THE CONTROL OF ANNUAL WEEDS IN YOUNG AND MATURE ORCHARDS BY MEANS OF TERBUTRYNE AND TERBUTRYNE/SIMAZINE MIXTURES

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Summary Chemical weed control in young orchards is problematic due to the sensitivity of the trees to the chemicals. In general, the standard recommended products when used at the recommended rates for mature orchards cause damage to the young trees. Under Israeli conditions even mature stone fruit trees are sensitive to simazine and diuron applications. Terbutryne as 50% wettable powder is today recommended for use in young orchards and stone fruit orchards of all ages for the control of annual weeds. The disadvantage to this treatment is that the biological activity of the treatment is of a very short duration (8-10 weeks). In the past two years we investigated the possibility of mixing terbutryne with simazine at very low rates. The trials were conducted on various soil types in avocado, mango, olive, persimmon, vine and apple orchards from the time of planting, and in stone fruit orchards of all ages. From these trials and from the semi-commercial applications we have found that the terbutryne/simazine mixture is not phytotoxic, effectively prevents germination of annual weeds and effectively controls existing annual weeds up to a height of 10 cm. It has also been found that the mixture prevents the germination of a wide spectrum of weeds for an extended period of time.

INTRODUCTION

It is of considerable importance to be able to prevent the germination of weeds in young orchards. In the first few years after planting tree development is most sensitive to both the conventional pre-emergent herbicides used and to the germinating weeds. Terbutryne was tested for a number of years in many types of orchards and on different types of soils at various rates without causing deleterious effects to the trees and satisfactorily controlling emerging and existing annual weeds up to a height of 5-7 cm. Terbutryne was also tested in fruit and citrus nurseries in almost all varieties. No damage was caused to the trees and no phytotoxic symptoms were observed. Terbutryne is now approved for use from the time of planting in stone fruit orchards, avocado, mango, olive, persimmon, vine and various citrus orchards. In stone fruit orchards the product is also approved for use on fruit bearing trees. The main disadvantage to terbutryne at the recommended rates is that it remains active in the soil for only a short period of time. After 8-10 weeks new annual weeds begin to emerge. In order to overcome this situation, we have performed over the past two years a number of trials where the terbutryne/simazine mixture has been tested. We have found that this mixture extends the biological activity in preventing the emergence of annual weeds, controls a wider spectrum of weeds, and effectively controls existing annual weeds up to a height of 10 cm. Today the mixture of terbutryne at 2 kg a.i./ha with simazine at 0.5 kg a.i./ha is approved for use in orchards from the time of planting, in stone fruit orchards, avocado, mango, olive, persimmon, vine and citrus. This mixture has also been tested in young apple orchards without showing any phytotoxic symptoms. In pear orchards terbutryne causes phytotoxic symptoms, a yellowing of the leaves which first is seen on the lower leaves and then spreads upwards.

METHODS AND MATERIALS

During the past two years many trials have been performed. The following gives a representative description of the different crops in which the chemicals were tested. The trials were conducted on different soil types and on different fruit trees from the age of planting onward. The trials were executed by means of knapsack sprayers either hand - operated or with a motor. All the trials consisted of 3-5 replications when each replication consisted of 3-5 trees. In most of the cases a strip of 1 m wide and 15 m in length was sprayed on each side of the tree row. The nozzles used were Tee-Jet and the spray volumes applied were between 150 - 500 l/ha. In the autumn trials the materials were activated in most cases by rain and in the spring the chemicals were activated either by rainfall or sprinkler irrigation.

Key to evaluations: Weed Control - 0 = area free of weeds
5 = over 70% of the area was covered with weeds

Phytotoxicity- 5 = no phytotoxicity
0 = trees killed

Trial No. 1:

In a stone fruit and apple nursery, seeds that were sown in January 1978, on Terra-Rosa soil, were sprayed with terbutryne at the rate of 1-2 kg a.i./ha when the plants were 15-25 cm height (during the month of May 1978). The plants were irrigated immediately after spraying.

RESULTS -

Phytotoxicity

	23.6.78			27.7.78		
	rate: kg a.i./ha		control	rate: kg a.i./ha		control
	1.0	2.0		1.0	2.0	
Peach	5.0	4.5	4.5	5.0	4.5	5.0
Apricot	5.0	4.5	5.0	4.5	4.5	5.0
Almond	4.5	4.5	4.5	5.0	4.5	5.0
Apple	5.0	3.5	4.5	5.0	3.5	4.5

Summary:

Only in apples was there any phytotoxicity symptoms observed. In the stone fruits there was a slight inhibition of growth observed. In a different trial on loess soil in a one year old nursery, two successive treatments were applied. The first on 12.12.77 and the second on 14.4.78. Terbutryne was applied at the rates of 2.5 - 3.5 kg a.i./ha. During the entire summer of 1978 no phytotoxic symptoms were observed on the apricot, plum or apple trees in the nursery.

Trial No. 2:

In a citrus nursery where the plants were grown in plastic bags, containing a sandy soil organic fertilizer mix, young citrus seedlings, 3-4 months after grafting were tested. The varieties: shamouti, lemon, valencia and various mandarines on seven different root stocks. Treatment: terbutryne at the rate of 1.5 kg a.i./ha + bromacil 0.4 kg a.i./ha. Date of application: 12.11.79. Weeds present: Erigeron sp., Cruciferae, and Amaranthus sp.

RESULTS -

10 days after the spray application the weeds were killed and the sacks remained free of weeds for a period of three months. During the month of March 1980 the germination of summer weeds began. The trees developed nicely during the summer months and no phytotoxic symptoms were observed.

Trial No. 3:

In an avocado and olive nursery plants were grown in plastic sacks in a soil mix containing sand and organic fertilizer. The seedlings were 3-6 months old. Two different varieties of avocado grafted on three different root stocks and olive seedlings rooted from cuttings were treated. Treatment: terbutryne at 2.0 kg a.i./ha + simazine 0.5 kg a.i./ha. Date of treatment: 23.3.80.

During three months after the treatment, the plants were observed. No differences in the development of the treated and untreated plants were observed nor were any phytotoxic symptoms discerned.

Trial No. 4:

Type of orchard: avocado   Varieties: Haas and Etinger   Soil: Heavy

Age of plants: 5 months after planting   Date of treatment: 9.11.79

Spray volume: 150 l/ha.

Prior to the trial, the entire area was sprayed with Paraquat, so that there were no existing weeds in the area at the time of the applications.

RESULTS - Evaluation of weed coverage after the various treatments

Treatment	Rate kg a.i./ha	2.1.80	3.2.80	14.3.80
terbutryne	2.0	0.32	0.6	1.6
terbutryne+simazine	2.0+0.75	0.1	0.1	0.4
simazine	0.75	0.1	1.8	2.0
control	-	3.6	4.0	4.2

At the end of the trial, the primary weeds that were in the control area were: *Malva sp.*, *Lamium sp.*, *Avena sterilis*, *Phalaris sp.*, *Polygonum sp.*, *Calendula sp.*

Trial No. 5:

Orchard: apricot   Variety: Canino   Soil: Medium   Age of trees: 2 years

Date of application: 12.12.79   Spray volume: 250 l/ha

At the time of treatment the weeds in the area were *Notobasis sp.*, Graminae and Leguminosae.

