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Response of Cole Crops to Combinations of Herbicides and Insecticides [1]

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Abstract. **Over a 6-year period (1969-1974) the efficacy of 3 insecticides and 24 herbicides and their interactions in combination were investigated when applied to field-seeded broccoli (*Brassica oleracea* L. Italica group), cabbage (Capitata group) and cauliflower (Botrytis group). Of these, broccoli was the most susceptible to injury. Of 212 herbicide-insecticide combinations, 26 caused phytotoxic symptoms in broccoli, 20 in cabbage and 8 in cauliflower. The insecticides, thionazin, fensulfothion and carbofuran, were each involved in 1 or more phytotoxic combinations in each of the 3 crops. Ten herbicides were involved in phytotoxic reactions: alachlor, aziprotryn, benefin, CDEC, chlorpropham, cycloate, prometryne, propachlor, prynachlor and PP493. Root maggot damage was reduced markedly by the insecticides. Carbofuran allowed less damage than either fensulfothion or thionazin. None of the herbicides showed any insecticidal properties, and some decreased the effectiveness of the insecticides.**

In the production of precision-drilled cole crops, insecticides for root maggot control are usually applied at drilling. Herbicides are normally applied with the insecticides or within a short period, but combined pesticide treatments may be phytotoxic (3, 4, 5). This report covers a 6-year (1969-1974) investigation to examine the actions of 24 herbicides and 3 insecticides and their interactions when applied in combination on field-seeded broccoli, cabbage and cauliflower.

Materials and Methods

'Northwest Waltham 29' broccoli; 'Golden Acre' cabbage and 'Snowball Y' cauliflower were seeded in a silt loam with a multiplegear V-belt seeder in 1969-71 and with a tractor mounted Stanhay Mark II precision seeder in 1972-74. The experimental design was a split plot, randomized block, with 4 replicates. In 1969-71 each plot consisted of one 24-m row for each crop. The plots were divided into 6-m sub-plots, 1 for each insecticide and a control. In 1972-74, since only 2 insecticides were used, the rows were 18 m long.

Herbicides (Tables 1 and 2) were selected on the basis of previous unpublished work, or reported effectiveness for weed control in brassicas. They were applied under pressure at 0.10 kg/cm^2 as preplant soil incorporated (ppi), preemergence (preE), or postemergence (postE) sprays. The ppi treatments were rotovated in immediately after application; the preE treatments were applied before emergence of weeds and crop; the postE treatments were applied when most of the weeds were at the first true-leaf stage.

The insecticides thionazin (Zinophos), fensulfothion (Dasanit) and carbofuran (Furadan) were selected for control of cabbage maggot, *Hylemya brassicae* (Bouché) because of proven efficacy (1, 2). In 1969-71 all herbicides were tested in combination with each of the 3 insecticides. In 1972-74 they were combined only with carbofuran and fensulfothion following withdrawal of thionazin by the manufacturer. The insecticides were applied as granules at 2 g a.i./10m of row in a 10-cm band over the row immediately after seeding and raked gently into the soil, or incorporated by the "bow wave" method produced by the coulter of the Stanhay seeder. A supplementary drench at 2 g a.i./liter per 10 m to wet the plants and 7.5 cm of soil on each side of the row was applied 28 days after seeding The drench was applied under pressure with a hand sprayer. Sprinkler irrigation was applied when necessary.

The compatibility of the pesticide combinations was assessed by their effect on seedling emergence, plant ht, yield, and maggot damage compared to the control plants. Seedling emergence was determined by counting the emergent seedlings at the first true-leaf stage. Plant ht was measured at thinning time, about 28 days after seeding. Yield included the total of several harvests of produce from each sub-plot. Estimates of maggot damage were made on 10 roots/sub-plot as follows: 0 = none, 1 = light, 2 = moderate, 3 = severe, and 4 = very severe. This index is expressed as % damage; 100% would indicate 10 roots with very severe damage.

