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Effects of Nitrogen and Foliar Sulphur Interaction on Grain Yield and Yield Components in Barley

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With 4 figures and 6 tables

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Abstract

In this study, conducted from 1979 to 1986 in southern Spain, the objective was to analyze the effects of a possible interaction between soil-applied N and foliar S applied to barley (Hordeum vulgare L.) during tillering on grain yield and to identify the mechanism involved. From 1979 to 1982, we used rates of 20, 40, 60 and 80 kg a.i. N ha^{-1}, together with 12.5 or 25 kg foliar a.i. S ha^{-1} during tillering. The results demonstrated that foliar S at both dosages acted as a partial (but not total) substitute for N, when the latter was applied at levels of 40 to 60 kg ha^{-1}. These effects of S did not appear to result only from a nutritive mechanism, but rather from a hormonal mechanism through the increase in ethylene biosynthesis. Therefore, during 1983 to 1986, we used 40, 60 and 80 kg a. i. N ha^{-1}, together with 12.5 a. i. S ha^{-1} and 0.55 kg a.i. ethrel (2-chloroethyl-phosphonic acid) ha^{-1}. The results showed that the effects of S and ethrel on yield were practically the same. Assayed with 40 and 60 kg N ha^{-1}, S and ethrel acted as partial (but not total) substitutes for N, exceeding the yield of the control without S or ethrel, and equalling the yield obtained with 20 kg more of N ha^{-1}. The S or ethrel applied with 80 kg N ha^{-1} presented an additive effect with the N. The increases in yield using S or ethrel were in all cases due to the increased final number of spikes m^{-2}, which was principally a consequence of the higher number of tillers formed but also a result of increased survival of tillers to form a viable spike. In addition, the positive effects of S on yield were greater the smaller the N dosage and the lower the annual yield. Finally, we present a possible mechanism of hormonal action, to explain how foliar S applied during tillering affects grain yield in barley.

Key words: Barley — foliar ethrel — foliar S — grain yield — soil-applied N

Introduction

Traditionally, in most crops, elemental sulphur has been used as an insecticide and fungicide, although it has been demonstrated to boost grain yield in cereals in areas where the soil application of S is less than the requirements of the crop (Noggle et al. 1986). In many areas of Europe, the change in the use of fertilizers from calcium or ammonium sulphates to others that contain little or no S have lead to S deficiencies in the soil, although atmospheric S can sometimes suffice to ensure adequate crop yield (Scott et al. 1984). Positive interactions of foliar S with soil-applied N have reportedly augmented yield to over control levels in different cereals (Eppendorfer 1968, Griffiths et al. 1995). This higher yield could be explained by increases in tillering or in the number of kernels per spike, suggesting a hormonal effect of S, through increased methionine in the vegetative tissues (Recalde Manrique and Díaz Miguel 1981). This amino acid is a recognized precursor in the biosynthesis of ethylene, one of the regulatory hormones of plant growth.

Many responses have been noted in barley after applying foliar ethephon or ethrel (2-chloroethyl-phosphonic acid), depending fundamentally on the environmental conditions and application timing (Foster and Taylor 1993). Application during tillering increases the number of tillers per plant (Lauer 1991, Ma and Smith 1992d), decreases the number of kernels per spike (Ma and Smith 1991, Moes and Stobbe 1991c) and usually has little effect on kernel weight or on yield (Ma and Smith 1992b). Ethephon used on barley as a top-dressing decreases the tiller height (Simmons et al. 1988, Ma and Smith 1992c), reducing lodging and diminishing serious economic losses (Moes and Stobbe 1991a, Bulman and Smith 1993). Finally, ethrel appears to be useful as a male gametocide when applied at the pre- and post- meiotic stages of pollen formation in barley (Colhoun and Steer 1982). The effects of a foliar application of ethrel have been ascribed to increased ethylene biosynthesis in plant tissues (Foster et al. 1992).

