Flavour and odour characteristics of species of *Allium* in relation to their capacity to stimulate germination of sclerotia of *Sclerotium cepivorum*

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Of many species or cultivars of *Allium* tested only six ornamental species showed little or no capacity to stimulate germination of sclerotia of *Sclerotium cepivorum*. All six species had S-methyl-L-cysteine sulphoxide as their principal flavour and odour precursor and their overall flavour and odour levels were low. All other species and cultivars were highly stimulatory, contained considerable amounts of S-1 or S-2-propenyl-L-cysteine sulphoxide as flavour and odour precursors and, with a few exceptions, they possessed high overall flavour and odour levels. These included several species which are thought to be related to cultivated edible forms. With the possible exception of *A. caeruleum* and *A. cyaneum* no evidence of resistance to infection by *S. cepivorum* was detected.

INTRODUCTION

The sclerotia of *Sclerotium cepivorum* Berk., the cause of white rot disease of onion and other species of *Allium*, are known to be capable of surviving in the field for at least 10 years in the absence of host plants (Coley-Smith, 1979). The germination of sclerotia in soil is specifically triggered by *Allium* species (Coley-Smith, 1960; Coley-Smith & Holt, 1966), little or no germination taking place in the absence of these plants. The effect of *Allium* species results from the exudation from their roots of non-volatile alkyl- and alkenyl-cysteine sulphoxides (Coley-Smith & Cooke, 1971) which are metabolized by the soil microflora to yield volatile sulphur-containing compounds which activate the dormant sclerotia (Coley-Smith & King, 1969; King & Coley-Smith, 1969). Amongst the volatile sulphur compounds tested by Coley-Smith & King (1969) 1-propyl and 2-propenyl (= allyl) compounds were very effective stimulants of germination whereas methyl compounds were not.

The genus *Allium* is large and complex and is thought to consist of some 500 species (El-Gadi & Elkington, 1977). The flavour and odour components of certain species have

been examined and Freeman & Whenham (1975) classified 27 species according to whether S-1-propenyl-(Group 1), S-2-propenyl-(allyl) (Group 2) or S-methyl-L-cysteine sulphoxide (Group 3) was present as the principal flavour and odour precursor. Characteristic examples of the three types were *A. cepa*, *A. sativum* and *A. aflatanense* respectively. *Allium* species and even cultivars are also known to vary in flavour and odour intensity as well as in type (Schwimmer & Weston, 1961; Schwimmer & Guadagni, 1962; Freeman & Whenham, 1975; Bajaj *et al.*, 1980).

Since flavour and odour compounds are specific triggers of germination of sclerotia of *S. cepivorum* a number of *Allium* species and cultivars were examined to discover whether variation in flavour and odour type and intensity is reflected by differences in capacity to stimulate germination of sclerotia of *S. cepivorum*.

MATERIALS AND METHODS

Allium species and cultivars

The species and cultivars used are listed in Tables 1, 2 and 3. Most were cultivated for a minimum of a year in open ground at the University of Hull Botanic Garden before

testing. The names of the species are as given by Wendelbo (1971) and Stearn (1980).

Isolates of *S. cepivorum*

Soil-tube experiments with seedlings and extracts were made with isolate J11 (ATCC 11793). Sclerotia of this isolate were grown in perlite-maizemeal cultures (15 g perlite, 8 g maizemeal, 40 ml distilled water) and were then conditioned in soil in the field for 3 months before use (Coley-Smith, 1960). Pot experiments were done with isolate J412. This was freshly isolated on agar from a sclerotium from an infested plot at the University of Hull Botanic Garden. Mature bulbs of *A. cepa* cv. Senshyu Yellow were inoculated with this isolate and were kept in closed polyethylene containers at 18°C for a week, then were left outside for 5 months in pots containing moist perlite which was watered occasionally. The sclerotia were washed off the infected bulbs and field-conditioned for 3 months before use.

Soil-tube experiments

Laboratory experiments were done using a modification of the nylon strip-soil tube method described by Coley-Smith (1980). Twenty sclerotia were placed between the nylon and the glass in 75 X 25 mm specimen tubes. In seedling experiments five seeds, chitted in moist sand at either 1 or 15°C, were placed just below the soil surface close to the nylon around the periphery of each tube and a sixth seed was placed in the centre. With a few species with small seeds, 10 or more chitted seeds were placed in each tube. Where propagules other than seeds were used the numbers varied according to the size of propagule (Table 1). The soil was a medium loam, pH 7.2, which was air-dried and sieved to 2 mm. The tubes were incubated in a growth room at 14°C with a 16 h photoperiod for 4 months or until all the seedlings had been killed. They were kept moist by frequent additions of distilled water.