Results and Discussion

Ppi treatments. Two deleterious herbicide-insecticide combinations were identified in the ppi treatments in broccoli, 3 in cabbage and 1 in cauliflower (Table 1). DCPA + CDEC with thionazin reduced seedling emergence in broccoli in 1970 and in cauliflower in 1969, and stunted initial growth of cauliflower. In the 1968 trial (4) DCPA + CDEC with thionazin reduced plant stand in cabbage and cauliflower but not in broccoli. DCPA + CDEC with fensulfothion caused stunting

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Table 1. Response of broccoli, cabbage and cauliflower to combinations of herbicides and insecticides when the herbicides were applied either as preplant soil incorporated (ppi) alone or followed by preemergence (preE) treatments, 1969 to 1974. (i = deleterious interaction, ni = no injury or interaction, HD = herbicide injury, C = carbofuran, F = fensulfothion, T = thionazin).

Herbicide (kg/ha)	Years tested	Interaction with insecticides or herbicide injury. All years other than stated are ni		
		Broccoli	Cabbage	Cauliflower
Ppi				
Trifluralin 1.12	1969, 70, 74	ni	ni	ni
DCPA 6.72 + CDEC 4.48	1969, 70	iT*(70)	iF*(69)	iT*(69)
Nitralin 3.36	1969, 70, 72, 74	HD*(72)	HD*(72)	HD*(72)
Butylate 3.36	1969	ni	ni	ni
EPTC 3.36	1969	ni	HD*	ni
Cycloate 4.48	1969	ni	iT*	ni
Aziprotryn 1.68	1970	ni	ni	ni
Aziprotryn 3.36	1970	HD*	iF*	HD*
Napropamide 1.12	1970	ni	ni	ni
Napropamide 2.24	1970, 71, 72, 73, 74	HD*(72)	HD*(73)	ni
Napropamide 4.48	1970, 71, 72, 73, 74	HD*(72) HD*(73)	HD*(71) HD*(72) HD*(73)	HD*(71) HD*(72)
Napropamide 1.12 + EPTC 3.36	1970	ni	ni	ni
Fluchloralin 0.84	1972	HD*	ni	ni
Fluchloralin 1.12	1971, 72, 73, 74	HD*(72) HD*(73)	ni	ni
Fluchloralin 1.68	1972	HD*	ni	ni
Fluchloralin 2.24	1971, 73, 74	HD*(71) HD*(73)	HD*(73)	ni
Dinitramine 0.37	1972, 73, 74	HD*(72) HD*(73)	ni	ni
Dinitramine 0.56	1971, 72, 73, 74	HD*(71) HD*(72) HD*(73)	HD*(72) HD*(73)	HD*(71) HD*(72)
Dinitramine 0.84	1971, 74	HD*(71)	HD*(71)	HD*(71)
Prometryne 2.24	1971	HD*	HD*	HD*
Prometryne 2.80	1971	iT*	HD*	HD*
Benefin 1.24 & 2.24	1972	HD*	HD*	HD*
Pendimethalin 0.84 & 1.68	1974	ni	ni	ni
Ppi & PreE				
Trifluralin 1.12 (ppi) + DCPA 6.72 (preE)	1970, 71	ni	ni	HD*(71)
Trifluralin 1.12 (ppi) + DCPA 13.44 (preE)	1970, 71	ni	HD*(71)	HD*(71)
Trifluralin 1.12 (ppi) + alachlor 2.24 (preE)	1970, 71, 73	iT*(71) HD*(73)	iTF*(71) HD*(73)	HD*(71)
Nitralin 3.36 (ppi) + DCPA 6.72 (preE)	1970, 71	ni	ni	HD*(71)
Nitralin 3.36 (ppi) + DCPA 13.44 (preE)	1970, 71	HD*	HD*	HD*
Nitralin 3.36 (ppi) + alachlor 2.24 (preE)	1970, 71, 73	iFC*(70) iT*(71) HD*(73)	iF*(70) iTFC*(71) HD*(73)	HD*(71)
Benefin 1.12 (ppi) + DCPA 6.72 (preE)	1970, 71	ni	ni	ni
Benefin 1.12 (ppi) + DCPA 13.44 (preE)	1970, 71	ni	ni	iT*(71)
Benefin 2.24 (ppi) + DCPA 6.72 (preE)	1970, 71	ni	iT*(70) HD*(71)	HD*(71)
Benefin 2.24 (ppi) + DCPA 13.44 (preE)	1970, 71	ni	HD*(71)	HD*(71)

