THE SUBSTITUTED TRIAZINE HERBICIDES IN NEW ZEALAND

By G. W. MASON, Ivon Watkins Ltd., New Plymouth

SUMMARY

A REVIEW is made of the present and prospective developments of some of the triazine herbicides in New Zealand. The most useful members at present registered commercially in New Zealand are the two chloro substituted triazines, simazine and propazine. With respect to non-selective weed control simazine has proved to be outstanding. Any of the minor limitations in spectrum of weed control shown by simazine have not been sufficiently overcome by other partly foliage absorbed triazines, such as atrazine and prometone, or mixtures of these. In the field of selective weed control simazine appears to have the widest applications in New Zealand. Crops showing practical levels of tolerance to simazine include maize, grapes, hops, berry, pip and citrus fruits, asparagus, strawberries, and forest and ornamental species in nurseries. The development of propazine for selective weed control in umbelliferous crops is discussed. Present research on the newer methoxy- and mercapto-triazines should demonstrate their possible values in New Zealand agriculture. Without doubt the triazine com-

TABLE 1

R ₁	R ₂	C1	R ₃	SCH ₃
CH ₃ CH ₂	CH ₃ CH ₂	simazine (5)*	OCH ₃ simetone (3200)*	simetryne (450)*
CH ₃ >CH CH ₃	CH ₃ >CH CH ₃	propazine (8.6)*	prometone (750)*	prometryne
CH ₃ >CH CH ₃	CH ₃ CH ₂	atrazine (90)*	atratone (1800)*	ametryne (185)*
(CH ₃ CH ₂) ₂	CH ₃ CH ₂	trietazine (20)*	—	—
(CH ₃ CH ₂) ₂	CH ₃ >CH CH ₃	ipazine (40)*	ipatone	—

*solubility in water in ppm.

pounds appear to be the most interesting group of new herbicides evaluated in New Zealand since the development of the hormone-type weedkillers.

INTRODUCTION

Synthesis and evaluation of the triazine derivatives were begun in 1952 in the Geigy Laboratories, Switzerland (Gysin & Knusli, 1956). A large number of compounds was prepared by replacing the three reactive chlorines of cyanuric chloride with one, two, or three alkylamino, alkoxy, or alkyl thioxy groups. These compounds were then tested for their phytotoxic properties. The most interesting compounds from the practical herbicidal aspect in New Zealand are listed in Table 1.

The 2-chloro-triazines, for instance simazine, have been widely tested both here and overseas. The 2-methoxy and, even to a lesser extent, the 2-methylmercapto analogues have received limited evaluation only.

Simazine and propazine appear to enter the plant only through roots unless the foliage is damaged by abrasion (Davis et al. 1959). The more soluble triazines, such as atrazine and especially the methoxy and mercapto compounds, are active both through the roots and the foliage, and therefore produce their toxic effects much more rapidly. It has become clear that the triazines, whatever their mode of entry into the plant, exert their primary action on some enzymatic process associated with photosynthesis. Many herbicidally active triazines have been shown to inhibit the Hill reaction drastically (Gysin & Knusli 1958). Simazine has been shown to block starch production by leaves in the light (Gast 1958). Ashton et al. (1960) have shown that simazine and two other related triazines rapidly inhibit carbon dioxide fixation in the light. The phytotoxicity of the triazines probably results from their blocking of the process of oxygen liberation in photosynthesis and the later accumulation of other toxic compounds. Consequently, because of their very specific mode of action by inhibiting a biochemical process unique to plants, the triazines appear to be compounds fundamentally very safe to man and animals. This is quite apart from their known low mammalian toxicity determined by recognised biological means.

NON-SELECTIVE WEED CONTROL

For a single compound to be a residual non-selective herbicide it must have an over-all toxicity to a wide range of plants, both broad-leaf and grass species, and exert its weedkilling effect over a long period. Furthermore, in order that the toxic effect is restricted solely to the area of application its solubility in water should be low to eliminate any risk of lateral movement and leaching. Of all the triazine herbicides, simazine appears to combine these features to the greatest extent.