RESULTS - Evaluation of weed coverage after the various treatments

Treatment	Rate kg a.i./ha	15.1.80	29.2.80	30.3.80
control	-	2.8	3.2	4.2
terbutryne	2.0	0.1	0.3	1.0
terbutryne+simazine	2.0+0.5	0	0.3	0.5
terbutryne+simazine	2.0+0.75	0	0.1	0.4

The main weeds in the control area were: Notobasis sp., Cruciferae, Erigeron sp., Medicago sp., Trifolium sp., Phalaris sp., Anagallis sp.

Repeated application of the same treatments was performed during the month of April in order to test phytotoxicity. No phytotoxic symptoms were observed after the repeated applications.

Trial No. 6:

Vines Variety: Perlette Soil: Sandy Age of vines: 7 months

Date of treatment: 13.1.80 Spray volume: 200 l/ha

At the time of the spray application the area was free of weeds.

RESULTS - Evaluation of weed coverage after the various treatments

Treatment	Rate kg a.i./ha	27.2.80	18.3.80	4.5.80
terbutryne	2.0	0	0.3	0.8
terbutryne+simazine	2.0+0.5	0	0	0.2
control	-	1	3	3.7

The weeds that existed in the control plots at the end of the trial: Erigeron sp., Galium sp., Solanum villosum, Amaranthus sp., Digitaria sanguinalis, Cruciferae.

Trial No. 7:

Persimmon Variety: Triumph Soil: Medium-Heavy Age of trees: 10 months

Date of treatment: 20.12.78 Spray volume: 400 l/ha

At the time of the spray treatment the weeds in the area consisted of recently germinated grasses and broadleaf weeds.

RESULTS - Evaluation of weed coverage after the various treatments

Treatment	Rate kg a.i./ha	21.2.79	22.4.79
terbutryne	2.5	0.2	0.8
terbutryne+linuron+simazine	1.5+0.5+0.5	0	0.2
terbutryne+simazine	2.0+0.5	0.2	0.4
control	-	4	4.5

The primary weeds in the control plots at the end of the trial were: Umbelliferae, Emex sp., Erigeron sp., Amaranthus sp., Notobasis sp., Lamium sp., Graminae, Raphanus sp.

Trial No. 8:

In a Japanese Plum Orchard a trial was performed on the varieties Metlee and Santa-Rosa grafted on mirobolan rootstock.

Age of trees: 13 years Soil: Heavy

Two successive spray applications were applied with the terbutryne/simazine mixture. Each spray application was sprayed at the mixture rate of terbutryne 2.0 kg a.i./ha and simazine 0.5 kg a.i./ha. The dates of the applications were 23/11/78 and 11/4/79. The spray volume used was 360 l/ha and was applied by a spray boom equiped with Flood-

Jet nozzles TK-2.

The primary weeds at the time of the first application were newly emerged Solanum villosum, Malva sp., Sonchus sp., and Phalaris sp.

RESULTS - Weed Evaluation

Treatment	Date of evaluation			
	3.1.79	10.4.79	10.6.79	12.8.79
terbutryne+simazine	0.3	0.6	0.2	0.4
control	3.0	4.5	3.3	4

At the time of the second spray application the control was sprayed with paraquat/diquat mixture.

The terbutryne/simazine mixture effectively controlled the existing weeds in the area and effectively prevented the germination of new annual weeds.

The winter weeds present in the control plots were: Sonchus sp., Malva sp., Phalaris sp., and Stellaria sp.

The summer weeds present in the control plots were: Amaranthus sp., and Erigeron sp.

DISCUSSION

The trials described above represent many more trials which were performed and in which similar results were attained. This past season conventional commercial applications were also performed in addition to applications through sprinklers and microjets. All these applications have produced satisfactory control. It appears that terbutryne at 2.0 kg a.i./ha is not phytotoxic to young fruit trees. In trials conducted in nurseries we saw that there is no phytotoxicity to decidous tree saplings except for apple, if terbutryne is sprayed and immediately washed off by sprinkler irrigation after the spray applications. Bearing and non-bearing pear trees are injured by terbutryne applications. We also did not note any phytotoxicity by terbutryne to trees that were regrafted on tree trunks of established orchards. In trial 3 (above) no phytotoxicity was observed when terbutryne at 2.0 kg a.i./ha was mixed with simazine at 0.5 kg a.i./ha and sprayed on young grafted saplings in a nursery. Spray applications of terbutryne alone, simazine alone, and terbutryne/simazine mixtures were compared in orchards that were newly planted. The mixture of terbutryne/simazine was always effective for a longer period of time and controlled a wider spectrum of weeds than either of the two products sprayed alone. In the trials performed we found that terbutryne or terbutryne/simazine mixtures could be used effectively to control weeds in all stone fruit orchards.

Acknowledgment

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NOTES

OXYFLUORFEN - A NEW VERSATILE SELECTIVE HERBICIDE

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Summary Oxyfluorfen 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene, is a new herbicide having mainly pre-emergence activity both on grasses and dicots, but which can also be used in post-emergence application alone or in combination with other post-emergence herbicides. Oxyfluorfen proved to be safe on cotton and soybean in dry areas with furrow irrigation and provided excellent initial and residual control of a number of important weeds. Transplanted onions proved to be tolerant to oxyfluorfen with application in pre-transplanting or 2-3 weeks after transplanting. Oxyfluorfen did not affect at all the rotation crops, wheat, corn, tomatoes, whatever rate was used. Oxyfluorfen demonstrated to be of high interest also for post-emergence weed control in vineyards, orchards, coffee plantations, in combination with low rates of paraquat or dalapon the efficacy of which is greatly potentiated by oxyfluorfen.

Resume L'oxyfluorfen 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyle) benzene, est un nouvel herbicide ayant surtout une activité de pré-le- vée pour la lutte contre le graminées et les dycotyledones, mais il peut aussi être utilisé en application de post-levée, seul ou en mélange avec d'autres herbicides de post-levée. L'oxyfluorfen a démontré sa sélectivité sur coton et soja en terrains secs avec irrigation par infiltration et a montré une excellent efficacité, initiale et residuelle sur de nombreuses adventices très importantes. L'oxyfluorfen est sélectif sur oignons repiqués en traitment de pré-repiquage ou 2-3 sémaines après repiquage. L'oxyfluorfen ne présente aucun risque pour les cultures suivantes telles que blè, mais, betterave, quelle que soit la dose utilisée. L'oxyfluorfen s'est également montré très interessant pour la destruction des advantices en post-levée dans les vignobles, vergers et plantations de café, en mélange avec des doses faibles de paraquat ou dalapon dont l'efficacité est notablement augmentée par l'oxyfluorfen

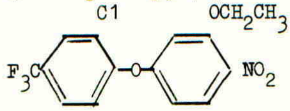
INTRODUCTION

Oxyfluorfen, formerly known as RH-2915, a new diphenyl ether, was discovered and developed by Rohm and Haas Co as a selective herbicide in several annual crops, in fruit trees and vine crops. Oxyfluorfen is 10 times more active than the old nitrophenyl ethers, nitrofen and fluorodifen. The product has both pre- and post emergence activity, and it is effective on a wide range of grasses and important dicots. Oxyfluorfen was first described by Yih and Swithenbank (1975). Oxyfluorfen is not recommended for pre-emergence application on annual crops where rainfall is common at the time of crop-emergence, or where sprinkler irrigation is made after crop emergence. Fruit-trees, vine and plantation crops proved to be thoroughly tolerant to oxyfluorfen up to the rate of 3 kg a.i./ha. Oxyfluorfen provides effective pre-emergence weed control at dosages ranging between 0.48 and 0.75 kg ai/ha depending on soil type and climate. Post-emergence application requires dosages between 1 and 1.5 kg ai/ha. For this type of application oxyfluorfen has demonstrated more utility in mixture with paraquat, diquat or dalapon the efficacy of which is greatly potentiated by oxyfluorfen which acts as a synergist.