*Statistically significant, 5% level.

of cabbage plants in 1969.

Cycloate at 4.48 kg/ha, with thionazin, reduced growth of cabbage, and tended to reduce seedling emergence and marketable yield. Broccoli and cauliflower were not affected.

Aziprotryn at 3.36 kg/ha retarded growth in all 3 crops. When aziprotryn was combined with fensulfothion growth of cabbage was retarded significantly more than when aziprotryn was applied alone. Injury to cauliflower significantly reduced

Table 2. Response of broccoli, cabbage and cauliflower to combinations of herbicides and insecticides when the herbicides were applied either preemergence (preE), preemergence + postemergence (postE) or postemergence, 1969 to 1974. (i = deleterious interaction, ni = no injury or interaction, HD = herbicide injury, C = carbofuran, F = fensulfothion, T = thionazin).

Herbicide (kg/ha)	Years tested	Interaction with insecticides or herbicide injury. All years other than stated are ni		
		Broccoli	Cabbage	Cauliflower
PreE				
Propachlor 4.48	1969, 70	ni	ni	ni
Propachlor 6.72	1969, 70	iT*(69)	HD*(69)	HD*(69)
Propachlor 4.48 + chlorpropham 0.56	1969	iT*	HD*	ni
Propachlor 6.72 + chlorpropham 0.56	1969	iTF*	HD*	ni
Propachlor 2.24 + nitrofen 2.24	1969, 70, 71, 73, 74	ni	ni	ni
Propachlor 3.92 & 4.48 + nitrofen 2.24	1969	ni	HD*	ni
Nitrofen 2.24	1969, 70	ni	HD*(69)	ni
Nitrofen 2.24 + chlorpropham 0.56	1970, 71, 73, 74	iF*(71)	ni	ni
Aziprotryn 2.24	1969, 70	HD*(69) iTFC*(70)	HD*(69) iF*(70)	HD*(69) HD*(70)
Aziprotryn 4.48	1969, 70	HD*(69) iF*(70)	HD*(69) iF*(70)	HD*(69) HD*(70)
Aziprotryn 1.12 + nitrofen 2.24	1970	iF*	iF*	HD*
Aziprotryn 2.24 + nitrofen 2.24	1970	iTF*	iF*	HD*
CDEC 4.48	1969	ni	iT*	ni
DCPA 10.08	1969	ni	ni	ni
Pronamide 0.84	1969	ni	ni	ni
Pronamide 1.68	1969	ni	HD*	ni
PP493[z] 0.28 & 0.56	1970	iF*	ni	HD*
PP493 0.84	1969, 70	HD*(69) HD*(70)	HD*(69) iF*(70)	HD*(69) HD*(70)
Alachlor 2.24	1970, 71, 73, 74	iF*(71)	ni	iF*(71) HD*(73)
Alachlor 4.48	1970, 71, 73, 74	iTF*(71)	iTF*(70) iTF*(71)	HD*(70) iT*(71)
Alachlor 2.24 + chlorpropham 0.56	1970	ni	ni	ni
Alachlor 1.12 + nitrofen 2.24	1970, 71, 73, 74	iTF*(71)	HD*(71)	HD*(71) iF*(73)
Napropamide 3.36	1971	ni	ni	ni
Napropamide 6.72	1971	ni	ni	HD*
Prynachlor 3.36	1971	iT*	HD*	iC*
Prynachlor 5.60	1971	iT*	HD*	iTF*
Prynachlor 3.36 + nitrofen 2.24	1971	HD*	HD*	HD*
BAY DIC 1897[y] 1.12 & 2.24	1971	HD*	HD*	HD*
Bulab (Buban 37)[x] 1.12 & 2.24	1973	ni	ni	ni
Pendimethalin 0.84 & 1.68	1974	ni	ni	ni
PreE + postE				
DCPA 6.72 (preE) + nitrofen 3.36 (postE)	1971	ni	ni	ni
PostE				
Nitrofen 1.34 & 2.02	1971	ni	ni	ni
CNP1032[w] 1.34	1973, 74	ni	ni	ni
CNP1032 2.68	1973, 74	ni	HD*(73)	ni