Initial trials in New Zealand begun in 1956 indicated that simazine had fulfilled these properties at least as effectively as comparable rates of the substituted urea sterilants monuron and diuron. In lower rainfall areas of New Zealand (25 in. per annum), such as Canterbury, simazine up to 20 lb a.i. per acre has given complete control of all vegetation on alluvial soils for more than 12 months. Where heavy growth of mixed vegetation, particularly of perennial grasses was present, it was found that simazine alone at less than 20 lb a.i. per acre was not effective in giving complete initial control. By contrast when simazine at 10 lb a.i. per acre was applied to bare ground complete residual weed control was obtained in such lower rainfall areas for up to one year. Compared with simazine, the more soluble monuron can exert some of its activity through the plant foliage, hence a quicker knockdown is obtained with this compound.

To compare both the knockdown and residual toxicity of four of the chloro substituted triazines, a trial was laid down on mixed wasteland vegetation on an alluvial gravel soil near New Plymouth in December 1959. The treatments were applied as the triazines alone, and in combination with a dalapon/amitrole mixture, all at the rate of 10 lb a.i. per acre.

Table 2 lists the mean control ratings obtained in an evaluation six months after the application.

TABLE 2

Chemical treatment	lb a.i. per acre	Mean control
Simazine	10	5.8
Atrazine	10	4.2
Trietazine	10	0
Propazine	10	0.8
Simazine/dalapon/amitrole	10	7.0
Atrazine/dalapon/amitrole	10	4.7
Trietazine/dalapon/amitrole	10	1.5
Propazine/dalapon/amitrole	10	5.7

It was concluded that simazine was the most effective soil sterilant and trietazine was clearly the least active. Propazine gave satisfactory residual weed control, but had little initial toxicity toward the standing vegetation. This fact has been observed in selective weed control studies when propazine has been applied post-emergence to the weeds. From these and other observations it seemed clear that simazine is the most effective sterilant of the triazines so far tested.

Attempts have been made to widen the control spectrum of simazine by combining it not only with dalapon/amitrole, but also with the methoxy propazine analogue known as prometone. Prometone with a much higher solubility (750 p.p.m.) than simazine has shown contact action and strong foliage absorption properties. When prometone has been applied alone for non-selective weed control under New Zealand conditions, up to 20 lb a.i. per acre has shown strong foliage activity but poor residual weed control properties. Where the trial vegetation was free of *Paspalum dilatatum* and clumpy perennial grasses the simazine combinations with dalapon/amitrole or prometone have performed about equal in knock-down and residual effectiveness. However, where perennial grasses and, in particular, *Paspalum* dominate the vegetation, the simazine/prometone mixture is less effective than when the simazine is combined with dalapon/amitrole. The difference in effectiveness may then be as wide as 1:4. It seems obvious, therefore, that though prometone contributes excellent knock-down properties to the simazine, it barely widens the spectrum of final plant control. In this respect atrazine/prometone mixtures look more effective both in acute toxicity and in the general spectrum of control of mixed weed populations.

In summary New Zealand results indicate that simazine is the most residual of all the organic type soil sterilants so far tested. Its unique properties as a soil sterilant can be most effectively utilised if applied to bare ground or in combination with specific foliage absorbed herbicides for residual control of standing vegetation. Further details on the use of simazine in non-selective weed control will be given by my colleague Mr A. Wratislav in the joint session on soil sterilants.

SELECTIVE WEED CONTROL

Few herbicides possess a true physiological or absolute selectivity toward plants, and most of them are applied within comparatively narrow safety limits. Normally, the maximum herbicidal activity toward the weeds with the minimum phytotoxic effect on the crop is obtained by the use of correct timing of application, by a selected dosage rate, and by application under the most favourable environmental conditions. Both the physiological and physical methods of obtaining selective weed control are utilised in the application of the triazine herbicides in crops. Early in the development of the triazines it was shown by Roth (1957) that the maize plants, even as a seedling, possessed a mechanism to detoxify simazine absorbed by the roots and translocated in the plant. By contrast, plants sensitive to simazine were not able to metabolise the herbicide to harmless compounds. Damage to maize could occur only with simazine when applied at grossly excessive

amounts or when foliage absorption occurred following mechanical damage to the leaves. Studies with C^{14} labelled simazine, using radio chromatograms and autograms, have confirmed that the simazine is metabolised by maize and that the original triazine ring is probably broken because radio-active carbon dioxide was evolved by the plant. Cucumber and cotton, which are sensitive to simazine, appeared to contain unchanged simazine (Davis et al. 1959). A further example of the true physiological selectivity of atrazine is shown by the work of Foy and Castelfranco (1960). Here a detoxification method was found against C^{14} labelled propazine which operates in the plant sorghum but not in oats, a plant highly sensitive to propazine.