Plant extract tests were also done in soil tubes. Onion extract concentration X was prepared by blending 10 g of mature bulb tissue in distilled water, filtering the homogenate through glass-fibre filter paper and

making up the filtrate to 250 ml. Extracts of other species were made in a similar manner using amounts of bulb or stem base tissue equivalent to 10 g of onion bulb. Equivalent weights of tissue were calculated from dry weight determinations made at 60°C. Dilutions of the extracts were made with distilled water and 1.5 ml of extract was added thrice weekly to each tube. The water contents of tubes were adjusted to 40% (Keen & Raczowski, 1921) $\equiv$ -40 kPa (Fawcett & Collis-George, 1967). The tubes were incubated in a growth room for a month at 14°C. In both seedling and extract experiments there were five replicate tubes per treatment.

Pot experiments

These were done in 18-cm-diameter plastic pots. The base of each pot was covered with coarse gravel and the rest of the pot was filled with a mixture of loam and grit (1:1 by volume). Two nylon fabric bags, each containing a small quantity of sand and 100 sclerotia, were buried 6 cm deep in each pot. Bulbs or other material of *Allium* species were planted in the pots, two pots per species, between November 1980 and April 1981. The numbers of bulbs used varied according to size (Table 2). The pots were left outside and watered with rain water when necessary. Nylon bags were sampled by wet sieving during November 1981 and the numbers of sclerotia surviving were counted.

Gas chromatography

Gas chromatographic analyses were done using a headspace method similar to that of Freeman & Mossadeghi (1970). The chromatograph was a PYE 104 instrument with dual column analyser, columns 2.8 m x 4 mm internal diameter glass, containing 8% Carbowax 1540 as the stationary phase on acid-washed dimethyl dichlorosilane-treated Chromosorb W. Flame ionization detectors were used. Temperature programme: 50°C for 10 min, then 2°C/min rise to 130°C, followed by isothermal conditions at this temperature. The carrier gas was oxygen-free nitrogen with a flow rate of 25 ml/min.

Bulb or stem base tissues were cut into small slices with a domestic chopper. Fresh

weights varied between 4 g (*A. sativum*) and 30 g (*A. aflatumense*) according to odour strength. The samples were incubated at 40°C for 30 min and the volatile materials were trapped in glass tubes filled with silanized glass wool and cooled with solid CO₂. The traps were heated to 180°C for 2 min and the desorbed volatiles released into the chromatograph. Resolved peaks were identified by methylene numbers (Dalglish *et al.*, 1966) and by spiking with reference compounds. Thiols, sulphides, disulphides and trisulphides with methyl, 1-propyl, 1-propenyl and 2-propenyl (allyl) radicals were identified. The quantities of the four radicals were obtained from peak areas and the percentage of each calculated. With mixed alk(en)yl compounds 50% of the total area was attributed to each radical. The method used may alter the relative amounts of the 1-propyl and 1-propenyl radicals due to the instability of 1-propenyl compounds at the high temperatures of the g.l.c. analytical procedure (Freeman & Whenham, 1975). For certain purposes the two radicals have consequently been summed.

Pyruvate determination

Total pyruvate was determined by the 2,4-dinitrophenylhydrazine method of Schwimmer & Guadagni (1962). It was not considered necessary to determine enzymically produced pyruvate since results of other workers (Freeman & Whenham, 1975) clearly demonstrate that a high proportion of total pyruvate in *Allium* species is produced enzymically from alk(en)yl cysteine sulphoxides. The methods used by these workers are likely to have underestimated rather than to have overestimated enzymically produced pyruvate.

RESULTS

Soil tube experiments with seedlings and other growing plants

Although high levels of germination of sclerotia occurred in the presence of most species tested (Table 1) there was little or no germination with a few species in Group 3. Amongst the species with stimulated germination there were considerable differences in the rate of response of sclerotia (Fig. 1). Germination of

sclerotia was usually succeeded by severe root infection which was recognized by the profuse spreading development of sclerotial initials along the roots (Fig. 2). With *A. caeruleum* and *A. cyaneum*, although root infection appeared to have taken place, the roots quickly collapsed and sclerotial initials were not formed. Infection could not therefore be confirmed with these two species. There was no evidence of tissue resistance in any of the other species and cultivars used. *A. rosenbachianum* and *A. stipitatum* grew successfully in the soil tubes for some months but eventually the seedling roots and foliage senesced and small dormant bulbs were produced. Senescence was accompanied by germination of sclerotia although the percentage recorded was low with both species. The same pattern of growth and senescence occurred with *A. aflatumense*, *A. cristophii* and *A. karataviense* but with these three species no sclerotia germinated. No sclerotia germinated in control tubes without plants in these experiments.