*Statistically significant, 5% level.

[z]PP493 = 2,6-difluoro-3,5-dichloro-4-hydroxy pyridine.

[y]BAY DIC 1897 = 6-(1,1-dimethylethyl)-3-(methylthio)-4-((phenylmethylene)-amino)-1,2,4-triazin-5(4*H*)-one.

[x]Bulab = 3',5'-dinitro-4'-(di-n-propylamino) acetophenone.

[w]CNP1032 = 2,4,6-trichlorophenyl-4-nitrophenyl ether.

marketable yield. In broccoli aziprotryn in combination with thionazin, tended to reduce seedling emergence, retard growth and reduce marketable yield. Combined with carbofuran it tended to reduce the number of broccoli seedlings.

Nitralin at 3.36 kg/ha retarded initial growth of all crops in 1 year out of 4. There was also a tendency for the nitralin-thionazin combination to reduce growth and marketable yield of cabbage in 1969, and seedling emergence of cauliflower in 1970.

EPTC at 3.36 kg/ha significantly reduced marketable yield of cabbage. In combination with thionazin it tended to reduce seedling emergence. Broccoli and cauliflower were not affected.

Napropamide at 2.24 kg/ha caused initial stunting of broccoli and cabbage in 1 year out of 5, but yield was not affected. At 4.48 kg/ha it stunted growth of broccoli and cabbage in 1972 and 1973 and cauliflower in 1971 and 1972. It also reduced the number of cabbage seedlings in 1971 and when combined with thionazin there was a trend for the injury to increase. Marketable yield was not affected.

Fluchloralin at 0.84 to 1.68 kg/ha retarded growth of broccoli. At 2.24 kg/ha both broccoli and cabbage were affected, but there were no significant differences between yields. Dinitramine at 0.37 to 0.84 kg/ha retarded growth of broccoli in most years. Cabbage and cauliflower showed slightly more tolerance to this herbicide, with no significant injury at the low rate. Prometryne at 2.24 and 2.8 kg/ha allowed fewer cabbage and cauliflower seedlings and stunted and reduced yield of all 3 crops. In combination with thionazin it increased the injury in all 3 crops, although significantly only in broccoli. Benefin at 1.12 and 2.24 kg/ha caused initial stunting in all crops but marketable yields were not affected.

Ppi + PreE treatments. Four deleterious herbicide-insecticide combinations were identified in the ppi + preE combinations in broccoli, 7 in cabbage and 1 in cauliflower (Table 1). Trifluralin at 1.12 kg (ppi) + alachlor at 2.24 kg/ha (preE) stunted broccoli and cabbage in 1971 and 1973. Combining these herbicides with thionazin increased the stunting and further decreased yield of both crops. Combinations with either thionazin or fensulfothion reduced seedling emergence of cabbage. Cauliflower was stunted 1 year out of 3. Trifluralin at 1.12 kg (ppi) + DCPA at 6.72 kg/ha (preE) caused initial stunting in cauliflower in 1971, but the combination did not affect the other crops. However, when the rate of DCPA was increased to 13.44 kg/ha the combination reduced the number of cabbage seedlings and stunted both cabbage and cauliflower.

