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Inhibition of spinach bolting by growth regulators

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Abstract

Spinach (*Spinacia oleracea* L.) plants must be harvested during a short period of time because they bolt just after producing some edible leaves. Maleic hydrazide (MH) and its commercial preparation "Antyrost" were found to inhibit bolting very strongly. The preparation Off-shoot-O showed very weak activity in suppressing bolting but diminished markedly the resistance of spinach plants to fungus diseases. Triiodobenzoic acid stimulated bolting, and the retardant succinic acid-2-2-dimethylhydrazide (SADH) did not affect bolting. Application of MH to inhibit spinach bolting cannot be recommended in practice before investigating the residues of this compound in leaves.

Spinach is a plant with a very short period in which it can be harvested. Very shortly after it forms a rosette of edible leaves, the flowering shoot appears which makes the plant unsuitable for use. Therefore, it is important to find a method of inhibiting or delaying bolting. Among chemical compounds which could be tried for this purpose, maleic hydrazide (MH) is one which inhibits plant growth by interfering with cell division (Greulach et al. 1953, 1954). This comound at a conc. of 1000 mg/l also delays the flowering of celery but in low concentrations (50-100 mg/l) gives the opposite effects (Wittwer et al. 1954). Similar results were obtained with kohlrabi (Borkowski 1962). MH in low concentrations accelerates the flowering of spinach (Kagawa 1959). The growth inhibiting properties of high concentrations of MH were used for temporary inhibition of the growth of main shoots in apple trees and to promote, by this means, their branching (Jankiewicz 1960, Jankiewicz and Kozyra 1973; Baldini et al. 1973), or to control the growth of ornamental trees and shrubs (Sachs et al. 1967, 1970). In Poland the commercial preparation "Antyrost" containing 30% dimethylamine salt of maleic hydrazide was tested as a herbicide.

2,3,5-triiodobenzoic acid (TIBA) is also known to be a growth inhibiting compound which acts by inhibiting the basipetal transport of auxin (see Leopold and Kriedemann 1975; Borkowski 1966, 1976).

The retardant succinic acid-2-2-dimethylhydrazide (SADH) was applied to New Zealand spinach by Kays and Austin (1975). They found a marked increase in the ratio of leaf dry matter to that of bolts. The retardant SADH is commonly used to diminish the vegetative growth of fruit trees and to promote flowering (see Jankiewicz 1979). In tomato plants SADH delays flowering (Veliath and Ferguson 1973, Borkowski 1976).

The commercial preparation Off-shoot-O containing short chain fatty acids (8-12C) kills the meristems, not injuring the rest of the plant. It has been used in nurseries to promote lateral branching of fruit trees (Quinlan and Preston 1973). This preparation, however, was not very promising in the experiments of Kays and Austin (1975) with New Zealand spinach.

Our aim was to investigate if the mentioned compounds could be applied to inhibit bolting in spinach (*Spinacia oleracea* L.).

MATERIALS AND METHODS

The experiment was carried out for 3 years. The plants were grown outdoors in 5 l pots containing compost soil. The plants of cv. Matador were sown in March or early April. Eleven plants were left in each pot. This appeared to be the minimal number since the population of spinach plants is composed of female, male and bisexual plants which differ in their ability to bolt (Chroboczek 1965). A similar number of each kind of plant was left in each pot. During the first half of May, the plants were supplied with 3 g of ammonium nitrate per pot (as solution). The growth regulators were applied in May when the largest male plants were about 5 cm high. The concentrations of growth regulators used are given in Table 1. SADH was applied to the soil (0,25 l per pot) while the other growth regulators were applied as sprays (0,12 l per pot).

The experiment was set up each year in four replications. One pot was considered as a plot. The height of the stem was measured on several dates and the plants were classified according to their stem height (higher or lower then 20 cm). For the statistical analysis of results, (the number of bolted plants) the criterion "Chi square" was used.

In 1977 the leaf dry matter was evaluated (dried at 60°)after collecting the plants on June 9th.

RESULTS

In the introductory experiments in 1975 only TIBA, SADH and MH were used for comparison with untreated plants. The inhibitory effect of SADH (1000-4000 mg/l) was only temporary and weak. TIBA stimulated bolting instead of inhibiting it. MH at conc. of 500 and 1000 mg/l decreased bolting, but at a conc. of 250 mg/l this effect was much less.

SADH in the 1976 and 1977 experiments affected only slightly plant growth even at a conc. of 4000 mg/l (Table 1).

TIBA in 1976 increased bolting as it did in 1975 and due to this we discontinued the use of this compound. MH showed bolting inhibition in 1976 only at a conc. of 1500 mg/l and in 1977 at concentrations 1000-2000 mg/l.

The best inhibition of bolting was obtained with the preparation "Antyrost" (produced by "Azot" in Jaworzno, Poland). The treated plants were compact and did not bolt. The leaves were healthy and not deformed, however, their color was somewhat lighter. Antyrost at the concentration of 2% acted too strongly (Table 1). The treated leaves were too hard and they contained 26% dry matter (Table 2).

The preparation Off-Shoot-O was used only in 1976-1977. This preparation at conc. 5% and 2,5% caused marked necroses when treatment was conducted on a sunny day (possible interaction with strong light). In addition plants treated with this preparation showed weakened disease resistance and, due to this, most of them became infected and died. Bolting inhibition resulting from this preparation was marked, but not so high as with MH and "Antyrost".