Table 1: Annual rainfall and analytical values for soils in southern Spain from 1979 to 1986

Year	Rainfall (mm)	Sand (%)	Silt (%)	Clay (%)	pH	O.M. (%)	Total N (%)	P ($g\ mg^{-1}$)	K ($g\ mg^{-1}$)
1979	340	25.7	42.1	32.2	7.7	1.5	0.12	19	245
1980	479	26.5	44.0	29.5	7.7	2.0	0.14	18	310
1981	394	27.7	41.8	30.5	7.7	1.8	0.13	19	340
1982	326	28.0	41.9	30.1	7.6	1.6	0.11	17	278
1983	310	25.4	42.6	32.0	7.5	1.5	0.10	19	282
1984	423	24.6	42.0	33.4	7.6	2.0	0.14	22	310
1985	480	26.6	42.9	30.5	7.5	1.9	0.16	20	290
1986	450	23.7	45.7	30.6	7.7	2.0	0.15	19	275

In this work, we present (i) the results of partial replacement of nitrogenous fertilizers by foliar sulphur during tillering in barley grown from 1979 to 1986 under Mediterranean conditions, and (ii) an explanation of the possible hormonal effect of foliar S on grain yield in this cereal.

Materials and Methods

Field experiments were carried out from 1979 to 1986 using the spring barley cultivar Pallas, at different sites in a Mediterranean environment (southern Spain). At all the sites, the soils were fine loamy, carbonatic, thermic, Calcicerollic Xerocrept, with very similar characteristics (Table 1). Plot size was 100 m^2, separated by uncultivated pathways 1 m wide from 1979 to 1984. In 1985 and 1986, each plot was 10 m long and 1.2 m wide with six rows, 20 cm apart. Each year the cultivar was sown at a rate of 120 kg ha^{-1} at the end of November, and harvested at the end of June. All plots received 18 kg of P ha^{-1} and 25 kg of K ha^{-1} at sowing. Information concerning statistical designs and nitrogen, sulphur and ethrel (2-chloroethyl-phosphonic acid) treatments is presented in Table 2.

During the Zadoks growth stages 37–39 (Zadoks et al. 1974), samples of between 20 and 30 plants per plot in each year were taken. In the laboratory, six representative plants per plot were selected to establish the mean number of stems per plant. At harvest, the following parameters per plot were also recorded: (a) number of spikes m^{-2}, determined by using a wooden quadrat from 1979 until 1984, and by counting the number of spikes in one 50-cm-long row during 1985 and 1986; (b) number of spikes per plant (mean of 10 plants per plot); (c) number of kernels per spike (mean of 10 plants per plot); and (d) mean weight of 1000 kernels. Grain was harvested with a plot combine and adjusted to 120 g kg^{-1} moisture.

The data were analysed using correlation and regression techniques. After analysis of variance, the differences between means were compared by the least significant difference test (Statgraphics 1992).

Results and Discussion

The analysis of variance (Table 3) showed that the year affected all the parameters studied, except final survival of the spikes in 1979 and 1980. The treatments (Table 3) influenced grain yield, number of spikes m^{-2}, the number of tillers per plant at the end of tillering, the number of spikes per plant at harvest and the final survival of spikes in all years. The interaction year × treatment (Table 3) was significant for the number of spikes m^{-2} and the final survival of spikes per plant at harvest and the final survival of spikes in 1981 and 1982; and for grain yield, number of spikes m^{-2}, weight per 1000 kernels, number of spikes per plant at harvest and final survival of spikes for the experiments carried out from 1983 to 1986.

In all years (Tables 4, 5 and 6), grain yield rose significantly with increasing N rates, the highest values being registered for the treatments with 80 kg N ha^{-1}, followed by the treatments with 60 kg N ha^{-1} and finally by those of 40 and 20 kg N ha^{-1}. The greatest increase in grain yield was due to a single yield component, number of spikes m^{-2}. Variations in the number of spikes m^{-2} were also responsible for increases in grain yield obtained for both barley (García del Moral et al. 1991, Ramos et al. 1995) and triticale (Ramos et al. 1993, García del Moral et al. 1995) grown in the same area.

During 1979 and 1980 (Table 4), 12.5 kg S ha^{-1} applied at tillering or at shooting in plots with 20 or 80 kg N ha^{-1} had no positive effect on grain yield with respect to control without S. Nevertheless, applying 12.5 kg S ha^{-1} at tillering to plots with 60 kg N ha^{-1} significantly increased grain yield compared with control without S or with 12.5 kg S ha^{-1} as a top-dressing (Table 4).