Nitralin at 3.36 kg (ppi) + alachlor at 2.24 kg/ha (preE) in 1970 caused significant stunting in broccoli and, when combined with fensulfothion or carbofuran, seedling emergence was reduced. In 1971 plant growth and marketable yield were affected by the herbicide treatment. When thionazin was added to the combination the injury was increased. This herbicide treatment stunted cabbage in 1971 and 1973 but not in 1970. In 1971 it also reduced seedling emergence and yield. The addition of any of the insecticides further reduced emergence, and thionazin further decreased marketable yield. Nitralin at 3.36 kg (ppi) + DCPA at 6.72 kg/ha (preE) stunted cauliflower in 1971. When thionazin was combined with this treatment the injury was more severe, although not significantly. When the rate of DCPA was doubled the herbicide combination stunted all 3 crops in both years, and the marketable yield of cabbage was reduced. Thionazin added to the herbicides tended to reduce yields still further.

Benefin at 1.12 kg (ppi) + DCPA at 13.44 kg/ha (preE) caused stunting of cauliflower in 1971. When thionazin was applied with the herbicide treatment the stunting was increased and as a result marketable yield decreased. Benefin at 2.24 kg (ppi) + DCPA at 6.72 kg/ha (preE) retarded growth of cabbage in 1970 and 1971. Plants were further retarded in 1970 with the addition of the thionazin treatment. In 1971 the plant stunting was reflected in a yield reduction. With the double rate for both benefin and DCPA the number of cabbage seedlings, plant growth, and marketable yield of cabbage were significantly reduced. When combined with thionazin there was a tendency for stunting to be increased and yield to be further reduced. Both herbicide mixtures caused stunting of cauliflower. Broccoli was the most tolerant to the benefin-DCPA mixtures and showed no injury or interaction.

PreE treatments. Twenty deleterious herbicide-insecticide combinations were identified in the preE treatments in broccoli, 10 in cabbage and 6 in cauliflower (Table 2). As shown in previous work (3, 4, 5) propachlor alone at 4.48 kg/ha was compatible with all 3 insecticides in the 3 crops. However, the 6.72 kg rate stunted all 3 crops in 1969 and reduced germination of broccoli and cabbage. Combining the high rate with thionazin increased the stunting of broccoli. When propachlor at 6.72 kg/ha was combined with chlorpropham the mixture was incompatible with thionazin and fensulfothion for broccoli. Propachlor at 4.48 kg + chlorpropham at 0.56 kg/ha plus thionazin reduced seedling emergence. With propachlor at 6.72 kg/ha, the herbicide mixture alone significantly reduced seedling emergence and plant growth. Combining it with fensulfothion or thionazin further reduced emergence. This combination with thionazin also increased stunting. Propachlor at 3.92 kg + nitrofen at 2.24 kg/ha caused stunting in cabbage. With propachlor at 4.48 kg/ha this mixture significantly reduced the number of cabbage seedlings. However, in 1969 nitrofen alone reduced seedling emergence of cabbage. Nitrofen at 2.24 kg + chlorpropham at 0.56 kg/ha, when combined with fensulfothion, significantly reduced seedling emergence of broccoli in 1 year out of 4.

