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Response of Rutabaga to Combinations of Herbicides and Insecticides[1]

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Abstract. **Over a 6-year period (1969-1974) the efficacy of 25 herbicides and 3 insecticides and their interactions in combination were investigated when applied to field seeded rutabaga (*Brassica napobrassica*). Of 215 herbicide-insecticide combinations tested only 29 resulted in phytotoxic interactions as measured by seedling emergence, plant height and marketable yield. Six combinations involved all the insecticides: thionazin, fensulfothion and carbofuran; 1 with carbofuran and thionazin, 1 thionazin and fensulfothion, 5 thionazin alone, and 2 fensulfothion alone. Only 6 herbicides were involved: alachlor, aziprotryn, pronamide, napropamide, prynachlor and chlorpropham; the last when combined with propachlor. Although fewer emergent seedlings were recorded with all insecticides in 1969 to 1971 only thionazin caused a significant reduction. Carbofuran and thionazin affected rutabaga growth detrimentally in the years 1969 to 1971, but in the following years carbofuran had no effect. Plant growth was not affected during any year by fensulfothion. In all years the insecticides resulted in significant increases in marketable yields of rutabaga. carbofuran was slightly better for control for cabbage maggot, *Hylemya brassicae* (Bouché) than either fensulfothion or thionazin. None of the herbicides showed any insecticidal properties, nor did they affect the efficacy of the insecticides.**

In the production of rutabagas both herbicides and insecticides must be applied simultaneously or serially within a short period. It has been shown in previous work (3, 4) that individual or combined pesticide treatments may be phytotoxic. This report covers a 6-year (1969-1974) investigation to examine the actions of 25 herbicides and 3 insecticides and their interactions when applied in combination to field-seeded rutabaga.

Materials and Methods

In a silt loam at the Research Station, 'Laurentian' rutabaga were seeded with a multiple-gear, V-belt seeder in 1969 to 1971 and with a tractor mounted Stanhay Mark II precision seeder in 1972 to 1974. The experimental design was a split plot randomized block with 4 replicates. In 1969-71 the plots consisted of two 12-m rows seeded at 2 g/row; in 1972-74 there were two 9-m rows, since only 2 insecticides were involved. The plots were divided into 3-m sub-plots, 1 for each insecticide and a control.

The selection of herbicide treatments (Tables 1 and 2) was based on previous work or reported effectiveness for weed control in brassica crops (unpublished). They were applied under pressure at 0.10 kg/cm^2 with a self-propelled plot sprayer as preplant soil incorporated (ppi), preemergence (preE) or postemergence (postE). The ppi treatments were incorporated with a rotovator immediately following spraying; the preE treatments were applied prior to emergence of both weeds and crop; and the postE treatments were made when the crop and the majority of the weeds were at the first true-leaf stage.

The insecticides, thionazin (Zinophos), fensulfothion (Dasanit) and carbofuran (Furadan) were selected because of proven efficacy (1, 2). In 1969-71 inclusive all herbicides were tested in combination with 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./10 m 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. Supplementary drenches 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 were applied 28, 49 and 70 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 observing their effects on germination, plant height, yield and maggot damage and compared to the control plants. Germination was determined by counting the emergent seedlings at the first true-leaf stage. Plant ht was determined by measuring the plants at thinning, about 28 days after seeding. Effect on yield was determined by harvesting mature roots from each sub-plot about 120 days after seeding. Efficacy of the insecticides was determined by grading maggot damage on 10 roots/sub-plot as follows: None, 0; light, 1: moderate, 2; severe, 4; and very severe, 8. This index is expressed as % damage based on 100% equal to 10 roots with very severe damage.

Results and Discussion

Ppi treatments. Only 2 deleterious herbicide-insecticide combinations were identified in the ppi treatments (Table 1). Aziprotryn at 1.68 kg/ha in combination with carbofuran or thionazin reduced germination significantly when compared to the herbicide and insecticide controls. This reduction was reflected in a decrease in marketable yield. Aziprotryn at 3.36 kg/ha decreased germination and marketable yield in all plots.

Nitralin at 3.36 kg/ha caused some initial plant retardation in 1 year out of 3 although yield was not affected. Napropamide at 2.24 and at 4.48 kg/ha caused initial stunting in 1 year out of 4 but marketable yields were not affected. Fluchloralin at 1.12 and at 2.24 kg/ha caused growth retardation in 1 year out of 3 but only the higher rate caused a decrease in yield. Dinitramine at 0.37 to 0.84 kg/ha was phytotoxic to the crop in most years, affecting plant growth and caused a significant decrease in yield. Prometryn at 2.24 and at 2.8 kg/ha reduced germination and yield. Butylate at 3.36 kg/ha and EPTC caused stunting, and EPTC also affected germination.