Chemical Properties

Common Name: 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene.

Chemical Structure:



Molecular Weight: 361.72

Physical State and Colour: Orange crystalline, solid at room temperature

Melting Point: 84-85°C

Vapour Pressure: 2×10^{-6} mm Hg at 25°C

Solubility: 0.1 ppm in water at 25°C. Soluble in most solvents.

Toxicology

Acute oral LD50	male rat	=	5,000	mg/kg	Tech. material
	dog	=	5,000	mg/kg	" "
Acute dermal LD50	albino rat	=	10,000	mg/kg	" "

METHODS AND MATERIALS

Effect of oxyfluorfen on cotton in Sudan and Egypt

Field trials were carried out on cotton in Sudan and Egypt during 1978 and 1979. Plot size varied from 30 to 50 m^2 and treatments were replicated 4 times in a randomized block. Oxyfluorfen, as 23.6% e.c. was applied with a knapsack sprayer with a spray volume of 400-600 l/ha.

Herbicide efficency and crop tolerance have been determined by using a 0-100 scale where 0 = no control of weeds or no injury, and 100 = 100% control of weeds or complete kill of crops.

Results are summarized in the following tables 1 and 2.

Table 1

% Control of weeds in cotton in Sudan in 1979

(Data recorded 75-80 DAT)

Treatment	Timing	No. of trials	rate kg a.i./ha	Dinebra retroflexa	Ipomea cordofana	Ocimum basicicum	Crop Injury (60 DAT)
oxyfluorfen	pre-sowing	1	0.30	70	45	65	0
oxyfluorfen	pre-sowing	1	0.45	90	70	70	0
oxyfluorfen	post-sowing	2	0.30	75	70	89	5
oxyfluorfen	post-sowing	2	0.45	90	80	90	7
fluometuron	post-sowing	2	0.80	57	60	76	0
oxadiazon	post-sowing	2	1.25	87	78	89	0

Table 2

% Control of weeds in cotton in Egypt in 1979 (mean of 3 trials)

(Data recorded 90-95 DAT)

Treatment all pre-em	Rate kg a.i./ha	Dinebra retroflexa	Chenopodium album	Beta vulgaris	Portulaca oleracea	Convolvulus arvensis	Sonchus oleraceus	Malva parviflora
oxyfluorfen	0.30	80	70	72	46	46	53	67
oxyfluorfen	0.45	82	78	87	86	56	56	73
pendimethalin	2.00	53	73	70	53	0	80	10
fluometuron	2.50	30	86	83	96	73	63	95
oxyfluorfen + fluometuron	0.15 + 2.00	86	100	80	100	91	100	100

Crop tolerance

In Egypt oxyfluorfen was completely safe for cotton at any tested rate. In Sudan it caused a slight photoxicity which was either nil or quite negligible and fully acceptable at the time of the last assessment. The difference is due to environmental conditions:

- In Egypt no rain at all after emergence of cotton (standard climatic conditions) and irrigation made by furrow; therefore there was no splash bringing chemical on vegetation.

- In Sudan, where heavy rainfalls are common, splashes brought some chemical on vegetation causing scorches. However, the high temperature, typical of that country, made the recovery very quick. Once the seedlings reach a certain height, leaves cannot be touched by splashes and then crop tolerance is excellent. Pre-sowing surface treatment improved crop tolerance but reduced weed control.

Weed control

In Sudan 0.3 kg post-emergence proved to be better than the standard fluometuron and nitrofen, although 0.45 gave an outstanding weed control, very close to the level of oxadiazon, both on grasses and broadleaves. Particularly interesting was the very good control (90%) achieved with 0.45 kg against the important grass Dinebra retroflexa. Pre-sowing application consistently reduced weed control and consequently this way of application does not appear interesting.

In Egypt acceptable results could be achieved only at 0.45 kg but in this country the rate will probably be increased to 0.6 kg. The complete lack of rains and the consequent dryness of the soil surface, except immediately after irrigation, are conditions making oxyfluorfen somewhat less effective. On the contrary in Sudan the continuous abundant moisture of the soil surface enhances oxyfluorfen activity. The mixture of oxyfluorfen + fluometuron was promising since both herbicides seem to have complementary activity.

In both countries assessments were made just before complete canopy cover.

Effect of oxyfluorfen on groundnuts in Sudan

Methods and Materials

Tests on groundnuts were carried out in Sudan in 1979, with the method specified above for cotton, but oxyfluorfen was applied both in pre-sowing and post-sowing pre-emergence.

Weed control

Pre-sowing application provided satisfactory results only at 0.45 kg but inferior to the same rate in post-sowing pre-emergence.

With post-sowing pre-emergence application the best results were achieved with the rate of 0.45 kg which provided outstanding control of the very important grass Brachiaria eruciformis and broadleaved weeds. This rate gave also a satisfactory control of the troublesome dicot Rhynchosia memnonia resistant to most herbicides and controlled insufficiently also by the standard oxadiazon. The rate of 0.3 kg gave inferior control of Ipomea cordofana, R. memnonia and Eclipta prostrata but was on the whole acceptable and with results at the same level as the standard nitrofen at 3.75 kg and close to those of oxadiazon.

Crop tolerance

Pre-sowing application allowed a good tolerance at both tested rates. With post sowing pre-emergence application oxyfluorfen caused some slight phytotoxicity, quite acceptable at the rate of 0.3 kg. The dosage of 0.45 caused scorches on leaves from splashes when rainfall occurred just after germination. However, 70 DAT the recovery of the crop was almost complete. Although local technicians consider this degree of phytotoxicity quite acceptable, further investigations are needed for a definitive conclusion on the acceptability of the crop tolerance at 0.45 kg.

Effect of oxyfluorfen on soybean in Egypt

Method and Materials

The same as for cotton. Three trials were carried out in Egypt in 1979.

Results

Table 3

% control of weeds in soybeans in Egypt in 1979

Treatment	Rate kg a.i./ha	Portulaca oleracea	Chenopodium album	Beta vulgaris	Amaranthus viridis	Dinebra retroflexa
oxyfluorfen	0.15	67	51	35	37	23
oxyfluorfen	0.30	85	70	61	56	63
oxyfluorfen	0.45	93	91	78	86	91
butralin	3.00	57	43	34	0	18
alachlor	2.40	54	60	29	0	86
alachlor + oxyfluorfen	1.20 0.15	96	96	88	-	96

Crop tolerance

No sign of phytotoxicity was detected at any tested rate. This is because of the absence of rain in Egypt during the season, and furrow irrigation. The excellent crop tolerance can obviously be related to countries having the same climatic conditions as Egypt.

Weed control

It was assessed at 75 and 80 DAT since later the canopy of vegetation prevented any further germination of weeds. Satisfactory results were achieved only with the rate of 0.45 kg with a degree of efficacy showing a tendency to be better (> 90% control) than in cotton tests on P. oleracea, C. album and D. retroflexa. This is due to the much quicker growth of soybean, the canopy of which covers the soil much earlier than in cotton.

Effect of oxyfluorfen on onions in Egypt in 1979-80

Method and Materials

The same as indicated for cotton, except size of single plot which ranged from 18 to 30 m^2. Oxyfluorfen was applied at different timings, i.e. before transplanting immediately after, 2, 3, 4 WAT (weeks after transplanting) and with the rate split in two applications, to find the best timing and way of application for weed control and to see whether crop tolerance would be affected by changing the time of application.