Aziprotryn at 2.24 or 4.48 kg/ha significantly reduced seedling emergence and plant growth in all 3 crops in both years. In 1970 combining the 2.24 rate with any of the 3 insecticides increased the injury in broccoli, and with fensulfothion further affected cabbage. Combining the 4.48 aziprotryn rate with fensulfothion further reduced seedling emergence of broccoli and cabbage with a resultant decrease in yield. No aziprotryn-insecticide interaction was detected in cauliflower, but both rates of the herbicide reduced yields in 1970. Aziprotryn at 1.12 kg + nitrofen at 2.24 kg/ha reduced seedling emergence in all 3 crops. When the mixture was combined with fensulfothion injury was increased and plant ht reduced in broccoli and cabbage. Increasing aziprotryn to 2.24 kg/ha in the mixture caused a significantly greater reduction in seedling emergence of all 3 crops, a significant reduction in the height of cauliflower, and slightly lower yields of broccoli and cauliflower. Combining this mixture with fensulfothion significantly increased the injury in broccoli and cabbage. Combining it with thionazin affected only broccoli. These results with aziprotryn (C-7019) are in agreement with previous work (3, 4, 5) in which several deleterious combinations were identified when aziprotryn was applied ppi or preE with the various insecticides.

CDEC at 4.48 kg/ha reduced seedling emergence and caused stunting of cabbage. Combination with thionazin increased this injury and tended to reduce seedling emergence of broccoli. Pronamide at 1.68 kg/ha caused initial stunting in cabbage. At 0.28 or 0.56 kg/ha PP493 caused initial stunting in broccoli and cauliflower. Combining it with fensulfothion increased broccoli injury. At 0.84 kg/ha PP493 injured all 3 crops in both years. Combining it with fensulfothion further reduced seedling emergence of cabbage in 1970 and decreased yield.

Alachlor alone at 2.24 kg/ha caused a significant reduction in seedling emergence of broccoli in 1 year out of 4. Combination with fensulfothion increased the injury and decreased yield. This treatment also injured cauliflower in 2 years out of 4, but it caused no significant injury or interaction in cabbage. Combination with fensulfothion significantly increased stunting

Table 3. Mean effect of insecticides on seedling emergence, plant ht and marketable yield of broccoli, cabbage and cauliflower, 1969-74.

Crop Insecticide	Seedling emergence (no./9 m)		Plant ht (cm)		Marketable yield (kg/plot)	
	1969-71	1972-74	1969-71	1972-73	1969-71	1972-73
Broccoli						
Thionazin	23.5 a[z]	–	10.3 a	–	3.0 a	–
Fensulfothion	42.8 b	73.9 a	11.6 ab	14.6 a	3.2 a	5.2 a
Carbofuran	43.8 b	72.4 a	12.4 b	14.9 a	3.9 b	5.9 a
Control (no insecticide)	54.1 b	72.6 a	13.2 b	15.1 a	3.8 b	6.0 a
Cabbage						
Thionazin	27.3 a	–	8.9 a	–	11.2 a	–
Fensulfothion	37.9 b	38.6a	9.4 a	11.2 a	11.0 a	6.5 a
Carbofuran	41.0 bc	39.7a	14.9 a	12.1 a	10.0 a	9.3 a
Control (no insecticide)	49.7 c	38.8a	10.9 a	11.9 a	10.6 a	7.7 a
Cauliflower						
Thionazin	41.4a	–	9.3 a	–	6.5 a	–
Fensulfothion	66.7b	59.3 a	10.0 ab	11.7 a	6.7 a	3.7 a
Carbofuran	74.3bc	62.9 a	11.0 bc	12.2 a	7.8 b	5.3 a
Control (no insecticide)	85.5c	61.8 a	11.8 c	11.9 a	6.6 a	4.5 a

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

of broccoli and cauliflower in 1971. Alachlor at 4.48 kg/ha significantly reduced seedling emergence, growth, and yield of broccoli in 1 year out of 4 and injured cauliflower in 2 years ouf of 4. Injury was increased when the 4.48 kg rate was combined with thionazin or fensulfothion. In 1970 and 1971 these combinations further reduced seedling emergence of cabbage and caused injury in broccoli in 1971. When thionazin and the 4.48 kg rate of alachlor were applied to cauliflower in 1971 it further decreased seedling emergence and growth. Alachlor at 1.12 kg + nitrofen at 2.24 kg/ha injured broccoli and cabbage in 1 year out of 4. Combining them with thionazin or fensulfothion further reduced seedling emergence of broccoli. The herbicide treatment caused injury to cauliflower in 2 years out of 4, and when fensulfothion was added plant retardation increased.