Except for these examples of maize and sorghum, which show a complete margin of safety to simazine and propazine respectively, the other fields of application of the triazine herbicides depend more on physical selectivity. Here the choice of the triazine is determined by: The susceptibility of the crop, the solubility of the triazine, the behaviour of the triazine in the soil (in particular the leaching and adsorption properties), and the weather conditions following treatment. The principal work in New Zealand with the triazine herbicides has been in determining the weed control activity and the crop selectivities of the four chloro substituted compounds, simazine, propazine, trietazine, and ipazine. Field experiments have been conducted under a wide range of soil and climatic conditions. The results will be discussed under the heading of crops and fields of application which show the most promise for one or more of the triazines as selective herbicides.

MAIZE

The absolute margin of safety and excellent control of broad-leaf weeds with pre-emergence applications of simazine from 2 to 4 lb a.i. per acre has been confirmed in small plot and large-scale practical applications in New Zealand. In a large-scale trial in Canterbury with green feed maize 1.5 lb a.i. per acre of simazine gave excellent control of broad-leaf weeds, particularly fathen (*Chenopodium album*). Fumitory (*Fumaria officinalis*) was only partly suppressed by this rate and over 2 lb a.i. per acre was required for its complete control. In this trial propazine and trietazine appeared to be equally as effective as simazine, but none of the triazines gave any control of regrowth plants of Californian thistle (*Cirsium arvense*). Post-emergence applications of amine 2,4-D were necessary for control of the emergent thistle shoots.

Larger-scale $\frac{1}{4}$ acre block trials have been carried out on hybrid maize in the Gisborne area with the triazine compounds. In this important maize growing district the principal weed is barnyard grass (*Echinochloa crusgalli*), also common are black nightshade (*Solanum nigrum*) and Prince of Wales feather (*Amaranthus hybridus*). Two series of trials were lost because of excessive flooding resulting from heavy rainfall two days after the treatments were made in the 1960 season. The following broadcast applications were made just before the emergence of the weeds and one week following planting in one of the surviving trials.

Treatments	lb a.i. per acre
Atrazine	1.4 and 1.75
Simazine	1.4 and 2.5

The weed population consisted of an 80 per cent stand of barnyard grass. Atrazine at 1.75 lb a.i. per acre gave almost complete control (90 per cent) of this grass, while simazine at 2.5 lb a.i. per acre was not quite as effective, but gave highly acceptable results (control 80 per cent). By comparison, the lower rate of 1.4 lb a.i. per acre of both compounds was poor, simazine giving 45 per cent control and atrazine 50 per cent control of the barnyard grass. The response of the maize in the treated blocks was most striking, particularly in the atrazine at 1.75 lb a.i. per acre. For the most economical application, simazine should be applied in a band at the time of seeding. Where the corn is drilled in 3 ft rows, a band 2 ft wide

should be treated over the drill row, leaving a 2 ft inter-row area for cultivation. Further work with simazine and atrazine at 2 to 4 lb a.i. per acre using this band treatment technique would permit a more economical comparison with post-emergence applications of amine 2,4-D ($\frac{1}{4}$ to 1 lb a.i. per acre).

HOPS

A small-scale plot trial was laid down in January 1960 in a mature stand of hops in Nelson. The soil was an alluvial clay loam and the following pre-emergence applications were made to the vine rows when the hops were in full leaf and at a maximum vine length.