Crop tolerance

Yield data clearly demonstrated that oxyfluorfen is safe to transplanted onions up to the rate of 0.75 kg whatever the timing of application is, and irrespective of splitting or not of the rate. Although the visual assessment recorded some slight phytotoxicity at the rate of 0.60 and 0.75 kg, in the yield tests these two rates did not affect the yield at all but, on the contrary, 0.75 kg gave 22 to 34% increase over handweeded check.

Weed control

Splitting of the rate in two applications did not enhance the performance in comparison with one single spray. Only for few treatments was there a tendency to provide better results for certain weeds. Therefore it does not seem necessary to consider this way of application.

The rate of 0.3 kg in post-transplanting application gave satisfactory results up to 120 DAT with >85% control of C. album, P. oleracea, M. parviflora and >81% of S. oleraceus and B. vulgaris. Only with very late assessment (157 DAT) was the control recorded insufficient, due to the decline of the chemical.

To achieve a very long residual efficacy (up to 157 DAT) it was necessary to raise the rate up to 0.6 kg. However, a residual efficacy covering an interval longer than 120 DAT is not necessary, since at that time onion bulb has completed the last stage of growth. Therefore the rate of 0.3 or 0.45 kg appears quite satisfactory and as the most recommendable.

The best timing of application seems to be between 3 and 4WAT. With this timing we exploit the post-emergence efficacy of oxyfluorfen against broadleaves already germinated, for applying it as late as possible in order to have the decline of the chemical in a period in which weed germination is quite negligible.

Among the various weeds involved in the tests only Coronopus squamatus and Convolvulus arvensis were rather tolerant to oxyfluorfen with a fair control at 0.75kg.

ROTATION CROPS

Wheat, corn, tomatoes were sown from 5 to 9 months after oxyfluorfen application. No injury or effect of any type was observable on these crops where oxyfluorfen was applied to the previous crops.

Oxyfluorfen applied for weed control in vineyards and orchards in mixture with paraquat or dalapon

Methods and Materials

Tests were made in 1976,77,78, and 79 in Italy, Yugoslavia, Greece and Egypt. Tests were arranged in 4 randomized blocks and single plot size varied from 25 to 40m^2. Oxyfluorfen was applied as e.c. 23.6% with a knapsack sprayer and a spray volume of 1000 l/ha.

Paraquat and dalapon were applied in tank mixture with oxyfluorfen in comparison with the same two herbicides alone. All treatments were made late post-emergence of weeds. The mixture with paraquat was tested in vineyards or orchards with weed population mainly based on annual weeds, while the mixture of oxyfluorfen with dalapon was tested when perennial grasses were absolutely dominant.

Weed control

A) Oxyfluorfen in mixture with paraquat had three main advantages, i.e.:
- the synergistic activity obtained versus many weeds. See data in table 4, concerning Cynodon dactylon, Digitaria scalarum, Digitaria sanguinalis, Lolium

multiflorum, Sonchus arvensis, Bidens pilosa, and Cyperus esculentus.

- the addition of activity related to a stronger post-emergence activity of oxyfluorfen than paraquat against certain weeds like Convolvulus arvensis, Diplotaxis erucoides, P. oleracea and Solanum nigrum.
- The residual activity of oxyfluorfen on weeds germinating after treatment.

  Optimum dose rate: oxyfluorfen 1.440 kg plus paraquat 0.270 kg but 0.960 kg of oxyfluorfen gave acceptable potentiation.

B) Oxyfluorfen in mixture with dalapon, in comparison with dalapon alone, potentiated greatly the efficacy of dalapon against perennial and annual grasses, therefore it was possible to achieve satisfactory results with a reduced rate of dalapon - 4.34 kg instead of 6.8/8.5 kg normally recommended - thus allowing full crop tolerance on vines and fruit trees.

The evaluation of the control versus C. dactylon was made both in the year of treatment - by assessing the efficacy on the vegetation - and in the year following the treatment by evaluating the percentage of rhizomes regrowth on the basis of the percentage of C. dactylon coverage.

Among the various ratios of the two compounds in combination, oxyfluorfen 1.4kg plus dalapon 4.34 kg was best. It gave 97% control at 80 DAT (with surfactant) of C. dactylon vegetation versus 63% of dalapon alone and 83% control of rhizomes (365 DAT) versus 40% with dalapon alone. Similar potentiation was achieved in the control of Bromus spp. in comparison with dalapon alone.

Furthermore oxyfluorfen-dalapon combination provided a better control of annual grasses and an interesting or excellent post-emergence efficacy against broadleaves: 90-94% control of S. nigrum 80 DAT, 100% of Veronica spp. 94% of Oxalis, mentioning only thoses listed in table 5. Of course all these weeds were unaffected by dalapon alone.

As a conclusion, oxyfluorfen-dalapon combination at the rate of 1.4 + 4.34 kg offers the following advantages over dalapon alone:

- quicker activity on vegetation of grasses;
- much better control of rhizomes of perennial grasses;
- higher efficacy on annual grasses;
- fair to outstanding efficacy on many broadleaves.

Crop tolerance

Oxyfluorfen proved to be quite safe to vines, apples, peaches, pears at all teasted rates, and this is in accordance with its characteristics, i.e. negligible water solubility and very little translocation from roots to shoots. Under certain climatic conditions some slight phototoxicity was detected on a small percentage of tender leaves with the appearance of very small necrotic spots and crinkling of younger leaves, due to vapour action. However, all these symptoms were very slight and never caused any stunting of crop, any delay in growth, or any other negative effect.

The mixture with dalapon at 4.25 kg was tested in vineyards located in many types of soil from heavy to medium-light textured, and also in vineyards with soil free from weeds. In no case we could detect phototoxicity induced by dalapon or any increase of botrytis attack.

GENERAL CONCLUSIONS

Oxyfluorfen at 0.45 kg ha applied in pre-emergence to cotton, soybeans and groundnuts under certain climatic conditions is safe to the crop and controls the most important grasses and dicots at a satisfactory level often superior to the standard herbicides.

Oxyfluorfen proved to be a selective and broad spectrum herbicide for transplanted onions at rates ranging from 0.3 to 0.6 kg ai/ha, allowing application at a wide interval of time starting from transplanting up to 4WAT.

Another field of application of oxyfluorfen with outstanding results is weed control in vineyards, orchards as a post-emergence herbicide in combination with dalapon for perennial grass control and with paraquat for general weed control. In these combinations oxyfluorfen gave a great potentiation of the post-emergence efficacy of dalapon and paraquat which were much more effective than when used alone. For this kind of application oxyfluorfen must be used at 1.4 kg ai/ha.