Soil tube experiments with plant extracts

Results with extracts were similar to those recorded with seedlings (Table 2). Extracts from the majority of species stimulated germination of sclerotia and with a few of these, particularly with those of Group 2, there was some germination at the lowest concentration of extract used. Extracts from *A. aflatumense*, *A. cristophii*, *A. karataviense* and *A. oreophilum* gave little or no germination even with the most concentrated extracts. With *A. rosenbachianum* a low level of germination occurred with the most concentrated extract.

Pot experiments with growing plants

The survival of sclerotia was clearly reduced in the presence of most *Allium* species tested (Table 3). This resulted from the decay of germinated sclerotia (Coley-Smith, 1960). All species which were tested as whole transplanted growing plants gave rather low survival levels and this may have resulted partly from the damage which occurred during transplanting. A strong *Allium* odour was noted at the time. *A. aflatumense*, *A. cristophii*, *A. karataviense* and *A. rosenbachianum* had very little effect

Table 1. Effect of *Allium* species and cultivars on germination of sclerotia of *Sclerotium cepivorum*

Species, cultivar and group ^a	Type and number of propagules. per tube	Chitting temp. (°C)	Germination of sclerotia		Infection of roots (+) or not (-)
			Arcsin ^b	S.E.	
Group 1					
<i>A. altaicum</i>	Seed 6	1	64.7	17.0	+
<i>A. carinatum</i> subsp. <i>pulchellum</i>	Seed 6	15	30.7	27.4	+
<i>A. cepa</i> cv. Robusta	Seed 6	15	53.7	18.8	+
<i>A. cepa</i> cv. White Spanish	Seed 6	15	52.2	17.5	+
<i>A. fistulosum</i> cv. Ishikuro	Seed 6	15	52.2	13.0	+
<i>A. fistulosum</i> cv. Long white bunching	Seed 6	15	54.6	13.6	+
<i>A. galanthum</i>	Seed 6	1	64.5	9.8	+
<i>A. galanthum</i> × <i>A. cepa</i>	Seed 6	1	73.8	15.5	+
<i>A. oschaninii</i>	Seed 6	1	64.0	11.8	+
<i>A. porrum</i> cv. Thor	Seed 6	15	45.6	11.6	+
<i>A. pskemense</i>	Seed 6	1	47.1	12.8	+
<i>A. pskemense</i> × <i>A. fistulosum</i>	Seed 6	1	42.7	16.0	+
<i>A. roylei</i>	Seed 6	1	47.3	6.8	+
<i>A. schoenoprasum</i>	Seed 10	15	52.6	17.4	+
<i>A. scorodoprasum</i>	Bulbils 6	15	55.6	14.6	+
<i>A. vavilovii</i>	Seed 6	1	61.7	12.1	+
Group 2					
<i>A. cyaneum</i>	Seed 15	1	36.6	8.4	?
<i>A. moly</i>	Bulb 1	—	75.0	16.6	+
<i>A. moly</i>	Seed 6	1	63.9	6.6	+
<i>A. neapolitanum</i>	Bulb 1	—	50.4	10.8	+
<i>A. roseum</i>	Seed 6	15	73.1	16.7	+
<i>A. sativum</i> cv. Brignoles 4	Bulblets 3	—	83.4	14.8	+
<i>A. sativum</i> cv. Rose Duvar	Bulblets 3	—	75.5	15.2	+
<i>A. triquetrum</i>	Seed 6	1	35.2	15.8	+
<i>A. tuberosum</i>	Seed 6	15	49.8	8.3	+
<i>A. vineale</i>	Bulbils 6	1	68.6	14.3	+
Group 3					
<i>A. aflatunense</i>	Seed 6	1	—	—	—
<i>A. caeruleum</i>	Seed 15	1	41.9	10.4	?
<i>A. cristophii</i> (= <i>A. albopilosum</i>)	Seed 6	1	—	—	—
<i>A. flavum</i>	Seed 10	1	57.8	20.0	+
<i>A. karataviense</i>	Seed 6	1	—	—	—
<i>A. oreophilum</i> (= <i>A. ostrowskianum</i>)	Bulb 1	—	—	—	—
<i>A. rosenbachianum</i>	Seed 6	1	12.9	13.9	—
<i>A. sphaerocephalon</i>	Bulblets 4	1	62.4	6.5	+
<i>A. stipitatum</i>	Seed 6	1	8.8	8.4	—

^aFreeman & Whenham (1975).^b% germination transformed.