Ppi+preE treatments. Two deleterious herbicide-insecticide combinations were identified in the ppi+preE combination treatments (Table 1). Trifluralin at 1.12 kg (ppi) + alachlor at 2.24 kg/ha (preE) caused stunting and yield reduction, and when combined with thionazin resulted in reduced germination as well. Nitralin at 3.36 kg (ppi) + alachlor at 2.24 kg/ha (preE) also proved incompatible with thionazin and this herbicide combination treatment alone caused stunting and yield reduction in 1973 and 1974.

PreE treatments. Several deleterious herbicide-insecticide combinations were identified in the preE treatments (Table 2) as follows: As in the previous work (3, 4) propachlor alone at

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Table 1. Response of rutabaga 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 interaction, HD = herbicide injury, C = carbofuran, F = fensulfothion, T = thionazin).

	Years tested					
	With 3 insecticides			With 2 insecticides		
Treatment (kg/ha)	1969	1970	1971	1972	1973	1974
Ppi						
Trifluralin 1.12	ni	ni	–	–	–	–
DCPA 6.72 + CDEC 4.48	HD*	ni	–	–	–	–
Nitralin 3.36	HD*	ni	–	ni	–	–
Aziprotryn 1.68	–	iTC*	–	–	–	–
Aziprotryn 3.36	–	HD*	–	–	–	–
Napropamide 1.12	–	ni	–	–	–	–
Napropamide 2.24 & 4.48	–	ni	ni	ni	HD*	–
Napropamide 1.12 + EPTC 3.36	–	ni	–	–	–	–
Fluchloralin 0.84	–	–	–	ni	–	–
Fluchloralin 1.12	–	–	ni	ni	HD*	–
Fluchloralin 1.68	–	–	–	ni	–	–
Fluchloralin 2.24	–	–	ni	ni	HD*	–
Fluchloralin 1.12 + prynachlor 3.36	–	–	–	ni	–	–
Dinitramine 0.37	–	–	–	ni	HD*	HD*
Dinitramine 0.56	–	–	HD*	ni	HD*	HD*
Dinitramine 0.84	–	–	HD*	–	–	HD*
Prometryn 2.24	–	–	HD*	–	–	–
Prometryn 2.80	–	HD*	–	–	–	–
Benefin 1.12 & 2.24	–	–	–	ni	–	–
Penoxalin 0.84 & 1.68	–	–	–	–	–	ni
Butylate 3.36	HD*	–	–	–	–	–
EPTC 3.36	HD*	–	–	–	–	–
Cycloate 4.48	ni	–	–	–	–	–
Ppi + preE						
Trifluralin 1.12 (ppi) + DCPA 6.72 & 13.44 (preE)	–	ni	ni	–	–	–
Trifluralin 1.12 (ppi) + alachlor 2.24 (preE)	–	–	iT*	–	HD*	ni
Nitralin 3.36 (ppi) +DCPA 6.72 & 13.44 (preE)	–	ni	ni	–	–	–
Nitralin 3.36 (ppi) + alachlor 2.24 (preE)	–	iT*	iT*	–	HD*	HD*
Benefin 1.12 (ppi) + DCPA 6.72 & 13.44 (preE)	–	ni	ni	–	–	–
Benefin 2.24 (ppi) + DCPA 6.72 & 13.44 (preE)	–	ni	ni	–	–	–

*Statistically significant, 5% level.

Table 2. Response of rutabaga 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 interaction, HD = herbicide injury, C = carbofuran, F = fensulfothion, T = thionazin)