Treatments	lb a.i. per acre
Simazine ----	2 and 4
Atrazine ----	2 and 4
Propazine ----	3 and 4
Trietazine ----	3 and 4

A 1 in. irrigation was made one week after the application, there being no rain in the intervening period. The principal weeds present at the assessment time, two months after the treatment were annual bluegrass (*Poa annua*), speedwell (*Veronica persica*), shepherd's purse (*Capsella bursa-pastoris*), black nightshade, and fathen. All treatments gave complete control of the weeds and there were no symptoms of leaf chlorosis in the hops from any treatments. It appears that simazine at 2 to 4 lb a.i. per acre applied pre-emergence to the weeds will give excellent selective control in mature hops.

GRAPES

An application of simazine and a simazine/amitrole mixture was made to a four-year stand of grapes, (variety Pedro Eximia) in a Taradale vineyard, Hawke's Bay, on a clay loam alluvial soil. The treatment was made in September 1960, when the grapes were at the stage of bud burst and the vine rows were free of weeds following cultivation. The applications were made to a 3 ft 6 in. band over the vine rows, and were as follows:

Treatments	lb a.i. per acre
Simazine ----	1, 2 and 4
Simazine + amitrole ----	0.85, 1.7, and 3.4 of each per acre

Extremely moist conditions were maintained for three months following the application and complete weed control was obtained with all treatments. There was no reduction in the vigour of the vines from any treatment, and the only symptom present was a slight marginal leaf chlorosis in all plots treated with the combinations containing 1.7 and 3.4 lb a.i. per acre of amitrole.

A small-scale plot trial was made to grape cuttings of the varieties Maccabeo, Pinotage, Ruby Carbanet, Palamino, and Humbert. At treatment time the cuttings were dormant and the buds were still covered by scales. Application was made over-all and before the emergence of the weeds. The following were the principal weeds present in the control areas at the time of inspection, three months after treatment: Fumitory, speedwell, fathen, tares (*Vicia sativa*), scarlet pimpernel (*Anagallis arvensis*), and seedling broad-leaf dock (*Rumex obtusifolius*). Complete weed control was obtained with simazine at 1.5 and 2 lb a.i. per acre, highly satisfactory control at 1 lb a.i. per acre, and marginal control at 0.75 lb a.i. per acre. There were no symptoms of damage or leaf chlorosis in the rooted cuttings.

Simazine and also atrazine have been used for selective pre-emergence weed control in vineyards in Europe for several years. It has been shown by Gast (1960) that healthy grape vines are able to metabolise simazine. Repeated applications to grapes of simazine up to 10 lb a.i. per acre for several consecutive years have shown no detrimental effect on yield or on quality in these European studies. In these tests the simazine has not appeared to accumulate and is present mainly in the upper 2 in. of soil. The non-accumulation of simazine residues in the soil is attributed to the loss

by absorption to the soil particles, the break-down of simazine by micro-organisms, and by the activity of the higher plants.

Under New Zealand conditions simazine at 2 to 4 lb a.i. per acre is likely to give at least three months' control of annual broad-leaf weeds and grasses, provided the application is made to weed-free ground and an adequate level of moisture is present in the soil in the first few weeks following application. In newly planted vines and in cutting beds simazine at 1 to 2 lb a.i. per acre is recommended, as grapes at this stage may not be able to metabolise the simazine as rapidly as the established plants. Overseas results with atrazine up to 5 lb a.i. per acre have shown that this triazine is selective to grapes even after the vines have begun to leaf out, provided directed sprays are used. It appears that atrazine is more effective against bindweed (*Convolvulus arvensis*), couch (*Agropyron repens*), and seedling weeds already emerged at the time of application. Further work with atrazine for couch control in vineyards is planned in New Zealand trials.

ASPARAGUS

Commercial applications of simazine at 1 to 2 lb a.i. per acre have been successfully used for the last two seasons for pre-emergence weed control in established asparagus in Hawke's Bay. Some damage has occurred with simazine at 1 to 2 lb a.i. per acre when used in seedling and first-year asparagus plantings. In clay soils 2 lb a.i. per acre of simazine is necessary for adequate weed control, and the application should be made in early September before weed growth commences and while there is still adequate soil moisture. No damage to the asparagus has resulted when simazine is applied when the spears have emerged above the ground. Further trials with more selective triazines such as ipazine are warranted for pre-emergence selective weed control in seedling and young asparagus plantings.