In 1981 and 1982 (Table 5), the S treatments of

Table 2: Statistical design and nitrogen, sulphur and ethrel treatments for spring barley field trials in southern Spain from 1979 to 1986

Year	Statistical design	Replications	N applied at		S[3] applied at		E[4] applied at
			sowing[1]	tillering[2]	tillering	shooting	tillering
			(kg a.i. ha^{-1})		(kg a.i. ha^{-1})		(kg a.i. ha^{-1})
1979–80	randomized blocks	4	20	–	–	–	–
			20	–	12.5	–	–
			20	–	–	12.5	–
			30	30	–	–	–
			30	30	12.5	–	–
			30	30	–	12.5	–
			40	40	–	–	–
			40	40	12.5	–	–
			40	40	–	12.5	–
1981–82	randomized blocks	4	20	20	–	–	–
			20	20	12.5	–	–
			20	20	25	–	–
			30	30	–	–	–
			30	30	12.5	–	–
			30	30	25	–	–
			40	40	–	–	–
			40	40	12.5	–	–
			40	40	25	–	–
1983–84 –85–86	randomized blocks	4	20	20	–	–	–
			20	20	12.5	–	–
			20	20	–	–	0.55
			30	30	–	–	–
			30	30	12.5	–	–
			30	30	–	–	0.55
			40	40	–	–	–
			40	40	12.5	–	–
			40	40	–	–	0.55

[1] Ammonium sulphate (21 %).
[2] Ammonium nitrosulphate (26 %).
[3] Elemental sulphur (80 %).
[4] Ethrel (48 %).

12.5 and 25 kg ha^{-1} at tillering improved the grain yield of all N treatments with respect to control without S.

From the results of these 4 years, we deduce the following.

1. Foliar S applied at 12.5 or 25 kg ha^{-1} during tillering increased grain yield when N was applied at 40 and 60 kg ha^{-1}. With treatments of 80 kg N ha^{-1}, however, S exerted a positive effect only in low-yield years.
2. The action of S during tillering coincided with that of N, significantly increasing the number of spikes m^2, but without altering the number of kernels per spike or the mean weight of 1000 kernels.
3. S applied at tillering in plots without N had no effect on grain yield, compared with control, as reported in studies on corn and wheat (Rabuffeti and Kamprath 1977, Spencer and Freney 1980).
4. The application of S at shooting did not statistically alter grain yield.

The effects of S applied during tillering did not appear to involve only a nutritive mechanism, such as correcting a soil deficiency in this element. In fact, the action of S did not depend on the dosage used (12.5 or 25 kg ha^{-1}) and, furthermore, the residual

Table 3: Mean square values and significance of analysis of variance for grain yield, yield components, stems per plant at the end of shooting, spikes per plant at harvest and spike survival in spring barley field trials in southern Spain from 1979 to 1986

Source	d.f.	Grain yield (kg ha^{-1})	Spikes m^{-2} (no.)	Kernels per spike (no.)	Mean weight of 1000 kernels (g)	Stems at end of shooting (no.)	Spikes at harvest (no.)	Spike survival (%)
1979–80								
Year (Y)	1	5489089**	32088**	893.24**	38.89**	6.24**	3.83**	35.0
Blocks	6	5737	72	0.37	2.08	0.11	0.13	47.2
Treatment (T)	8	1975072**	9330**	0.62	2.14	1.21**	1.88**	401.3**
Y × T	8	9389	314**	1.04	1.29	0.03	0.02	55.7*
Error	48	29137	98	0.87	1.12	0.10	0.06	28.1
CV (%)		9	6	4	3	10	11	7
1981–82								
Year (Y)	1	10457689**	58254**	174.22**	221.90**	14.58**	20.37**	3700.1**
Blocks	6	22593	40	1.20	1.45	0.15	0.03	9.9
Treatment (T)	8	419439**	3593**	0.30	0.89	1.01**	0.95**	118.7**
Y × T	8	17639	241**	0.59	1.30	0.11	0.12*	88.0**
Error	48	22443	79	0.74	1.10	0.07	0.05	14.2
CV (%)		9	5	4	3	8	10	5
1983–84–85–86								
Year (Y)	3	45722133**	232552**	166.96**	787.54**	20.38**	20.26**	2657.5**
Blocks	12	12993	55	0.47	0.45	0.03	0.03	9.6
Treatment (T)	8	1820486**	15199**	0.72	0.16	1.85**	1.95**	237.5**
Y × T	24	86708**	524**	1.12	1.29**	0.08	0.10**	40.0**
Error	96	27039	67	0.91	0.35	0.06	0.05	11.2
CV (%)		6	4	4	2	7	9	5

*, ** Significant at the 0.05 and 0.01 levels of probability, respectively.

sulphates applied with nitrogen fertilizers appeared to be adequate to cover the nutritive needs of the crop in terms of S. Therefore, we consider the action of S applied at tillering to be more hormonal that nutritive, since it is well known that elemental S is absorbed by the leaves both in the form of vapour and as SO_2, being quickly metabolized and incorporated by sulphated amino acids and proteins (Turrel and Weber 1955, Legris-Delaporte et al. 1987). This S could increase the methionine content in the plant, an amino acid recognized as a precursor in ethylene biosynthesis, which could raise the levels of this endogenous phytohormone, this rise accounting for the effects noted in the final number of spikes and in grain yield.