	Years tested					
	With 3 insecticides			With 2 insecticides		
Treatment (kg/ha)	1969	1970	1971	1972	1973	1974
PreE						
Propachlor 4.48	ni	ni	–	–	–	–
Propachlor 6.72	HD*	ni	–	–	–	–
Propachlor 4.48 + chlorpropham 0.56	iTF*	–	–	–	–	–
Propachlor 6.72 + chlorpropham 0.56	iF*	–	–	–	–	–
Propachlor 2.24 + nitrofen 2.24	–	ni	–	–	ni	ni
Propachlor 3.92 & 4.48 + nitrofen 2.24	ni	–	–	–	–	–
Nitrofen 2.24	ni	–	–	–	–	–
CDEC 4.48	ni	–	–	–	–	–
DCPA 10.08	ni	–	–	–	–	–
Pronamide 0.84	iF*	–	–	–	–	–
Pronamide 1.68	HD*	–	–	–	–	–
PP 493[z] 0.28 & 0.37	–	ni	–	–	–	–
PP 493 0.84	HD*	ni	–	–	–	–
Alachlor 2.24	–	HD*	iTFC*	–	ni	ni
Alachlor 4.48	–	HD*	iTFC*	–	HD*	HD*
Alachlor 2.24 + chlorpropham 0.56	–	ni	–	–	–	–
Alachlor 1.12 + nitrofen 2.24	–	ni	iTFC*	–	ni	ni
Nitrofen 2.24	–	ni	–	–	–	–
Nitrofen 2.24 + chlorpropham 0.56	–	ni	ni	–	ni	ni
Aziprotryn 2.24 & 4.48	–	ni	–	–	–	–
Aziprotryn 1.12 & 2.24 + nitrofen 2.24	–	ni	–	–	–	–
Napropamide 3.36 & 6.72	–	–	iT*	–	–	HD*
Penoxalin 0.84 & 1.68	–	–	–	–	–	HD*
Prynachlor 3.36 & 5.60	–	–	iTFC*	–	–	–
Prynachlor 3.36 + nitrofen 2.24	–	–	iTFC*	–	–	–
BAY DIC 1897[y] 1.12 & 2.24	–	–	ni	–	–	–
Bulab (Buban 37) 1.12 & 2.24	–	–	–	ni	–	–
PreE + postE						
DCPA 6.72 (preE) + nitrofen 3.36 (postE)	–	–	ni	–	–	–
PostE						
CNP 1032[x] 1.34 & 2.68	–	–	–	–	HD*	–
Nitrofen 1.34 & 2.02	–	–	ni	–	–	–

*Statistically significant, 5% level.

[z]PP 493 = 2,6-difluoro-3,5-dichloro-4-hydroxy pyridine.

[y]BAY DIC 1897 = chemistry unknown.

[x]CNP 1032 = 2,4,6-trichlorophenyl-4-nitrophenyl ether.

4.48 kg/ha proved compatible with all of the 3 insecticides. But when propachlor was combined with chlorprophan the mixture was incompatible with thionazin and fensulfothion, reducing germination. Pronamide at 0.84 kg/ha in combination with fensulfothion reduced germination. Alachlor at 2.24 and at 4.48 kg/ha interacted in 1 year out of 4 with the 3 insecticides to cause a decrease in germination. In other years the herbicide alone caused some crop injury, with the 4.48 kg rate affecting yield significantly. The mixture alachlor at 1.12 kg + nitrofen at 2.24 kg/ha was incompatible in 1 out of 4 years with the 3 insecticides and reduced germination significantly. Napropamide at 3.36 and 6.72 kg/ha combined with thionazin reduced germination. This herbicide alone caused some initial plant retardation. Prynachlor at 3.36 and at 5.6 kg/ha and the mixture prynachlor at 3.36 kg + nitrofen at 2.24 kg/ha proved incompatible with the 3 insecticides causing a significant reduction in germination.

PreE and postE treatments. Nitrofen applied postE either alone or following a preE application of DCPA showed no deleterious herbicide-insecticide interaction (Table 2). CNP 1032 at 1.34 and at 2.68 kg/ha was phytotoxic to the crop.

Insecticide effects. Although there was a trend in the years 1969 to 1971 for all 3 insecticides to reduce germination of rutabaga only thionazin caused a significant reduction (Table

Table 3. Mean effect of insecticides on germination, plant ht and marketable yield of rutabaga 1969-1974.

Insecticide	Germination (no./9 m) 1969-71	Germination (no./9 m) 1972-74	Plant ht (cm) 1969-71	Plant ht (cm) 1972-74	Marketable yield (kg/plot) 1969-71	Marketable yield (kg/plot) 1972-74
Thionazin	91.0a[z]	–	8.6a	–	15.6c	–
Fensulfothion	116.7b	77.5a	10.3c	15.4b	15.0b	14.4b
Carbofuran	118.7b	77.8a	9.3b	16.1c	16.4c	15.6c
Control (no insecticide)	124.3b	77.3a	9.9c	15.1a	14.9a	11.5a

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

3). In later experiments, 1972 to 1974, fensulfothion and carbofuran did not affect germination. Carbofuran and thionazin affected plant ht detrimentally during the period 1969 to 1971 but in the following years carbofuran had no detrimental affect. Plant ht was not affected detrimentally by the other insecticides. Use of the insecticides resulted in significant increases in marketable yields in all years. This result demonstrates the efficacy of the insecticides for maggot control (Table 4). Each year root maggots were reduced markedly by the insecticides, with carbofuran affording slightly better control than either fensulfothion or thionazin. None of the herbicides showed any insecticidal properties, nor did they significantly affect the efficacy of the insecticides.