STRAWBERRIES

Three small-scale plot trials have been carried out in the last year for pre-emergence weed control in first-year strawberry plantings. The varieties tested in these trials included Redgauntlet, Lassen, Shasta, and Captain Cook. Broadcast applications were made within one month of planting and to a freshly cultivated weed-free bed. Fresh leaf growth of the strawberries was usually just beginning at the time of treatment. Table 3 lists the treatments and mean weed control ratings made five and nine weeks after application to a first-year planting of variety Redgauntlet in a fine alluvial sandy loam soil at Wanganui. The principal weeds present in the control area at the time of rating were annual bluegrass, annual chickweed (*Stellaria media*), shepherd's purse, speedwell, twincrest (*Coronopus didymus*), perennial ryegrass (*Lolium perenne*), and broad-leaf dock.

TABLE 3

Chemical		lb a.i. per acre	Mean control rating	
			5 weeks	9 weeks
Chlorpropham	----	4	8.5	8.5
Simazine	----	1	7.6	8.4
Propazine	----	2	7.6	8.0
Trietazine	----	2	7.9	7.5
Amiben	----	2	6.1	6.9
2,4-DES	----	5.4	4.2	3.8

Soil moisture conditions were almost excessive at all stages of the trial and soil temperatures were generally cool. No retardation of the growth

of the young strawberry plants was evident in the initial stages, and the only symptoms of marginal leaf chlorosis were shown by the propazine treatments. Some reduction in plant vigour and an effect on the yield of berries were evident from propazine at 2 lb a.i. per acre. Both chlorpropham and simazine gave excellent control of these winter weeds and were distinctly superior to the commonly used 2,4-DES.

A further trial was made as an early spring treatment of first-year Captain Cook variety strawberries growing in a clay loam soil near Papakura, Auckland. Very few weeds developed in the trial block, and only an assessment of tolerance of the strawberries to the treatments could be made. Under these conditions chlorpropham at 4 lb a.i. per acre caused considerable injury to the strawberries, resulting in stunting and abnormal berry formation. Chlorpropham at 2 lb a.i. per acre caused a slight initial check of the strawberries, which later recovered. Simazine and propazine at 1 lb a.i. per acre caused no growth retardation, and no symptoms of chlorosis were evident in the strawberries. According to the grower, yields were normal from the triazine-treated areas. The same grower made a practical application of simazine at 1.25 lb a.i. per acre to a 1 acre block of established Captain Cook variety strawberries in March 1961. A slight burn of young leaves and later a marginal chlorosis resulted from this application. The plants grew out of this initial effect and two months later appeared to be comparable to the untreated plants. The weed control was complete.

The following strawberry varieties have been evaluated for tolerance to simazine at 2 lb a.i. per acre, six to eight weeks after planting in a commercial application: Lassen, Cambridge 407, Merton Princess, Cambridge Vigour, Madame Lefebure, and Huxley. They appeared to be quite tolerant to this treatment. Climax, Redgauntlet, and Shasta appeared to be slightly susceptible to the treatment. Summarising the tests with strawberries, it appears that, in general, satisfactory pre-emergence weed control can be obtained with simazine at 1 to 2 lb a.i. per acre. The lower rate is recommended for weed control in light sandy loam soils and the 2 lb a.i. per acre rate in clay loams and organic soil types. For Redgauntlet, Shasta, and Captain Cook directed sprays are recommended until further experimental data are accumulated. Wherever strawberries are planted through black polythene liners, simazine at 2 to 4 lb a.i. per acre should give extended weed control in the inter-row areas.