Table 4

Oxyfluorfen + paraquat - summary of 4 years test results in Italy, Greece and Egypt

Mean % control 30 and 60-70 DAT

Weeds	oxyfluorfen		oxyfluorfen		oxyfluorfen + paraquat		oxyfluorfen + paraquat		paraquat	
	product kg a.i./ha									
	0.96		1.44		0.96 + 0.27		1.44 + 0.27		0.54	
	DAT									
	30	60/70	30	60/70	30	60/70	30	60/70	30	6/70
Grasses										
Cynodon dactylon	54	20	72	28	83	30	87	45	66	0
Digitaria sanguinalis	43	-	56	50	86	80	100	90	80	55
Digitaria scalarum	-	-	20	13	68	52	70	62	35	16
Lolium multiflorm	-	-	60	40	96	90	100	96	80	49
Dicots										
Amaranthus retroflexus	-	-	63	56	100	96	100	96	71	60
Bidens pilosa	63	59	81	70	91	88	95	92	71	43
Chenopodium album	-	-	60	60	95	80	96	90	40	40
Cirsium arvense	-	40	55	45	76	52	85	56	68	40
Convolvulus arvensis	90	50	93	61	97	62	98	66	45	0
Cyperus esculentus	-	-	60	30	83	82	92	82	20	17
Diplotaxis erucoides	-	-	100	95	100	90	100	96	80	55
Oxalis cernua & corniculata	-	-	100	85	100	96	100	100	50	35
Portulaca oleracea	90	84	94	90	100	100	100	100	58	0
Solanum nigrum	-	-	95	90	100	90	100	100	40	0
Sonchus spp.	-	-	25	15	90	88	96	92	56	25
Taraxacum officinale	-	-	50	30	57	19	66	45	20	0

TABLE 5

OXYFLUORFEN + DALAPON

SUMMARY OF 4 YEARS' TEST RESULTS IN ITALY, EGYPT AND YUGOSLAVIA IN ORCHARDS AND VINEYARDS

Mean % of Control 30 - 80 - 365 DAT

Treatment	Rate kg a.i./ha	Cynodon dactylon			Lolium multiflorum		Digitaria sanguinalis		Bromus spp.		Setaria spp.		Convolvulus arvensis		Solanum nigrum		Veronica hederaefolia		Oxalis cernua and corniculata	
		DAT 30	80	365	30	80	30	80	30	80	30	80	30	80	30	80	30	80	30	80
Oxyfluorfen + Dalapon	0.96 4.34	71	76	55	78	80	78	80	60	90	-	-	-	-	-	-	100	100	-	-
Oxyfluorfen + Dalapon	1.40 3.40	69	78	40	80	81	85	87	50	75	-	-	-	-	-	-	100	100	97	95
Oxyfluorfen + Dalapon	1.40 4.34	92	94	74	85	84	100	100	60	93	96	100	75	55	100	90	100	100	97	94
Oxyfluorfen + Dalapon + Surfactant (Polyglycol Ether)	1.40 4.34 0.22	95	97	83	90	85	100	100	-	-	96	100	73	56	100	94	-	-	-	-
Dalapon	4.34	53	63	40	53	70	90	35	30	40	75	80	0	0	0	0	0	0	0	0

EGYT 2250 A NOVEL POTENTIAL PGR COMPOUND

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Summary EGYT 2250 a new PGR compound is very promising as a seed dressing for corn and sunflower and preemergent application in tomato, and red pepper. This compound promotes not only the germination of plants, but exerts a growth promoting effect in the vegetative development stage of plants as well, and it has a marked crop yield increasing effect in the generative phase. A further advantage of the new compound is mild insecticidal activity and low toxicity in addition to the absence of cholinesterase blocking effects.

INTRODUCTION

A new type of biologically active compound has been found among derivatives of oxime-ethers which were synthetised in the Research Laboratory of EGYT Pharmacochemical Works.

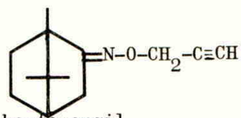
Compounds of this type show plant growth promoting activity on a large number of cultivated plants. This has been established in greenhouse and field trials.

EGYT 2250 has a mild insecticidal activity as well which was investigated in laboratory tests.

PHYSICAL AND CHEMICAL PROPERTIES

Chemical name: ±-2-propargyloxyimino-1,7,7-trimethyl-bicyclo-2,2,1-heptane

Chemical structure:



Common name: proposed	heptopargil
EGYT Code:	EGYT 2250
Molecular weight:	205.29
Boiling point:	95°C/133 Pa
Appearance:	Yellowish oil with special odour
Specific gravity:	0,9867 g/cm^3
Solubility:	H_2O: 0,1 g/100 ml. Miscible with protic and aprotic solvents

Formulations: EC 50, 50% w/w for pre-and postemergence application
EC 50 for seed dressing

Assay: by GLC. Chromosorb, OV101 3%, 8 feet, FID, Sample 250°C, Oven 160°C.

TOXICOLOGY

Broad-scale investigations on the toxicity of EGYT 2250 are in progress. Results from acute oral studies indicate its low toxicity.

LD_{50} acute oral in mg/kg body weight	rats	
EGYT 2250	male	female
	2000	1400

METHODS AND MATERIALS

Green house tests: Seeds of bean, carrot, flax, red pepper, tomato, spinach, barley and sorghum were sown in pots, 20 x 20 cm, filled with sand. The pots were treated prior to plant emergence. The green weights of the 4-weeks-old plants were measured, and the data were compared to those observed on the untreated controls.

Field trials: The field trials were on a Loxlom sandy loam soil with 4 replicates and 10 m^2 plot size. Application was made using a hand precision sprayer giving spray volumes of 250-500 l/ha at pressures of 2-4 kg/cm^2.

The plots were hoed to remove weeds. Plant growth effects were evaluated by measuring the height, fresh and dry-weight of the plants, or by harvesting ear yield.

Seed dressing: corn (KSC365 Hungarian single cross type) and sunflower seeds were placed into a dragee pan, rotating the pan, and wetting the seeds with an aqueous solution of a binding agent e.g. sodium carboxy methyl cellulose and aqueous solution of EGYT 2250 EC, and drying by air draught, T_{max} 40°C.

Insecticidal test:
100 g of bean seeds were coated with a spray liquid containing 1,0% by weight of active agent to give 250, 500, 1000 ppm of a.i. The control seeds were not treated. The seeds were put into small cylindrical flasks, 20 insects each were placed into the flasks and were covered with a cloth. After 14 days the survivors were counted. The results are expressed in percentage control.

RESULTS

We have studied the effects of EGYT 2250 on cultivated plants in the greenhouse. The data of Table 1 show greatest fresh weight increases in flax, tomato, spinach and barley with 0.1 Kg/ha and with 0.2 Kg/ha for the other crops. Fresh weight increases were 18-40% above untreated controls.

Table 1

Fresh weight 4 weeks after pre-emergence treatment in sand

Crop	Fresh weight (per cent of control) 0.1 Kg/ha	0.2 Kg/ha
Bean	110	135
Carrot	105	140
Flax	118	105
Red pepper	95	140
Tomato	120	112
Spinach	135	-
Barley	120	105
Soghum	130	130

We have been studying in more detail the effect of this compound on corn and sunflower as a seed dressing, and in preemergence applications in the greenhouse and open air tests. The experiments are still in progress. The data of Table 2 indicate that, within the limits of experimental error, there was no difference between untreated controls and seed dressed with a composition free of active ingredient. Corn seedlings from treated seeds were 43 - 48 per cent taller and 52 - 54 per cent heavier than controls and sunflowers were were 28 - 46 per cent taller and 38 - 42 per cent heavier.

Table 2

Effect of seed dressing on corn and sunflower under greenhouse conditions

Treatment	Germination %	Height %	Fresh weight %	Height %	Fresh weight %
		14th day		28th day	
Corn					
Untreated	92	100	100	100	100
Coated without a.i.	95	105	102	103	94
150g a.i./100kg	95	143	152	148	154
Sunflower					
Untreated	90	100	100	100	100
Coated without a.i.	92	103	102	101	99
150g a.i./100kg	96	128	138	146	142

Table 3

Small plot trial with corn seed dressing

Treatment	Height	Fresh weight % of control	Ear yield
Coated without a.i.	98	103	101
150g a.i./100Kg	127	125	120

Table 3 demonstrates that seed treatment of corn gave plants which were 27% taller, a fresh weight 25% greater and an ear yield 20% greater than the control or coated seed without a.i. The results were the same on large plots.