Napropamide at 6.72 kg/ha retarded initial plant growth of cauliflower and when combined with fensulfothion there was a tendency for further injury.

Prynachlor at either 3.36 or 5.60 kg/ha significantly reduced seedling emergence, plant ht, and yield of broccoli, all of which was magnified when thionazin was applied with the herbicide. With cauliflower the 3.36 kg/ha rate caused initial plant retardation. This injury was increased by the addition of carbofuran. There was also a trend for fensulfothion to increase the injury. The 5.60 kg/ha prynachlor rate also retarded plant growth, and the addition of either thionazin or fensulfothion increased the injury. Prynachlor at 3.36 + nitrofen at 2.24 kg/ha significantly reduced seedling emergence of broccoli, and the addition of thionazin or fensulfothion tended to cause further reduction. The prynachlor-nitrofen mixture retarded initial growth of both cabbage and cauliflower and tended to lower the yield of cabbage.

BAY DIC 1897 at 1.12 or 2.24 kg/ha completely destroyed all 3 crops. In a previous trial (5) there was no injury to rutabaga.

PreE and postE treatments. Nitrofen applied postE, either alone or following a preE application of DCPA, caused no injury or deleterious herbicide-insecticide interaction (Table 2). These results are similar to those for rutabaga (5). CNP1032 applied postE at 1.34 or 2.68 kg/ha caused no injury or interactions in broccoli or cauliflower. The higher rate caused a significant yield reduction in cabbage in 1973.

Insecticide effects. From 1969 to 1971, when the insecticides were applied over the seeded area, fensulfothion and thionazin significantly reduced seedling emergence, especially thionazin (Table 3). There were no significant differences

Table 4. Average percentage cabbage maggot damage (1969-1973) after various combinations of insecticide and herbicide treatments, Agassiz, B.C.[z]

Year Treatment	Broccoli	Cabbage	Cauliflower
1969			
Carbofuran	0.2	0.5	0.6
Carbofuran & herbicides	0.2	0.7	0.6
Fensulfothion	0.2	0.8	1.1
Fensulfothion & herbicides	0.2	0.9	1.7
Thionazin	2.8	1.7	6.5
Thionazin & herbicides	2.9	2.5	7.9
Herbicides	66.9	47.3	73.5
Untreated	64.7	49.5	78.7
1971			
Carbofuran	0.0	0.0	0.0
Carbofuran & herbicides	0.0	0.0	0.0
Fensulfothion	0.0	0.0	0.0
Fensulfothion & herbicides	0.0	0.0	0.0
Thionazin	0.0	0.0	0.0
Thionazin & herbicides	0.0	0.0	0.0
Herbicides	22.7	18.4	23.1
Untreated	24.1	19.2	17.7
1972			
Carbofuran	0.0	0.0	0.0
Carbofuran & herbicides	0.0	0.0	0.0
Fensulfothion	0.0	0.0	0.0
Fensulfothion & herbicides	0.0	0.0	0.0
Herbicides	9.9	17.2	11.9
Untreated	8.7	23.8	13.7
1973			
Carbofuran	1.0	2.8	1.9
Carbofuran & herbicides	1.2	2.4	3.0
Fensulfothion	0.6	2.5	7.8
Fensulfothion & herbicides	3.3	6.0	7.6
Herbicides	51.0	56.0	77.5
Untreated	56.9	62.8	80.3

[z]Maggot damage in 1970 in untreated crops average 5.4% and less than 0.3% where insecticides were applied.

between number of seedlings in plots treated with carbofuran and fensulfothion, nor between plots with carbofuran and the untreated plots. Thionazin significantly reduced plant ht of broccoli and cauliflower, and yield of broccoli. Fensulfothion reduced plant ht of cauliflower. Carbofuran significantly increased the yield of cauliflower. From 1972 to 1974, when the insecticides were incorporated by the coulter of the Stanhay seeder, there were no significant differences in seedling emergence, plant ht or marketable yield (Table 3).