FOREST AND ORNAMENTAL NURSERIES

Two trials have been carried out in forest nurseries in cooperation with the Forest Research Institute, Rotorua. The first trial was on Douglas fir (*Pseudotsuga taxifolia*), when about one year old and 4 to 6 in. high. The weeds already emerged consisted of sheep sorrel (*Rumex acetosella*), regrowth plants, 95 per cent, and spurrey (*Spergula arvensis*), 5 per cent. Post-emergence applications were made with simazine, propazine, trietazine, and diuron up to 2 lb a.i. per acre. Practically no control of the weeds was obtained, because they were well established up to 3 in. in height and almost flowering. The only evidence of the treatments three months later was a slight marginal chlorosis in some of the weeds. The second treatment was made to young nursery stock 4 to 8 in. high of the following conifer species: Douglas fir, *Thuya plicata*, *Cryptomeria japonica*, *Cupressus lawsoniana*, *Pinus monticola*, *Pinus radiata*, and *Pinus pseudo-strobus*. These have been planted one week previously in 6 in. rows in a Whakarewarewa pumice loam soil. The principal weeds which were just germinating included spurrey, twincrest, lady's thumb (*Polygonum persicaria*), white clover (*Trifolium repens*), subterranean clover (*Trifolium subterraneum*), narrow leaf plantain (*Plantago lanceolata*), annual bluegrass, five finger (*Digitaria sanguinalis*), sheep sorrel (both seedlings and regrowth plants), and couch. The trial was laid out in 1/200th acre plots running across the

planting lines of all the conifer species. Table 4 lists the treatments and the weed control ratings made five weeks and seven and a half months after treatment.

TABLE 4

Chemical	lb a.i. per acre	Mean rating	
		5 weeks	7½ months
Diuron	3.2	9.9	6.5
Simazine	2	9.6	5.8
Propazine	2	9.6	5.8
Ipazine	4	9.7	5.3
Diuron	1	8.9	4.6
Simazine	1	9.5	4.1
Propazine	1	8.6	2.3
Neburon	2	8.6	1.0
Trietazine	2	8.3	1.7
"Alipur"	1	7.4	0.6
Amiben	4	7.4	0.8
Control	—	0	0.8

Though diuron has been as effective as simazine at comparable rates of application in its total weed control, severe damage has resulted to all species except Douglas fir. No injury or retardation in growth of the conifers was shown by any of the other treatments. The most resistant conifers to the diuron treatments were Douglas fir, then *Pinus* species, while the most sensitive were *Cryptomeria* and *Cupressus*. The other substituted urea, neburon, has been clearly less effective than the triazine, simazine, and propazine, though it was completely non-injurious to any of the conifer species. A remarkable level of weed control was maintained for over six months by simazine and propazine at 2 lb a.i. per acre, with an apparent margin of safety toward the conifer species tested. The only weeds not controlled were regrowth couch and sorrel, with an occasional lady's thumb and white clover. As a result of these evaluation trials the Forest Research Institute has recommended that forest nurseries use simazine at 2 lb a.i. per acre applied post-emergence to the conifer plantings and pre-emergence to the weeds. Limited trials in nursery stock plantings have been carried out with simazine and trietazine at 1, 2, and 3 lb a.i. per acre in New Plymouth on a light brown loam soil. Application was made to the beds over the plants and also as directed sprays. A range of species has been tested, including rhododendron, azalea, prunus, euonymus, and andromeda. Some leaf chlorosis was evident from the topical applications, and certain sensitive species were defoliated when the application was made to young spring growth. These species also had a high proportion of roots very near the soil surface. The principal conclusions that could be drawn from these trials are that simazine is selective in established plantings of many woody species provided that their roots are not mainly confined to the soil surface. Directed sprays may be preferable at the time when much foliage is present. For the greatest margin of safety it seems desirable to apply simazine in more frequent applications, such as every two to three months at 1 lb a.i. per acre, rather than to rely on a heavier dosage up to 4 lb a.i. per acre for season long weed control. In heavier clay soils and soils with a high organic matter content 2 lb a.i. of simazine may be safely applied, and more complete weed control will be obtained with this rate for longer periods. Because of the tremendous diversity in soil and weather conditions following application, quite apart from the wide range of species present in many nursery plantings, it is recommended that a small plot test be carried out before the application of general treatments with simazine at the above rates.

UMBELLIFEROUS VEGETABLE CROPS

The new development of a pre-emergence selective weed control in carrots using propazine at 1 to 2 lb a.i. per acre will be fully described in

another paper at the Conference. Further trials have also been carried out with propazine and related triazine compounds in other vegetable members of the family umbelliferae such as parsnips and celery.