Table 4

Pre-emergence application to corn, tomato and red pepper

Treatment Kg a.i./ha	Height	Fresh weight % of control	Ear yield		
	Corn	Corn	Corn	tomato	red pepper
0.1	105	105	102	98	101
1.0	121	127	118	109	112
3.0	127	135	116	118	115
5.0	115	115	107	119	124

Table 4 indicates that EGYT2250 applied preemergence has some effect even at 0.1 Kg/ha in corn but the most active dose is between 1 and

3 Kg/ha. A promising effect on tomato and red pepper was also demonstrated. Advantageous side effects were found from seed-dressing. EGYT2250 exhibits mild insecticidal activity against a great number of insects including house flies and dried bean beetle. Broad-scale investigation of these effects is in progress. The data in Table 5 indicate that the compound can be used successfully to kill stored grain insect pests such as the dried bean beetle at a concentration of 250ppm.

Table 5

Protection of bean seeds from dried bean beetle Achanthoscelides obtectus

Dose ppm	Time	Activity per cent control EGYT2250	Dichlorphon
250	60 min	17.5	45
	120 min	35	72
	240 min	65.5	100
	1440 min	100	100
250	14 days	95	
500	" "	100	
1000	" "	100	

DISCUSSION

EGYT2250 represents a new type of plant growth promoting compound with a mild insecticidal activity. Doses are 50 - 150g/100Kg of seed as a seed dressing and 1 - 3 Kg/ha in pre-emergence or preplanting application. We have been studying its effectiveness since 1976 under both greenhouse and field conditions. The experiments are still in progress. We are hoping to apply this compound successfully as a seed-dressing on corn and sunflower and in pre-emergent or preplanting use on tomato, red pepper, bean and other crops. It seems to be promising against granary pests as well.

INTERACTIONS BETWEEN BENAZOLIN AND OTHER HERBICIDES FOR BROAD-LEAF WEED CONTROL IN SOYBEANS

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Summary Benazolin can be used at rates between 250 and 450 g a.i./ha to give excellent control of *Xanthium* in soybeans. It has been shown recently that when mixed with low rates of other post-emergence herbicides, such as bentazon, a more than additive effect is noted on *Xanthium* and outstanding control of *Abutilon* and *Datura* is also achieved. So marked is this effect that rates below those recommended for field use can be used. It is indicated that the presence of benazolin in the spray substantially increases the rate of uptake of bentazon. Interactions with other compounds such as acifluorfen, have also been noted on weeds in sub-tropical crops.

Resume La benazolin utilisee dans les cultures de soja entre 250 et 450 g m.a./ha est tres efficace contre *Xanthium*. On a recemment demontre que des melanges de benazolin avec des faibles doses de differents herbicides de post-levee, comme la bentazon, ont un effet herbicide plus qu'additif contre *Xanthium* et une efficacite exceptionnelle contre *Abutilon* et *Ipomoea*. Cet effet est tellement marque l'on peut utiliser des doses inferieures aux doses recommandees. On indique que la presence de benazolin accroit de facon substantielle l'activite de la bentazone. D'autres interaction avec des produits comme l'acifluorfen ont ete aussi observees sur cultures sub-tropicales.

INTRODUCTION

The herbicidal properties of benazolin were first described in 1963 by Brookes and Leafe. Since its discovery it has found widespread use for the control of *Galium* and *Stellaria* in cereals and oil seed rape and has been a major component of a wide range of very effective products giving broad spectrum broad-leaf weed control (Lush *et al* 1968 and Rea *et al* 1976).

The value of benazolin for weed control in undersown cereals was never developed into legumes because of phytotoxicity problems but recent work has shown that good selectivity can be achieved in tropical legumes such as soybeans at rates that control *Xanthium*. The narrowness of the weed spectrum, however, meant that broad spectrum weed control required the addition of other post-emergence herbicides such as bentazon and acifluorfen.

METHOD AND MATERIALS

In glasshouse trials seeds of crops and weeds were sown in a light sandy loam soil in 9 cm pots. These were grown in the glasshouse under a 16 hour day where the minimum temperature was 16^{o}C. At the 3-4 leaf stage the plants were sprayed with the appropriate rate of benazolin in a spray volume of 1,000 l/ha. Assessments were made ten days after spraying.

In Australian trials crops and weeds were drilled using a Stanhay precision seed drill. When the plants had reached the 4-6 leaf stage they were sprayed with the appropriate herbicide in a spray volume of 390 l/ha. Assessments were made 14 days after treatment.

Field trials were conducted in 1979 in Kentucky and Illinois in soybeans by University collaborators under the grant-in-aid system. In all cases mixtures of benazolin and bentazon or acifluorfen were applied post-emergence to both weed and crop. Visual assessments for percent broad-leaf weed control and crop injury were made on randomised complete block experiments with four replicates.

Applications were made in Kentucky when the soybeans were at the second trifoliate leaf stage and assessments were made twenty-one days later. In Illinois soybeans were treated at the 6th or 7th trifoliate leaf stage. Crop effects were assessed 10 days after treatment whilst percent weed control measurements were taken 28 days after treatment.

The herbicidal responses of the mixtures were calculated using the Colby equation (Colby 1967).

RESULTS

1. Glasshouse Results - The effectiveness of benazolin in controlling a number of important weeds of soybean is shown in Table 1. The effect on the two weeds *Xanthium* and *Datura* was particularly encouraging at the 200 g/ha rate whilst at 300 g/ha a good effect was noted on all weeds except *Ipomoea*. However, at the highest rate some damage to soybean became apparent. This damage was typically epinasty and slight leaf deformity that disappeared after 3-4 weeks growth. These data showed that benazolin had some potential for broad-leaf weed control in soybeans but that mixtures would be essential for broad spectrum activity. It was towards this end that trials were initiated at the Kooree Research Farm, Australia.

Table 1

Effect of benazolin under glasshouse conditions on various broad-leaf weeds of soybean - Glasshouse data

Treatment	Rate g a.i./ha	Amaranthus	Abutilon	Ipomoea	Portulaca	Xanthium	Sida	Datura	Soybean*
Benazolin	100	2	5	5	8	5	4	4	0
	200	4	5	5	8	7	6	7	1
	300	7	7	5	9	9	8	10	2

*Assessed on a scale 0-10 where 0 is no effect and 10 is complete control. Average of four replicates.

2. Australia - Table 2 shows the results of preliminary trials with benazolin and bentazon alone and in combination in maize, peanut and two varieties of soybean against *Xanthium pungens*. No combination had any effect on any of the crops, showing that the potential for these mixtures extends into crops other than soybeans. Against *Xanthium*, all the benazolin/bentazon combinations gave better weed control that would have been expected using the Colby calculation. No rate of benazolin alone gave an acceptable effect on the weed. Whilst the 400 g/ha rate of bentazon alone was more effective, control was again not satisfactory.

All three rates of benazolin, however, when mixed with 400 g/ha bentazon gave increased weed kill and acceptable repression of growth of the surviving plants.