Only 29 out of 215 herbicide-insecticide combinations tested showed phytotoxic interactions as measured by seedling emergence, plant ht and marketable yield. Six combinations involved all the insecticides; thionazin, fensulfothion and carbofuran; 1 involved carbofuran and thionazin, 1 thionazin and fensulfothion, 5 thionazin alone and 2 fensulfothion alone. Only 6 herbicides out of 25 were involved; alachlor, aziprotryn, pronamide, napropamide, prynachlor and chlorpropham; the last when combined with propachlor.

The results were not fully consistent each year possibly because of soil and weather interactions. But there was general agreement with previous work conducted in 1968 (4). In that previous test propachlor at 4.48 kg/ha was compatible with all of the 3 insecticides, whereas at 6.72 kg/ha, when combined with thionazin it caused a phytotoxic interaction. In the present test the 4.48 kg rate again proved compatible with any of the insecticides. The 6.72 kg rate was not incompatible with thionazin but it did show herbicidal damage in 1969. In the present series propachlor at both rates when mixed with chlorpropham gave phytotoxic interactions with thionazin and fensulfothion.

The results obtained with aziprotryn are also somewhat in agreement with previous work (4), the 3.36 kg rate being phytotoxic to rutabaga. The 1.68 kg rate applied ppi resulted in a deleterious interaction with thionazin and carbofuran.

Hamill and Penner (5) reported that the combination of the herbicide alachlor with carbofuran interacted synergistically to reduce barley seedling growth but not corn. In greenhouse studies, Phatak (7) found that alachlor at 2.24, 3.36 and 4.48 kg/ha reduced rutabaga emergence significantly. In our studies alachlor in 1971 showed a deleterious interaction with all 3 insecticides. In most years the 4.48 kg rate caused herbicidal injury. Hamill and Penner (5) concluded that the basis for the observed interaction appeared to be greater alachlor uptake by barley plants grown from seed treated with carbofuran.

Nash and Harris (6) reported that interactions generally occurred between pesticides having a water solubility greater than 20 ppm, except for chlorthal and captan. None of the highly insoluble chlorinated hydrocarbon insecticides were involved in a phytotoxic interaction. In our trials all herbicides with phytotoxic interactions also had a water solubility greater than 20 ppm with the exception of pronamide. Some of the herbicides having solubility greater than 20 ppm which did not cause a phytotoxic interaction included: benefin, CDEC, prometryn, butylate, EPTC, cycloate and propachlor. However, of these, butylate, EPTC, prometryn, and propachlor, when applied alone did cause herbicidal injury. The insecticides used in this trial have a water solubility well over 20 ppm (carbofuran, 700; fensulfothion, 1600; and thionazin, 1140 ppm). Thus our results would appear to be in general agreement with those obtained by Nash and Harris (6).

Although the results may be inconsistent from year to year, the data from this trial show that economic losses may occur in field sown rutabaga when any of the 6 herbicide treatments, as previously mentioned, is combined with one or more of the insecticides. Finally, in agreement with Nash and Harris (6) caution should still be exercised when applying 2 different pesticides simultaneously or serially within a short period to control different pests, even though the data indicate that herbicide-insecticide phytotoxic interactions are relatively infrequent.

Table 4. Average percentage maggot damage after treatments with herbicides and insecticides 1969-1974.

Treatment	Maggot damage (%) 1969	1970	1971	1972	1973	1974[z]	Mean
Carbofuran	0.0	0.0	0.0	0.0	0.0	2.1	0.4
Carbofuran/ herbicides	1.0	0.1	0.1	0.2	0.2	1.3	0.5
Fensulfothion	0.0	0.0	0.0	0.0	0.9	2.1	0.5
Fensulfothion/ herbicides	1.3	0.1	0.2	0.4	0.8	3.4	1.0
Thionazin	0.0	0.0	0.0	–	–	–	0.0
Thionazin/ herbicides	2.0	0.4	0.4	–	–	–	0.9
Herbicides	73.4	11.9	12.6	16.9	65.3	11.1	31.9
Untreated	68.7	13.8	12.4	15.0	70.1	14.5	32.4

[z]Only one insecticide spray applied, 60 days after seeding.

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