A pre-emergence trial was laid down in parsnips planted seven days previously in an Ohakune silt loam soil. The principal species present at evaluation five weeks later were sheep sorrel, fathen, spurrey, and perennial ryegrass (*Lolium perenne*). Table 5 lists the treatments and the mean weed control ratings made five and 15 weeks after treatment.

Excellent season-long weed control was obtained with ipazine at 4 lb a.i. per acre, propazine at 2 lb a.i. per acre, amiben 4 lb a.i. per acre, and chlorpropham at 4 lb a.i. per acre. All treatments appeared to be selective toward the parsnips, though trietazine at 2 lb a.i. per acre produced a slight marginal chlorosis in some of the parsnip leaves. The treatments with the highest crop vigour ratings were propazine 2 lb a.i. per acre, amiben 4 lb a.i. per acre, ipazine 4 lb a.i. per acre, and trietazine 2 lb a.i. per acre. Because of the excellent weed control obtained with propazine at 2 lb a.i. per acre in this and many other trials and because of its selectivity toward parsnips it appears that this triazine can also be recommended as a selective pre-emergence herbicide in this crop.

TABLE 5

Chemical	lb a.i. per acre	Mean rating	
		5 weeks	15 weeks
Propazine	2	8.3	7.7
Ipazine	4	9.3	6.9
Chlorpropham	4	7.3	7.1
Amiben	4	8.2	7.7
Propazine	1	7.7	6.6
Ipazine	2	6.8	4.9
Trietazine	2	6.4	5.0
Trietazine	1	6.9	5.3
Control	—	0	4.4

Two trials have been carried out with propazine for pre-emergence weed control in transplanted celery. Applications were made to variety Handley's Golden Supreme 725 one week after planting. Where necessary a 1 in. overhead irrigation followed the application. The principal weeds present in the control areas were fathen, annual chickweed, wireweed (*Polygonum aviculare*), annual nettle (*Urtica urens*), and lady's thumb. Complete weed control has been obtained for the duration of the crop with propazine at 1, 1.5, and 2 lb a.i. per acre. Plots treated with CDEC at 8 lb a.i. per acre which had already received one hoeing were reinfested with annual nettle and fathen 12 weeks after treatment. Slight marginal leaf chlorosis was evident in one replicate of each of the propazine plots treated with 1.5 and 2 lb a.i. per acre. The early growth following the propazine treatments was chlorotic, but subsequent new leaves were normal in colour. The height, flavour, and tenderness of the celery from propazine treated plots were normal compared with the untreated controls at the time of harvesting. Further work is planned with propazine in transplanted celery, and also an assessment will be made of any residual effects on subsequent crops planted in propazine treated soils.

BERRY, BUSH, PIP, AND CITRUS FRUITS

Though only limited work has been carried out in New Zealand with simazine for preventative weed control in established planting of these fruit crops, extensive overseas tests, both in North America and Europe, have indicated a satisfactory margin of tolerance to simazine. Recommended applications are 2 to 4 lb a.i. per acre to tree and bush crops established for three years and applied to the soil following cultivation and before the emergence of new weed growth. Up to one season's weed control may be obtained in sandy and silty loam soils with simazine treatments at

2 lb a.i. per acre, and in clay, clay loam, and organic soil types with 4 lb a.i. per acre of simazine. Further work with simazine in these tree and berry fruit crops in New Zealand is fully justified.

An extensive series of trials has been carried out in New Zealand in the last year with different triazines for pre-emergence weed control in a variety of vegetable and field crops. The following summarises our present information on the most promising developments for the various triazines worthy of further evaluation:

Chemical	Treatment lb a.i. per acre	Crop
Simazine	1 to 2	field and green peas, broadbeans, and potatoes.
Atrazine	2 to 4	maize, sweet corn, and grapes.
Propazine	1 to 2	field and green peas, celery, parsley.
Trietazine	1 to 2	peas, potatoes, soybeans, strawberries, tobacco, broadbeans, tomatoes and vegetable and field brassica crops such as cabbage, cauliflower, chou moellier, and possibly swedes.

(Pre-emergence applications of trietazine to directly seeded brassica crops should not exceed 1 lb a.i. per acre).