DISCUSSION

The compound which most effectively inhibited bolting in this experiment was maleic hydrazide and its commercial preparation, "Antyrost". It is possible that the lower concentrations of Antyrost 0.2—0.5% may find application in plantations producing for the processing industry if the ammount of toxic residues will not be too high. According to Isenberg (see Whitwell et al. 1973), 15 mg MH per 1 kg fresh wt. of onion is the maximum residle allowed in the USA. It must be kept in mind, however, that low concentrations of MH stimulate rather than inhibit the bolting of spinach (Kagawa 1959). If the residues of MH would be too high for the use of Antyrost in practice, another compound must be looked for, which would similary inhibit bolting of spinach but which would deteriorate during processing or which is less toxic. Other compounds which were used in this experiment cannot be recommended for further trials to inhibit bolting in spinach. It is interesting

Table 1

Influence of growth regulators on the bolting of spinach treatment on May 19th in 1976 and on May 11th (see I, below) or on May 14th (see II) in 1977

Treatment	Averages per one pot and per treatment			
	No. of shoots > 20 cm on June 16th 1976	No. of shoots > 20 cm on June 7th 1977	Average lenght (cm) of 5 highest plants on June 2nd 1976	Average lenght of 6 highest plants on June 7th 1977
Control plants	10.0	9.2	31.6 def[Y]	47.4 i
TIBA 60 mg/l	9.8	—	40.0 g	—
TIBA 90 mg/l	10.0	—	40.1 g	—
TIBA 180 mg/l	8.9	—	35.2 efg	—
SADH 1000 mg/l	9.2	—	26.7 cd	—
SADH 2000 mg/l	9.1	—	29.0 cdef	—
SADH 4000 mg/l	8.5	6.6 *	25.2 cd	40.9 hi
Antyrost 0.5%	0.2 **	—	14.0 ab	—
Antyrost 1.0%	0 **	—	9.8 a	—
Antyrost 0.1% I	—	3.3 **	—	30.3 fg
Antyrost 0.25% I	—	0.8 **	—	18.7 abcd
Antyrost 0.5% I	—	1.1 **	—	14.3 abc
Antyrost 1.0% I	—	0.5 **	—	11.6 a
Antyrost 2.0% I	—	0.6 **	—	9.6 a
Antyrost 0.1% II	—	2.1 **	—	27.7 efg
Antyrost 0.25% II	—	1.1 **	—	18.0 abcd
Antyrost 0.5% II	—	0.5 **	—	15.3 abc
Antyrost 1.0% II	—	0.3 **	—	13.1 ab
Antyrost 2.0% II	—	0.2 **	—	11.3 a
MH 500 mg/l	9.8	—	36.7 fg	—
MH 1000 mg/l	9.1	2.6 **	27.0 cde	25.5 defg
MH 1500 mg/l	7.0 *	1.6 **	21.8 bc	22.3 cdef
MH 2000 mg/l	—	1.2 **	—	22.7 cdef
MH 1000+SADH 4000 mg/l	6.4 **	4.9 **	26.5 cd	34.6 gh
Off-shoot-O 1.2% II	—	0.3 **	—	21.1 bcde
Off-shoot-O 2.5% II [Z]	—	0 **	—	9.9 a
Off-shoot-O 5.0% II	6.4 **	died	10.9 a	died
Off-shoot-O 10.0% [Z]	3.0 **	—	9.0 a	—
LSD at P=0.05			8.3	9.1

*, ** — differences significant in comparison with control plants as shown by the test χ^2 (LSD at P=0.05 or 0.01).

Y — the numbers marked with the some letter do not differ significantly with each other at P=0.05.

Z — about half of the plants were dead due to fungus diseases on the day of measurement of the plants.

that TIBA stimulates bolting in spinach, whereas, it is a growth inhibitor for other plants (see "Introduction"). SADH is almost non-active with spinach. The preparation Off-shoot-O causes too strong side-effects among

Table 2

Dry matter content in spinach leaves on June 9th, 1977

Treatment	Per cent dry matter
Control plants	14.9
SADH 0.4%	15.5
Antyrost 1% and 2%	26.3

which the decrease in disease resitance is the most important and interesting from a theoretical point of view.

The results show that the chemical inhibition of spinach bolting is possible. Further work is needed, however, to introduce this method into practice, possibly using other compounds.

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Zahamowanie wybijania pędów kwiatowych u szpinaku za pomocą regulatorów wzrostu

Streszczenie

Rośliny szpinaku (*Spinacia oleracea* L.) muszą być zbierane w krótkim czasie, gdyż wybijają w pędy kwiatowe zaraz po wytworzeniu niewielkiej liczby jadalnych liści. Hydrazyd kwasu maleinowego (MH) i jego handlowy preparat "Antyrost' okazał się środkiem silnie hamującym wybijanie w pędy kwiatowe. Preparat Off-shoot-O słabo hamował wybijanie, natomiast silnie obniżał odporność roślin szpinaku w stosunku do chorób grzybowych. Kwas trójjodobenzoesowy stymulował wybijanie szpinaku w pędy kwiatowe zamiast hamować je. Retardant 2,2-dwumetylohydrazyd kwasu bursztynowego (SADH) nie wpływał na wybijanie. Zastosowanie hydrazydu kwasu maleinowego w celu zahamowania wybijania pędów kwiatowych szpinaku nie może być polecane w praktyce, zanim nie zbada się pozostałości tego związku w liściach.