To test the above hypothesis, from 1983 to 1986 we applied foliar S and ethrel during tillering to plots with 40, 60 and 80 kg of N ha^{-1}. The results with 12.5 kg S ha^{-1} and 0.55 kg a.i. ethrel ha^{-1} (Table 6) were practically the same: (a) assayed together with 40 and 60 kg N ha^{-1}, the S and ethrel applications significantly increased yield and number of spikes m^{-2} over control and equalled the yield obtained with 20 kg more of N ha^{-1} (Table 6); (b) applied together with 80 kg N ha^{-1}, S and ethrel applications significantly increased yield and the final number of spikes m^{-2} in relation to control without S or ethrel, although this apparently occurred only in years of depressed grain yield (Table 6).

Given that, in all years, the variations in grain yield caused by the N, S and ethrel treatments were explained only by the final number of spikes m^{-2}, we analysed the number of tillers per plant at the end of shooting (stages 37–39 of Zadoks et al. 1974), the final number of spikes per plant and the final percentage of spike survival. The aim was to determine whether the effect of S during tillering on the final number of spikes was due to an increase in the number of tillers formed or to their survival to produce more spikes at harvest, or to both. The results indicated that, during 1979 and 1980 (Table

Table 4: Mean values of grain yield, yield components, stems per plant at the end of shooting, spikes per plant at harvest and spike survival in response to N and S treatments and years in spring barley field trials in southern Spain during 1979 and 1980

Variable				Grain yield (kg ha^{-1})	Spikes m^{-2} (no.)	Kernels per spike (no.)	Mean weight of 1000 kernels (g)	Stems at end of shooting (no.)	Spikes at harvest (no.)	Spike survival (%)
Treatment										
Ns	Nt	St	Ssh[1]							
20	–	–	–	1265c[2]	128d	22.5a	32.1a	2.55c	1.64c	64.4b
20	–	12.5	–	1350c	133d	22.3a	31.5a	2.60c	1.68c	64.0b
20	–	–	12.5	1305c	128d	22.1a	30.7a	2.53c	1.65c	65.4b
30	30	–	–	1985b	175c	23.0a	31.3a	3.01b	2.30b	76.3a
30	30	12.5	–	2345a	203ab	22.4a	31.6a	3.41a	2.70a	79.3a
30	30	–	12.5	2055b	178c	22.8a	31.7a	2.96b	2.24b	75.5a
40	40	–	–	2385a	198b	22.7a	30.4a	3.38a	2.69a	79.7a
40	40	12.5	–	2430a	203ab	22.5a	31.1a	3.36a	2.70a	80.4a
40	40	–	12.5	2340a	208a	22.7a	31.2a	3.43a	2.71a	79.2a
Year										
1979				1658b	151b	19.0b	29.9b	2.73b	2.03b	73.1a
1980				2210a	193a	26.0a	32.7a	3.32a	2.49a	74.5a

[1] Ns = nitrogen at sowing; Nt = nitrogen at tillering; St = sulphur at tillering; Ssh = sulphur at shooting.
[2] Within treatments and years, means followed by the same letter do not differ significantly at the 0.05 probability level using the least significant difference test.