Fig. 1. Germination of sclerotia of *S. cepivorum* in the presence of seedlings of ●, *A. galanthum* × *A. cepa*, amphidiploid; ○, *A. flavum* and ■, *A. carinatum* subsp. *pulchellum*.

on sclerotium survival. Results with *A. oreophilum* were variable.

Chemical analyses of *Allium* species

The results of chemical analyses were on the whole similar but not identical to those obtained by Freeman & Whenham (1975). The groups proposed by these workers have been slightly modified for convenience of presentation (Table 4). Species with >50% 1-propyl + 1-propenyl radical have been included in Group 1, all species containing the 2-propenyl radical in Group 2 and species with >50% of the methyl radical in Group 3. Some of the species were clearly borderline and two *A. carinatum* subsp. *pulchellum* and *A. chinense* were placed in different groups from the ones in which they were included by Freeman & Whenham (1975). It is clear

Fig. 2. Severe spreading infection of roots of *A. neapolitanum* accompanied by development of sclerotial initials of *S. cepivorum* in soil tube.

Table 2. Effect of extracts of *Allium* species and cultivars on germination of sclerotia of *Sclerotium cepivorum*

Species, cultivar and group ^a	Experiment	Germination of sclerotia in extracts							
		X		X/10		X/100		X/1000	
		Arcsin ^b	S.E.	Arcsin	S.E.	Arcsin	S.E.	Arcsin	S.E.
Group 1									
<i>A. carinatum</i> subsp. <i>pulchellum</i>	2	67.1	7.2	59.9	18.6	31.6	14.4	8.8	8.4
<i>A. cepa</i> cv. Robusta	1	65.7	3.7	56.2	9.9	15.1	14.1	4.6	10.2
	2	55.6	14.8	56.2	13.1	45.0	7.4	13.4	8.6
	3	57.4	9.7	45.7	10.1	29.8	4.2	11.4	6.8
<i>A. fistulosum</i> cv. Ishikuro	3	55.4	10.1	42.7	6.6	32.3	12.0	4.6	10.2
<i>A. porrum</i> cv. Musselburgh	1	87.4	5.8	60.9	10.4	17.6	14.6	2.6	5.8
Group 2									
<i>A. moly</i>	1	70.2	13.5	63.3	7.6	51.2	11.7	20.8	13.4
<i>A. sativum</i> cv. Rose Duvar	1	71.3	6.1	65.4	11.1	61.3	9.0	34.9	11.4
	2	68.7	6.9	53.0	11.2	53.3	13.3	21.7	4.5
	3	51.8	11.8	48.0	9.3	41.3	10.5	23.2	5.1
<i>A. tuberosum</i>	3	52.3	9.3	53.5	9.5	26.8	6.8	19.6	12.1
<i>A. ursinum</i>	2	63.1	13.3	69.1	15.7	46.3	10.1	15.9	10.9
Group 3									
<i>A. aflatunense</i>	2	2.6	5.8	—	—	2.6	5.8	—	—
<i>A. chinense</i>	2	68.2	3.5	63.1	10.6	31.2	10.8	7.7	7.1
<i>A. cristophii</i>	1	7.1	10.4	—	—	6.3	8.8	3.7	8.2
<i>A. karataviense</i>	3	—	—	—	—	3.7	8.2	—	—
<i>A. oreophilum</i>	1	5.2	7.1	5.2	7.1	5.2	7.1	—	—
<i>A. rosenbachianum</i>	3	18.0	5.8	—	—	—	—	—	—
Control (distilled water)	1	3.7	8.2	—	—	—	—	—	—
	2	8.8	8.4	—	—	—	—	—	—
	3	5.2	7.1	—	—	—	—	—	—

^aFreeman & Whenham (1975).^b% germination transformed.

that there is no absolute distinction between the three groups but they are nevertheless useful for certain purposes. Most of the Group 3 species had low pyruvate levels as well as high methyl contents. With a few exceptions pyruvate levels of Group 1 and particularly of Group 2 species were higher than those of Group 3. In Group 1 the lowest pyruvate levels occurred in the two leek cultivars (*Allium porrum*), a feature which is being investigated further.