Table 2

Effect of benazolin and bentazon alone and in combination on Xanthium control - Australia

Treatment	Rate g a.i./ha	Maize	Peanut	Davis Soybean	Semstar Soybean	Xanthium % kill Actual	Xanthium % kill Expected	Xanthium % growth inhibition Actual	Xanthium % growth inhibition Expected
Benazolin	100	0	0	0	0	0	-	10	-
	200	0	0	0	0	0	-	20	-
	300	0	0	0	0	0	-	26	-
Bentazon	400	0	0	0	0	38	-	65	-
	800	0	0	0	0	83	-	88	-
Benazolin + bentazon	100 + 400	0	0	0	0	50	38	83	69
	200 + 400	0	0	0	0	49	38	73	72
	300 + 400	0	0	0	0	60	38	76	74

These data were sufficiently encouraging for further work to be undertaken in the U.S.A. All American trials were co-ordinated by Boots-Hercules Agrochemicals staff and were conducted through the University grant-in-aid system. Data from two collaborators at the University of Kentucky and at Illinois University are presented below.

3. Kentucky - The results of the effects of benazolin, bentazon and acifluorfen alone and in combination are shown in Table 3. Clearly, benazolin on its own is not giving adequate control of the Xanthium and the total weed control achieved is far from satisfactory. Similarly, bentazon at the 280 kg a.i./ha rate (which is much lower than the recommended field rate) is not giving acceptable weed control. However, the combination of bentazon at 280 g a.i./ha and benazolin at both 140 and 280 g a.i./ha give control of both Xanthium and the other broad-leaf weeds which is far greater than that which would be expected from the Colby calculation. Whilst a similar effect on Xanthium and total weed control is not seen with the benazolin/acifluorfen combinations (Table 3) the very important weed Sida is controlled more effectively by the mixture than the activity of either component would suggest.

4. Illinois - Data from Illinois are shown in Tables 4-6. When applied early (Table 4) bentazon had limited effectiveness on the weeds Abutilon theophrasti and Datura stramomium at the low rate of 125 g a.i./ha and even rates of 375 g a.i./ha did not control Abutilon. Benazolin on the other hand was very effective at inhibiting the growth of both these weeds at the low rate of 125 g a.i./ha but failed to kill either weed even at the high rate of 375 g a.i./ha. The combination treatments showed no benefit of adding 125 g a.i. benazolin to bentazon for Velvet leaf control but outstanding control of Jimson weed was achieved with all low rate benazolin combinations. The apparent slight reduction in control of Abutilon noted with the 125 g a.i./ha combinations disappeared with the 250 g a.i./ha mixtures and Datura control was outstanding. Worthy of special note was the 250 g benazolin plus 125 g bentazon mixture where single component data would

have predicted 0% kill and 95% growth inhibition whilst actual data showed 82% kill and 98% growth inhibition.

Later stage applications (Table 5) showed a similar trend in that Abutilon control was marginally inferior in the mixtures than would have been predicted whilst Datura control was outstanding. No treatment would have been expected to control Datura but in fact some weed kill was achieved in all but one combination and in all cases acceptable weed suppression occurred. It must be remembered that these weeds were 6-12 inches high and would consequently be extremely difficult to control.

Acifluorfen/benazolin combinations (Table 6) produced similar results on Datura and Xanthium. Acifluorfen was more active on Datura than bentazon whilst in this trial benazolin produced similar effects to the bentazon trial inhibiting growth rather than killing the weed. In nearly every case all acifluorfen/benazolin combinations produced an effect which was substantially superior to that which would have been predicted by Colby. Worthy of particular note are the 125 g a.i./ha benazolin plus 125 g a.i./ha acifluorfen which predicted 17% control and achieved 78% and the 250 g a.i./ha benazolin plus 125 g a.i./ha acifluorfen which predicted 17% kill and achieved 65%. Similar results are shown for Xanthium control. At the rates used acifluorfen had no effect on this weed and yet all combinations showed more severe effects than benazolin on its own. This was particularly true of the benazolin 250 g a.i./ha combinations.

Table 3

Effect of benazolin, bentazon and acifluorfen alone and in combination on weed control in soybeans (Rieck, Witt and Bugg - University of Kentucky)

Treatment	Rate g a.i./ha	Xanthium	% control	Sida		Total Broad-leaf Weed	
		Actual	Expected	Actual	Expected	Actual	Expected
Benazolin	140	32	-	28	-	21	-
	280	35	-	42	-	45	-
Bentazon	280	62	-	-	-	64	-
	840	90	-	-	-	93	-
Acifluorfen	280	84	-	38	-	82	-
	560	88	-	45	-	89	-
Benazolin/ Bentazon	140 + 280	88	74	-	-	84	72
	280 + 280	97	75	-	-	92	80
	140 + 840	92	93	-	-	91	94
	280 + 840	100	93.5	-	-	96	96
Benazolin/ Acifluorfen	140 + 280	95	90	70	55	88	86
	280 + 280	68	90	66	64	72	90
	140 + 560	85	92	65	60	89	91
	280 + 560	92	92	87	68	94	94

Table 4

Effect of benazolin and bentazon alone and in combination on weed control in soybeans early application (Slife - Illinois University)

Treatment	Rate g a.i./ha	Weed Height (inches)	Abutilon % kill		Abutilon % growth inhibition		Datura % kill		Datura % growth inhibition		Soybean injury (%)
			Actual	Expected	Actual	Expected	Actual	Expected	Actual	Expected	
Benazolin	125	3-8	0	-	83	-	0	-	85	-	0
	250	3-8	0	-	95	-	0	-	95	-	0
	375	3-8	0	-	94	-	0	-	99	-	1
Bentazon	125	3-8	0	-	0	-	0	-	0	-	0
	250	3-8	53	-	0	-	83	-	0	-	0
	375	3-8	53	-	10	-	100	-	-	-	0
Benazolin + Bentazon	125 + 125	3-8	0	0	94	83	7	0	93	85	0
	125 + 250	3-8	7	53	83	83	100	83	-	85	0
	125 + 375	3-8	27	53	80	85	100	100	-	-	1
	250 + 125	3-8	0	0	47	95	82	0	98	95	0
	250 + 250	3-8	7	53	94	95	98	83	90	95	0
	250 + 375	3-8	40	53	97	96	100	100	-	-	1

Table 5

Effect of benazolin and bentazon alone and in combination on weed control in soybeans late application (Slife - Illinois University)

Treatment	Rate g a.i./ha	Weed Height (inches)	Abutilon % kill		Abutilon % growth inhibition		Datura % kill		Datura % growth inhibition		Soybean injury (%)
			Actual	Expected	Actual	Expected	Actual	Expected	Actual	Expected	
Benazolin	125	6-12	0	-	85	-	0	-	89	-	0
	250	6-12	0	-	87	-	0	-	87	-	0
	375	6-12	0	-	83	-	0	-	91	-	0
Bentazon	125	6-12	0	-	0	-	0	-	0	-	0
	250	6-12	0	-	0	-	0	-	0	-	0
	375	6-12	0	-	0	-	0	-	0	-	0
Benazolin + Bentazon	125 + 125	6-12	0	0	82	85	20	0	86	89	0
	125 + 250	6-12	0	0	70	87	33	0	83	87	0
	125 + 375	6-12	0	0	73	83	3	0	80	91	2
	250 + 125	6-12	0	0	85	85	0	0	82	89	1
	250 + 250	6-12	0	0	83	87	38	0	82	87	0
	250 + 375	6-12	0	0	83	83	33	0	88	91	0

Table 6

Effect of benazolin and acifluorfen alone and in combination on weed control in soybeans early application (Slife - Illinois University)