Table 5: Mean values of grain yield, yield components, stems per plant at the end of shooting, spikes per plant at harvest and spike survival in response to N and S treatments and years in spring barley field trials in southern Spain during 1981 and 1982

Variable			Grain yield (kg ha^{-1})	Spikes m^{-2} (no.)	Kernels per spike (no.)	Mean weight of 1000 kernels (g)	Stems at end of shooting (no.)	Spikes at harvest (no.)	Spike survival (%)
Treatment									
Ns	Nt	St[1]							
20	20	–	1165d[2]	137e	23.1a	31.0a	2.63c	1.65d	62.1d
20	20	12.5	1475c	165c	23.3a	31.6a	2.93b	2.03c	68.0bc
20	20	25	1455c	160cd	23.1a	31.1a	2.88bc	1.99c	68.0bc
30	30	–	1445c	153d	23.3a	31.5a	2.83bc	1.89c	65.2cd
30	30	12.5	1755b	182b	23.4a	31.3a	3.38a	2.31b	67.2bc
30	30	25	1720b	187b	22.9a	31.2a	3.40a	2.40b	69.3b
40	40	–	1705b	180b	23.6a	31.9a	3.45a	2.44ab	69.6b
40	40	12.5	1840a	199a	23.3a	30.8a	3.56a	2.64a	73.6a
40	40	25	1850a	198a	23.4a	31.5a	3.51a	2.63a	74.5a
Year									
1981			1220b	145b	21.7b	33.1b	2.72b	1.69b	61.4a
1982			1982a	202a	24.8a	29.5a	3.62a	2.75a	75.8a

[1] Ns = nitrogen at sowing; Nt = nitrogen at tillering; St = sulphur at tillering.
[2] Within treatments and years, means followed by the same letter do not differ significantly at the 0.05 probability level using the least significant difference test.

Table 6: Mean values of grain yield, yield components, stems per plant at the end of shooting, spikes per plant at harvest and spike survival in response to N, S and ethrel treatments and years in spring barley field trials in southern Spain from 1983 to 1986

Variable				Grain yield (kg ha^{-1})	Spikes m^{-2} (no.)	Kernels per spike (no.)	Mean weight of 1000 kernels (g)	Stems at end of shooting (no.)	Spikes at harvest (no.)	Spike survival (%)
Treatment										
Ns	Nt	St	Et[1]							
20	20	–	–	1395d[2]	158e	25.5a	34.6a	2.85d	1.75d	60.4f
20	20	12.5	–	2375c	198cd	25.1a	34.7a	3.22c	2.22c	67.4de
20	–	–	0.55	2389c	203c	25.7a	34.6a	3.26c	2.24c	67.7de
30	30	–	–	2400c	193d	25.2a	34.4a	3.22c	2.15c	65.4e
30	30	12.5	–	2805b	229b	25.5a	34.6a	3.60b	2.58b	70.1bc
30	30	–	0.55	2775b	231b	25.5a	34.6a	3.58b	2.59b	71.2ab
40	40	–	–	2775b	230b	25.5a	34.4a	3.63b	2.54b	68.8cd
40	40	12.5	–	2940a	252a	25.6a	34.6a	3.84a	2.80a	72.4a
40	40	–	0.55	2938a	253a	25.1a	34.6a	3.89a	2.84a	72.6a
Year										
1983				1224d	126d	22.3d	27.6c	2.43d	1.53d	62.5b
1984				2149c	173c	26.7a	37.0a	3.44c	2.08c	59.7c
1985				3724a	298a	26.9a	37.4a	4.20a	3.19a	75.7a
1986				3271b	269b	25.8b	36.2b	3.76b	2.86b	75.9a

[1] Ns = nitrogen at sowing; Nt = nitrogen at tillering; St = sulphur at tillering; Et = ethrel at tillering.
[2] Within treatments and years, means followed by the same letter do not differ significantly at the 0.05 probability level using the least significant difference test.

4), the application of 12.5 kg S ha^{-1} during tillering in plots with 60 kg N ha^{-1} significantly increased the final number of spikes per plant with respect to control without S or when S was applied at shooting. This increase was due principally to the higher number of tillers per plant at the end of shooting, and, to a lesser degree, to their increased survival to form spikes at harvest (Table 4).

In 1981 and 1982 (Table 5), the S treatments during tillering at the two rates, when accompanied by 40 and 60 kg N ha^{-1}, significantly increased the final number of spikes per plant, due both the greater number of tillers per plant at the end of shooting and to their increased survival to form spikes at harvest. Nevertheless, in the treatments with 80 kg N ha^{-1}, the S application at either of the two rates increased the final number of spikes, due more to tiller survival than to the number of tillers at the end of shooting (Table 5).

From 1983 to 1986, the effect of the S and ethrel treatments during tillering at all N levels, in relation to control, was due to the higher number of tillers per plant at the end of shooting and to their increased survival to form spikes at harvest (Table 6). Many authors (Simmons et al. 1988, Lauer 1991, Stobbe et al. 1992) indicated that ethrel or ethephon increases the final number of spikes in barley by reducing senescence of the secondary tillers formed at the beginning of development, although Moes and Strobbe (1991b) found that survival of these secondary tillers was not enhanced by ethephon. Evidence from other studies (Foster et al. 1991) suggests that environmental moisture during the treatment can be crucial to the growth and survival of young tillers.