DISCUSSION

It is clear from this investigation that although stimulation of germination of sclerotia of *S. cepivorum* is confined to *Allium*, members of this genus vary considerably in their stimulatory capacity. The six species which had either weak or no effects on sclerotial germination i.e. *A. aflatumense*, *A. cristophii*, *A. karataviense*, *A. oreophilum*, *A. rosenbachianum* and *A. stipitatum*, all belonged to Group 3 of Freeman & Whenham (1975). They were all characterized by the presence of S-methyl-L-

Table 3. Survival of sclerotia of *Sclerotium cepivorum* in the presence of *Allium* species and cultivars

Species, cultivar and group ^a	Survival of sclerotia	
	Arcsin ^b	S.E.
Group 1		
<i>A. carinatum</i> subsp. <i>pulchellum</i>	37.8	6.7
<i>A. cepa</i> cv. Robusta	56.9	24.4
<i>A. cepa</i> var. <i>ascalonicum</i> cv. Giant yellow	42.2	27.0
<i>A. fistulosum</i> cv. Ishikuro	45.7	11.1
<i>A. porrum</i> cv. Musselburgh	46.4	22.3
<i>A. schoenoprasum</i>	40.5	11.4
Group 2		
<i>A. longicuspis</i>	23.0	13.2
<i>A. moly</i>	28.3	15.0
<i>A. neapolitanum</i>	51.6	16.4
<i>A. sativum</i> cv. Rose Duvar	53.1	1.2
<i>A. triquetrum</i>	7.5	3.6
<i>A. ursinum</i>	32.1	16.9
<i>A. vineale</i>	37.9	10.4
Group 3		
<i>A. aflatunense</i>	82.9	10.8
<i>A. chinense</i>	32.5	18.3
<i>A. cristophii</i>	87.2	3.3
<i>A. flavum</i>	41.1	10.3
<i>A. karataviense</i>	83.6	4.7
<i>A. oreophilum</i>	66.9	25.9
<i>A. rosenbachianum</i>	76.4	10.3
Control	87.2	3.3

^aFreeman & Whenham (1975).^b% survival transformed.

cysteine sulphoxide as their principal flavour and odour precursor. In all six species over 90% of the total flavour precursors present consisted of the methyl derivative. In addition they all had a low flavour intensity, as measured by pyruvate analysis. The remaining four species which were assigned to Group 3, *A. caeruleum*, *A. chinense*, *A. flavum* and *A. sphaerocephalon*, possessed considerable stimulatory activity. In these the principal flavour and odour precursor was again S-methyl-L-cysteine sulphoxide but the 1-propyl and 1-propenyl derivatives were also present in considerable quantity. The flavour intensity of three of these four species was moderately high but was low in *A. sphaero-*

cephalon. All four species were clearly borderline between Groups 1 and 3 as was *A. carinatum* subsp. *pulchellum*. It appears that amongst *Allium* species absence of stimulatory activity requires both the presence of the methyl derivative as principal flavour and odour precursor and also a low overall flavour and odour intensity. It is interesting that Coley-Smith & King (1969) who tested many sulphides found methyl compounds were relatively ineffective in stimulating germination whereas 1-propyl and particularly 2-propenyl (=allyl) compounds were highly effective.

Amongst the species used here several are thought to be related to cultivated edible

Table 4. Gas chromatographic and pyruvate analysis of *Allium* species and cultivars

