher for plant without sulphur fertilization and as far as the first index *Fm* is concerned, differences were significantly higher (Table 1).

Table 1: Relative chlorophyll content (SPAD) and chlorophyll fluorescence parameters in spring oilseed rape leaves depending on sulphur fertilization

	Days after sowing			
	51	58	66	77
	Developmental stages			
Sulphur fertilization (kg per ha)	Stem elongation	Bud formation	Full flowering	End of pod formation
	Chlorophyll content (SPAD)			
0	47.5	57.2	49.2	49.6
40	46.4	57.1	48.8	49.1
LSD $_{(\alpha=0,05)}$	0.77*	n.s.	n.s.	n.s.
Chlorophyll fluorescence parameters during bud formation stage - 58 DAS				
Sulphur fertilization	*Fo*	*Fm*	*Fv/Fm*	*Pi*
0	504	2607	0,805	3,38
40	462	2369	0,804	3,11
LSD$_{(\alpha=0,05)}$	n.s.	50,1**	n.s.	n.s.

F_o - fluorescence level when plastoquinone electron acceptor pool (*Qa*) is fully oxidised,
F_m - fluorescence level when *Qa* is transiently fully reduced
F_v/F_m maximum quantum efficiency of photosystem II and
P_i - fluorescence index

Table 2: PAR transmission (%) and leaf area index LAI of spring oilseed rape cv. Licosmos depending on sulphur fertilization

	PAR transmission		LAI	
Sulphur fertilization	Days after sowing		Days after sowing	
(kg per ha)	58	77	58	77
0	13	13	2,64	2.51
40	14	12	2,54	2.51
LSD$_{(\alpha=0,05)}$	n.s.	n.s.	n.s.	n.s.

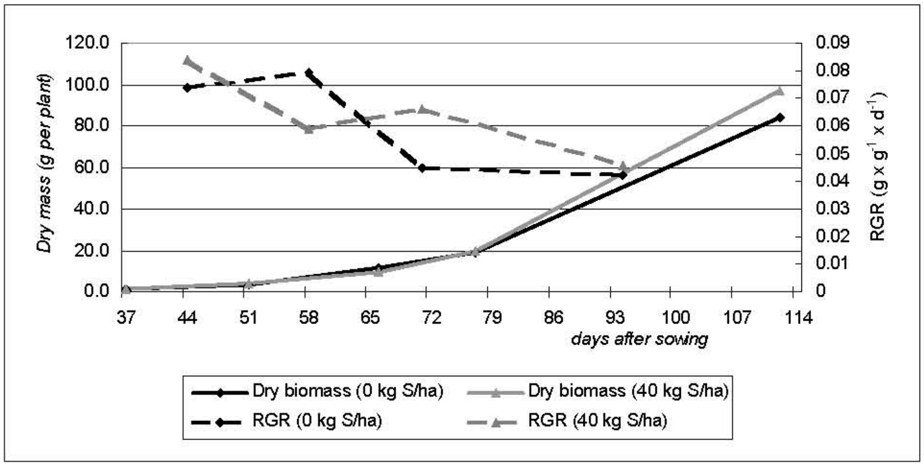

Fig. 1: Dynamics of increment of aboveground dry mass and changes of relative growth rate (RGR) of spring oilseed rape depending on sulphur fertilization

Sulphur fertilization had no effect on PAR transmission as well as LAI values in both measurements i.e. 58 and 77 days after sowing, during flowering and pod formation period (Table 2). However, slight positive tendency for PAR absorption and LAI stabilization as well as slight reduction of chlorophyll content with the same PAR absorption rate was observed for plants fertilized with sulphur.

Analyzing curves presenting the aboveground biomass accumulation, it is important to note, that plants from plots fertilized with sulphur accumulated more dry biomass compared with plants without sulphur fertilization (Figure 1). During first measurements (37, 51, 66 and 77 DAS) biomass accumulation was similar for plants with and without sulphur fertilization. Larger biomass accumulation was only observed at the end of plant development, when the aboveground dry biomass increment was 16% higher for plants fertilized with sulphur.

The highest values of RGR for plants fertilized with sulphur were observed during first measurement while for plants with no such fertilization the highest RGR values were noticed during second measurement. After this stage, strong decrease of RGR was observed and finally, since third measurement that index stabilized. RGR curves indicate different patterns of biomass accumulation for plants with and without sulphur fertilization.

DISCUSSION

The above-described experiment proved that sulphur fertilization increased the aboveground dry biomass of spring oilseed rape by 16% percent but it did not influence the seed yield.

Sulphur fertilization modified the growth of plants as follows: plants fertilized with sulphur absorbed slightly more PAR at the beginning of July than plants without sulphur fertilization and over the first days of June their maximal fluorescence (*Fm*) was lower. During the early developmental stages, sulphur fertilization had negative effect on the growth of leaves and chlorophyll content, but this negative effect was not visible during further developmental stages. Probably, plants did not lack sulphur during the first phase of growth up to flowering independently of fertilization, but during further developmental stages plants fertilized with sulphur reach better physiological state, which is proved by: chlorophyll content, lower values of *Fo* and higher values of *Fm* (informing about lower PAR absorption by photosystems). As a consequence, biomass accumulation increased more rapidly and values of RGR in the late developmental stages were higher for plants fertilized with sulphur compared with respective values for plants with no sulphur fertilization. As a result, final dry biomass of fertilized plants was significantly higher. Larger decrease of LAI values at the end of vegetation period for plants with no sulphur fertilization indicates quicker leaves decay.

Results of previous research conducted in Polish conditions in the years 1969-1974 [9] indicate positive effect of sulphur fertilization on yield of rapeseed and seed quality. However, observed effect was rather marginal and significant only on worse soils. Similar results were obtained in the 80's and 90's of 20th century [10]. They observed that weak reaction of double-low rapeseed cultivar to sulphur fertilization.

Positive effect of sulphur on seed yield and its quality is visible and significant when sulphur content in soil is low [11-13]. Analogically, sulphur fertilization does not influence the yield when sulphur content in soil is quite high [14].

CONCLUSIONS

Sulphur fertilization delayed the development of leaves and their chlorophyll content in early developmental stages, but this negative effect disappeared in later growth stages. Plants fertilized with sulphur absorbed larger amount of PAR during later growth stages and their maximal fluorescence (*Fm*) was lower compared with plants with no sulphur fertilization.

Sulphur enabled higher efficiency of photosynthesis: Relative Growth Rate (RGR) of plants fertilized with sulphur showed earlier maximum in comparison with plants with no sulphur fertilization. Sulphur fertilization had significant positive effect on biomass accumulation but it did not influence the seed yield.

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