The effects of S applied during tillering on grain yield are represented in Figs 1, 2 and 3. These Figures show that the percentage increase in grain yield due to S applied at tillering depended significantly on the yield attained each year at each N dosage. Thus, at 40 kg N ha^{-1} (Fig. 1), with the addition of 12.5 kg S ha^{-1}, yield exceeded that of control by at least 20 % in years of medium or high grain yield, and from 40 by 80 % in years of low yield. With 12.5 kg S ha^{-1} together with 60 kg N ha^{-1} (Fig. 2), yield rose above control values by about 30 % in low-yield years, whereas in years producing more than 2500 kg ha^{-1}, S only slightly increased yield. Finally, with 80 kg N ha^{-1} (Fig. 3), S applied at tillering increased grain yield over control only in

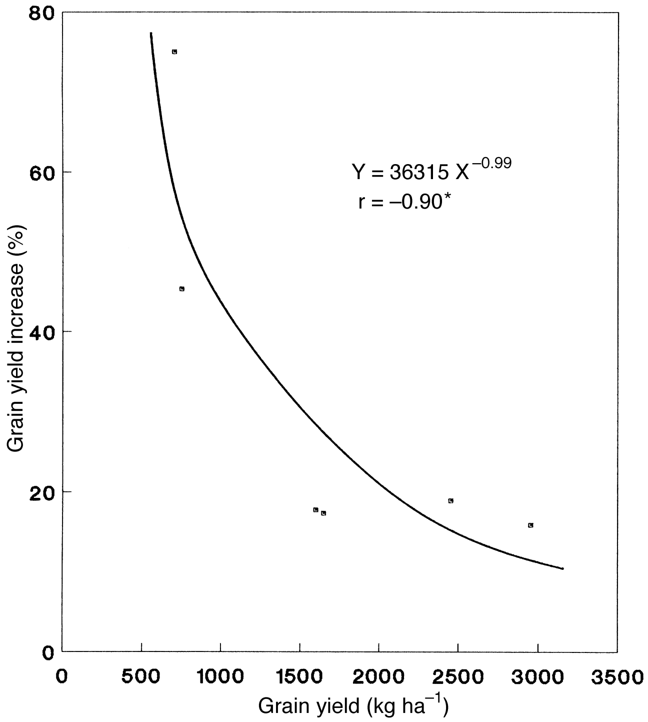

Fig. 1: Regression of percentage increase in grain yield obtained in barley by applying foliar S at 12.5 kg ha^{-1} and 40 kg N ha^{-1}, in comparison with control without S

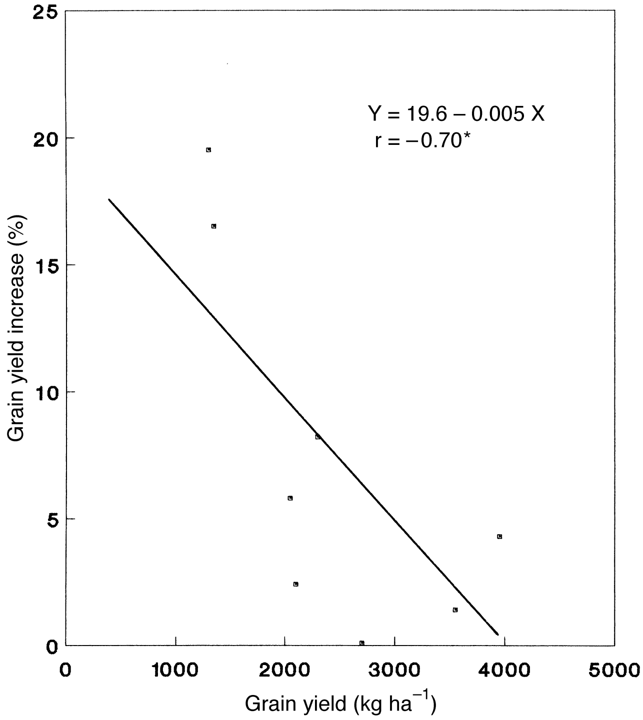

Fig. 3: Regression of percentage increase in grain yield obtained in barley by applying foliar S at 12.5 kg ha^{-1} and 80 kg N ha^{-1}, in comparison with control without S