Over the 5 years during which root maggot damage was assessed, severe damage occurred in 1969 (64.3%) and 1973 (66.7%), moderate damage occurred in 1971 (20.3%) and 1972 (15.4%) and light damage occurred in 1970 (5.4%). Each year root maggot damage was reduced markedly by the insecticides. In an experiment in 1973, where the supplementary spray 28 days after seeding was omitted, damage increased slightly for both insecticides. Carbofuran appeared to give slightly better control than fensulfothion (Table 4). None of the herbicides showed any insecticidal properties and sometimes they appeared to decrease the effectiveness of the insecticides. In several plots receiving preE and postE herbicide sprays in combination with carbofuran or fensulfothion, there was 10 to 20% maggot damage. In plots without the herbicides, there was only 2% damage with carbofuran, and 8% with fensulfothion. In untreated plots, maggot damage in cauliflower averaged 39% over the 5 years; in broccoli and cabbage, 32%.

Of 212 herbicide-insecticide combinations tested 26 caused phytotoxic interactions in broccoli, 20 in cabbage and 8 in cauliflower as measured by seedling emergence, plant ht and marketable yield. Each of the 3 insecticides were involved in 1 or more phytotoxic reactions in each of the 3 crops (Tables 2, 3). Fensulfothion (26) and thionazin (24) were most frequently involved in deleterious combinations: carbofuran was involved in only 4. Ten of the 24 herbicides were involved: alachlor, aziprotryn, benefin, CDEC, chlorpropham, cycloate, prometryne, propachlor, prynachlor and PP493. All except benefin and cycloate were involved in broccoli injury; alachlor, aziprotryn, benefin, CDEC and cycloate were involved in cabbage injury; and alachlor, benefin, CDEC, and prynachlor in cauliflower injury.

The results of these experiments support those of Nash and Harris (7) who reported that interactions usually occurred between pesticides having a water solubility greater than 20 ppm, and that none of the highly insoluble chlorinated hydrocarbon insecticides were involved in a phytotoxic interaction. In our previous work with rutabaga (5) we reported that pronamide was the only herbicide with a water solubility of less than 20 ppm that caused phytotoxic interactions. In this investigation pronamide did not interact with any of the insecticides. Napropamide, which has a solubility greater than 20 ppm, was not identified with phytotoxic interaction, but it did cause significant herbicidal damage to all 3 crops. Several of the herbicides with solubility greater than 20 ppm, which were not involved in a phytotoxic interaction in the previous trial with rutabaga (5), did cause phytotoxic interactions in cole crops in the present test. These were: benefin, CDEC, cycloate, prometryne, and propachlor. The only herbicides with solubility greater than 20 ppm which were not involved in phytotoxic interactions in either test were 2 thiocarbamates; butylate and EPTC. Butylate did not cause herbicide injury, but EPTC caused injury in cabbage and, in combination with thionazin, reduced seedling emergence, although not significantly.

The herbicidal injury and phytotoxic interactions of alachlor in the 3 cole crops are consistent with the results of Hamill and Penner (6), Phatak (8) and our work with rutabaga (5).

As in the previous tests (3, 4, 5) the results presented in this paper were not fully consistent each year possibly because of the many environmental interactions of soil and weather. Although the results are inconsistent from year to year, the data show that economic losses may occur in field-sown broccoli, cabbage and cauliflower when certain herbicides, especially those with a water solubility above 20 ppm, are applied simultaneously with insecticides or within a short period.

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