Species, cultivar and group ^a	Relative proportions of alk(en)yl radicals				Pyruvate μmol/g dry weight
	methyl	1-propyl ^b	1-propenyl	2-propenyl	
Group 1					
<i>A. altaicum</i>	10.75	82.74	6.51	—	NT ^c
<i>A. carinatum</i> subsp. <i>pulchellum</i>	49.04	40.05	10.91	—	196.25
<i>A. cepa</i> cv. Robusta	12.19	78.53	9.28	—	70.50
<i>A. cepa</i> cv. White Spanish	16.61	70.47	12.92	—	60.00
<i>A. cepa</i> var. <i>ascalonicum</i> cv. Giant Yellow	21.80	66.38	11.82	—	70.00
<i>A. fistulosum</i> cv. Ishikuro	9.25	85.02	5.73	—	62.50
<i>A. galanthum</i>	14.08	75.52	10.40	—	118.75
<i>A. galanthum</i> × <i>A. cepa</i>	21.37	70.60	8.03	—	67.50
<i>A. oschaninii</i>	6.41	81.53	12.06	—	82.50
<i>A. porrum</i> cv. Thor	8.88	84.19	6.93	—	16.25
<i>A. porrum</i> cv. Musselburgh	10.79	78.31	10.90	—	15.00
<i>A. roylei</i>	9.76	74.33	15.91	—	78.75
<i>A. schoenoprasum</i>	21.99	70.45	7.56	—	65.00
<i>A. scorodoprasum</i>	29.56	54.23	16.21	—	40.00
<i>A. vavilovii</i>	21.67	69.27	9.06	—	68.75
Group 2					
<i>A. cyaneum</i>	45.45	17.24	4.03	33.28	116.25
<i>A. longicuspis</i>	32.25	0.68	—	67.07	161.25
<i>A. moly</i>	47.97	5.15	—	46.88	98.75
<i>A. neapolitanum</i>	76.32	0.97	0.25	22.46	77.50
<i>A. roseum</i>	40.65	3.36	—	55.99	13.75
<i>A. sativum</i> cv. Brignoles 4	16.96	3.75	—	79.29	163.75
<i>A. sativum</i> cv. Rose Duvar	16.16	4.34	—	79.50	155.00
<i>A. triquetrum</i>	57.58	24.87	4.11	13.44	38.75
<i>A. tuberosum</i>	35.26	4.17	3.60	56.97	103.75
<i>A. ursinum</i>	30.53	7.14	—	62.33	90.00
<i>A. vineale</i>	44.91	20.01	5.11	29.97	50.00
Group 3					
<i>A. aflatunense</i>	98.77	1.23	—	—	10.00
<i>A. caeruleum</i>	60.71	18.84	20.45	—	77.50
<i>A. chinense</i>	51.35	34.54	14.11	—	48.75
<i>A. cristophii</i>	91.98	7.02	1.00	—	6.25
<i>A. flavum</i>	71.04	15.24	13.72	—	70.00
<i>A. karataviense</i>	99.33	0.67	—	—	8.75
<i>A. oreophilum</i>	92.77	5.56	1.67	—	13.75
<i>A. rosenbachianum</i>	97.37	2.13	0.50	—	17.50
<i>A. sphaerocephalon</i>	53.75	36.72	9.53	—	10.25
<i>A. stipitatum</i>	98.00	1.95	0.05	—	16.25

^aFreeman & Whenham (1975).^bAmount exaggerated by artefact formation during g.l.c.^cNot tested, insufficient material.

species. *A. cepa* is often considered to be derived from *A. oschaninii*, *A. fistulosum* is closely allied to *A. altaicum* and *A. sativum* is probably derived from *A. longicuspis* (Stearn, 1980). All these wild species were highly stimulatory and were readily infected by hyphae from germinating sclerotia. No definite evidence of tissue resistance was seen although there was some doubt about infection of *A. caeruleum* and *A. cyaneum*. The roots of these two species were extremely thin and delicate and probably supported too little hyphal growth of *S. cepivorum* for infection to be apparent. It is interesting however that of the 16 species tested by Adams & Papavizas (1971) only *A. caeruleum* appeared to possess any significant resistance. Several other species tested are capable of hybridizing with *A. cepa* or *A. fistulosum* (McCollum, 1971, 1974; Vosa, 1976; El-Gadi & Elkington, 1977). *A. galanthum*, *A. pskemense*, *A. roylei* and *A. vavilovii* were also highly stimulatory and susceptible to infection. They also had similar flavour and odour levels to *A. cepa* and *A. fistulosum*. Even if the known sterility of some of the hybrids between these species and *A. cepa* and *A. fistulosum* could be overcome there appears to be no possibility of using them to introduce either a reduced capacity to stimulate germination of sclerotia or resistance to *S. cepivorum* into cultivated edible forms.

The soil tube germination method, with a small number of replicates, together with the sensitive isolate (J11) of *S. cepivorum* (Coley-Smith & Holt, 1960) used in this investigation, were satisfactory for detecting the large differences in stimulatory activity reported, despite the high level of replicate variation as shown by some of the standard error values. It is possible that such methods would not detect smaller differences in stimulatory activity and resistance between species and cultivars which might exist and be of considerable significance on a field scale (Rahe, 1981). If such small differences do exist they would only be detectable in experiments on a much larger scale than those reported here. Work to investigate this possibility is being continued.

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