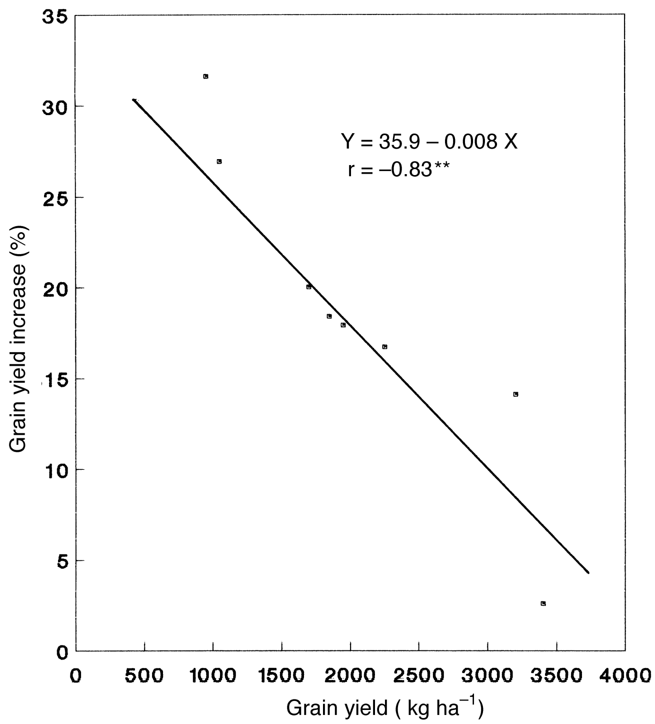

Fig. 2: Regression of percentage increase in grain yield obtained in barley by applying foliar S at 12.5 kg ha^{-1} and 60 kg N ha^{-1}, in comparison with control without S

years with yield under 1500 kg ha^{-1}. In years with grain yield over 2000 kg ha^{-1}, the percentage increase in yield by S was quite low.

The close parallel between the results obtained with foliar S and ethrel during tillering supports the idea that the action of S is principally hormonal, by increasing ethylene biosynthesis, as would result from ethrel applications. Figure 4 presents a scheme of the possible mechanism of the hormonal action of S and ethrel applied at tillering. Currently, ethylene is believed to modulate and activate the other hormones in plants: auxins, gibberellins and cytoquinines. Ethylene antagonizes the synthesis and polar transport of auxins (Sachs and Hackett 1972, Evans 1984), thereby diminishing apical dominance and thus stimulating tillering by permitting greater development of lateral buds (Stoskopf and Law 1972, Ma and Smith 1992a). Ethylene has also been demonstrated to depress the action of gibberellins (Scott and Leopold 1967), shortening the stem in cereals (Sachs and Hackett 1972) and increasing the number and diameter of the vascular bundles in the tillers (Zaher et al. 1973). Ethylene is also a synergic agent of cytokinines (Lau and Yang 1973), and thus its application could stimulate root growth (Bragg et al. 1984). As each new tiller develops its own