Ipazine: This is the most promising of the new chloro substituted triazines for selective weed control in a wide range of vegetable crops. Because ipazine is of higher solubility and is formulated as an emulsifiable concentrate, it has a certain amount of post-emergence activity and appears to be more effective under lower soil moisture conditions than simazine and propazine. The rates of application suggested for further evaluation are 1 to 4 lb a.i. per acre applied before the emergence of the weeds and following the seeding of the crop.

Preliminary studies with various methyl mercapto analogues have indicated that this is a most interesting group of the triazine compounds. Compared with the chloro substituted triazines, such as simazine and propazine, they have a much shorter soil persistence, are much more soluble, and show an entirely different toxicity spectrum in crops. They appear to be selective toward small grains, peas, beans, fodder beet, and certain brassica crops, including rape and kale. Turnips, and more particularly swedes, are probably more susceptible. Of this group tested in New Zealand ametryne seems the most active and warrants further evaluation at rates of 1 to 3 lb a.i. per acre applied pre- and post-emergence to crops and weeds.

CONCLUSIONS

From the large series of tests carried out in New Zealand in the last two years it appears that simazine, propazine, and atrazine are the most active of the chloro substituted triazines. Because of their low solubility and specific physiological selectivity toward certain crops, simazine and propazine seem to offer the widest practical applications for pre-emergence and preventive weed control. In crops tolerant to simazine such as maize, grapes, berry and citrus fruits, hops, and conifers, 2 to 4 lb a.i. per acre should give extended weed control. Where there is a lower margin of safety in crops such as asparagus, strawberries, broad beans, and surface rooting nursery plants, 1 to 2 lb a.i. per acre of simazine should be used. The lower rate of application is suggested for sandy soils and the higher rate for clay and peaty soils. The application of propazine seems to be principally restricted to umbelliferous crops where simazine does not show any selectivity. Though several crops show more tolerance to trietazine, for instance, brassicas, strawberries, and legume crops, its weed control activity is about one half that of simazine and propazine; therefore its prospects for practical application in New Zealand appear to be limited. Because ipazine shows higher weed control activity than trietazine and has a wide range

of tolerance crops, it appears to be the most promising new chloro triazine for further field evaluation. Of the methoxy triazines, prometone is the only member of interest, principally for total vegetation control when combined with simazine or atrazine to give a quicker knockdown. The methyl mercapto triazines, in particular ametryne, show potential interest for pre- and post-emergence weed control in crops which hitherto have shown little tolerance to triazines. These include brassicas and beets, both as vegetable and field crops.

Undoubtedly the triazine compounds are continuing to provide most interesting areas of research for weed control problems still remaining to be solved in New Zealand agriculture.

Literature cited

Ashton, F. M., Zweig, G., and Mason, G. W., 1960. "The effect of certain triazines on $C^{14}O_2$ fixation in red kidney beans". *Weeds*. 8: 448-451.

Davis, D. E., Funderburk, H. H., and Stansing, N. G. 1959. "The absorption, translocation of C^{14} labelled simazine by corn, cotton and cucumber". *Weeds* 7: 300-309.

Foy, C. L., and Castelfranco, P. 1960. "Distribution and metabolic fate of C^{14} labelled simazine and four related alkylamino triazines in relation to phytotoxicity". *Plant Physiol.* 35: Supplement xxvii.

Gast, A. 1958. "Über pflanzenwachstumsregulatoren" *Experimentia*. 14: 134.

Gast, A. 1960. "Neue erfahrungen mit simazin in rebbau". *Schweiz. Zeit. für Obst und Weinbau*. 69: 203-210.

Gysin, H., and Knüsli, E. 1956. "Chemistry and herbicidal properties of triazine derivatives". *Proc. Third Brit. Weed Control Conf.* 615-622.

Gysin, H., and Knusli, E. 1958. "Activity and mode of action of triazine herbicides". *Proc. Fourth Brit. Weed Control Conf.*

Roth, W. 1957 "Etude comparée de la réaction du maïs et du blé à la simazine substance herbicide". *C.r. Acad. Sci.* 245: 942-944.