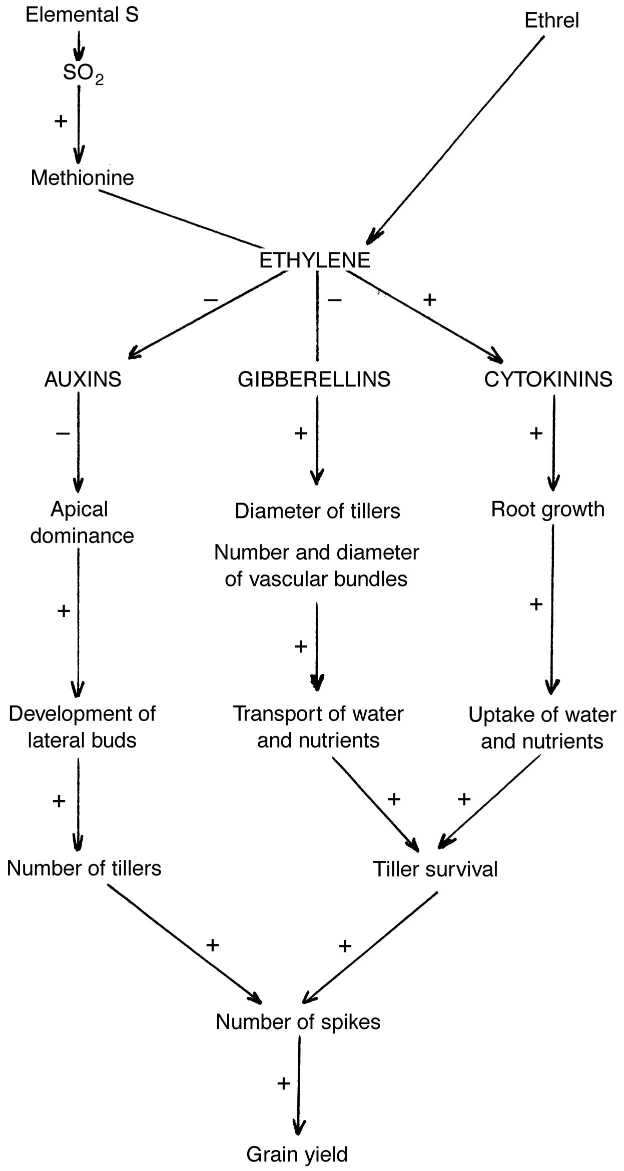

Fig. 4: Scheme of the possible hormonal mechanism of S and ethrel for the increase in the number of spikes and grain yield in barley. +, stimulation; −, depression

root system, which in turn supplies the necessary nutrients and water, production of a greater quantity of roots would enable better use of soil resources, especially under unfavourable or dry conditions (Welbank et al. 1974).

As a consequence of the modulating action described above, one early foliar application of S in barley can stimulate the formation of a high number of tillers with a strong capacity for using the available water resources and, therefore, the plant would be better adapted to survive and produce spikes in dry environments. This fact could explain the increases found with these applications in the number of final spikes and hence in the final grain yield.

Zusammenfassung

Stickstoff- und Blattschwefelinteraktion hinsichtlich der Wirkungen auf den Kornertrag und die Ertragskomponenten bei Gerste

In dieser Untersuchung in den Jahren 1979–1986 im südlichen Spanien, wurde die mögliche Interaktion zwischen einer Bodenanwendung von N und Blattanwendung von S bei Gerste (*Hordeum vulgaris* L.) während der Bestockung hinsichtlich der Wirkungen auf den Kornertrag und die zugrundeliegenden Mechanismen untersucht. Von 1979–1982 verwendeten wir Mengen von 20, 40, 60 und 80 kg N/ha zusammen mit 12,5 bzw. 25 kg Blattanwendung von S/ha während der Bestockung. Die Ergebnisse zeigen, daß die Blattanwendung von S in beiden Anwendungsmengen wirkte als ein Teil- aber nicht Gesamtsubstitut für N, wenn N mit Mengen von 40–60 kg/ha angewendet wurde. Diese Wirkungen von S scheinen nicht eine Folge des Ernährungsmechanismus, sondern hormoneller Mechanismen über eine Erhöhung der Äthylenbiosynthese zu sein. Daher verwendeten wir während der Jahre 1983–1986 40, 60 und 80 kg N/ha zusammen mit 12,5 kg S/ha und 0,55 kg Ethrel (2-Chlorethylphosphonsäure)/ha. Die Ergebnisse zeigen, daß die Wirkungen von S und Ethrel auf den Ertrag praktisch gleich sind. Anwendungen von 40 und 60 kg N/ha, S und Ethrel wirkten als teil- (aber nicht Gesamt-) Substitute für N und übertrafen den Ertrag der Kontrolle ohne S oder Ethrel, waren aber vergleichbar mit dem Ertrag, der mit 20 kg N/ha oder mehr erzielt wurde. Die Anwendung von S oder Ethrel mit 80 kg N/ha ergab eine additive Wirkung hinsichtlich des N. Die Erhöhungen des Ertrages unter Verwendung von S oder Ethrel waren in allen Fällen eine Folge der erhöhten Anzahl von Ähren/m^2, wobei dies eine Folge der größeren Anzahl von Bestockungstrieben und weniger des Überlebens von befruchtungsfähigen Ähren war. Ferner erwiesen sich die positiven Wirkungen von S auf den Ertrag um so größer je geringer die N-Anwendung und je geringer der Ähresertrag war. Schließlich geben wir eine mögliche Erklärung für eine hormonelle Wirkung, wie die Blattanwendung von S in der Phase der Bestockung den Kornertrag bei Gerste beeinflußt.

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