Treatment	Rate g a.i./ha	Weed Height (inches)	Datura % kill		Datura % growth inhibition		Xanthium % kill		Xanthium % growth inhibition		Soybean injury (%)
			Actual	Expected	Actual	Expected	Actual	Expected	Actual	Expected	
Benazolin	125	0-2	0	-	90	-	0	-	90	-	0
		2-5	0	-	83	-	0	-	82	-	
	250	0-2	0	-	93	-	0	-	93	-	0
		2-5	0	-	90	-	0	-	91	-	
	375	0-2	0	-	99	-	0	-	98	-	0
		2-5	0	-	99	-	17	-	99	-	
Acifluorfen	125	0-2	17	-	47	-	0	-	0	-	0
		2-5	23	-	20	-	0	-	0	-	
	250	0-2	83	-	88	-	0	-	0	-	2
		2-5	50	-	20	-	0	-	0	-	
	375	0-2	100	-	-	-	0	-	0	-	1
		2-5	100	-	-	-	0	-	0	-	
Benazolin + Acifluorfen	125 + 125	0-2	78	17	95	95	0	0	95	90	0
		2-5	17	23	92	86	0	0	88	82	
	125 + 250	0-2	100	83	-	90	0	0	95	90	1
		2-5	93	50	90	86	0	0	94	82	
	125 + 375	0-2	100	100	-	-	0	0	99	90	3
		2-5	100	100	-	-	0	0	99	82	

DISCUSSION

It has been shown convincingly that benazolin has a significant effect on the growth of certain very important broad-leaf weeds in soybeans. This is particularly true of Xanthium, Sida, Datura and Abutilon. However, the effects are such that even at rates which are non-economic the weeds are frequently not completely killed by treatment. Relatively high rates of bentazon and acifluorfen have to be used to control these weeds and even at these relatively high rates there are deficiencies in the weed control spectrum particularly with late stage applications and especially with acifluorfen on Xanthium and Abutilon.

The results from field trials with benazolin/bentazon and benazolin/acifluorfen mixtures have shown that these combinations give more than additive control of these four important weed species. So effective are the treatments that rates below those recommended for field use in combination with benazolin from 125-300 g a.i./ha benazolin can be used. Even relatively large weeds are also controlled.

It has been reported (Bugg et al 1980) that the reason for the excellent results achieved with benazolin/bentazon mixtures is that the addition of benazolin significantly increases the rate of translocation of bentazon in the plant. Similar experiments with ^{14}C-labelled acifluorfen did not show a similar response and consequently it is possible that there is a different basis for the enhancement of herbicide activity by benazolin between these two compounds. Further work is planned to investigate these responses in more detail.

Preliminary data not reported here also show that combinations such as benazolin/dinoseb have given results which produce weed control which is greater than that which would have been predicted by the effects of their single components. It has also been shown that the previously reported synergism between benazolin and dicamba (Lush et al 1968) can be extended to the control of important weeds such as Abutilon, Ipomoea and Xanthium. These results opens up the prospect of combinations of benazolin with a wide range of herbicides in the very important high acreage crops soybeans and corn.

Acknowledgements

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MICROENCAPSULATED THIOCARBAMATE HERBICIDES: A REVIEW OF THEIR PHYSICAL, CHEMICAL AND BIOLOGICAL PROPERTIES

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Summary Physical, toxicological and biological properties of microencapsulated formulations of two thiocarbamate herbicides are discussed. Microencapsulation slows the volatilisation of both EPTC and vernolate, and thus removes the need for immediate soil incorporation. Trials have demonstrated that when microencapsulated, both these herbicides maintain excellent activity when incorporated 8 and 24 hours after application. This formulation technique also decreases the acute toxicity of the thiocarbamate herbicides.

INTRODUCTION

The thiocarbamate herbicides EPTC + protectant (Eradicane) butylate + protectant SUTAN+) and vernolate + protectant SURPASS) are well established maize herbicides in many parts of the world (Blair 1976). When applied correctly these materials will control a wide range of economically important grasses such as Agropyron repens, Sorghum halepense, Cynodon dactylon, Echinochloa crus-galli, Digitaria sanguinalis, Setaria spp. and a number of broadleaved weeds, including atrazine resistant Amaranthus retroflexus, Chenopodium album and others. Most thiocarbamates are volatile and thus for optimum control of these weeds they must be incorporated into the soil immediately after application (Koren, 1968). In some countries, however, this requirement for immediate incorporation is proving to be a constraint to the use of EPTC + protectant and related herbicides in maize.

Although volatility is a property of the active ingredient it can be affected by formulation type. Recently Stauffer Chemical Company developed a novel formulation process, which encloses a thiocarbamate herbicide in polymer-based microcapsules dispersed in an aqueous system. This technique which was described by Scher (1977) not only reduces the volatility of the herbicide, but also confers other useful properties including reduced mammalian toxicity, increased selectivity, reduced soil movement, and the prospect of lower application rates.

This paper discusses some of the physical, toxicological and biological properties of microencapsulated formulations of thiocarbamate herbicides.

PHYSICAL PROPERTIES

Typically a microencapsulated product is an aqueous suspension of 1 - 200 micron sized particles each of which is composed of a solid or liquid herbicide core surrounded by a polymeric wall (Fig. 1). This wall isolates and protects the core material in storage, but is designed to release it in a controlled manner when the microcapsules are exposed to the environment i.e. after spraying. The release rate from this system can be modified by varying microcapsule size, wall thickness or wall permeability.

The microencapsulated formulations of EPTC + protectant and vernolate + protectant contain 360 g/l and 480 g/l of the herbicide ingredient respectively, together with suspending and buffering agents. Both formulations have good physical properties, they are unaffected by hard or soft water, and they can be tank-mixed with a wide range of other products, including liquid fertilizers.

TOXICOLOGY

Tests with highly toxic organophosphorus insecticides have clearly demonstrated that microencapsulated formulations exhibit much reduced acute toxicity when compared with emulsifiable concentrates of the same material. Although a similar trend has been observed with thiocarbamates (Table 1), the decrease is less dramatic since these compounds are inherently of low toxicity.

Table 1

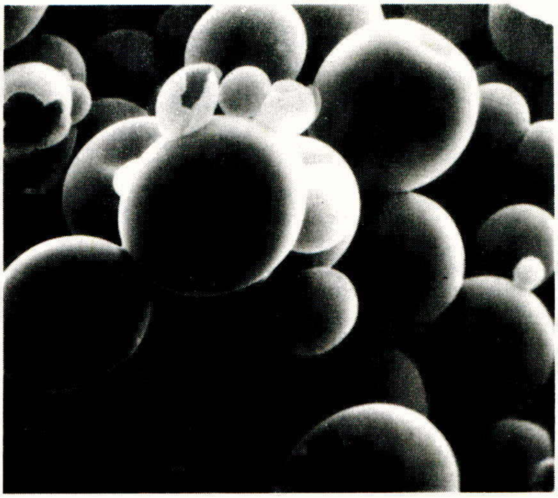
Acute Toxicity of two Formulations of EPTC + Protectant

	Acute oral LD 50 (rat)	Acute dermal LD 50 (rabbit)
EPTC + protectant Microencapsulated formulation	5000 mg/kg	5000 mg/kg
EPTC + protectant Emulsifiable concentrate	2000-2870 mg/kg	3830 mg/kg

Thiocarbamates formulated as emulsifiable concentrates are frequently found to be skin and eye irritants. In contrast the data presented in Table 2 show that water-based microencapsulated formulations of two thiocarbamates are non-irritating to either the skin or eyes of test animals.

Figure 1

Electron scanning photomicrograph of microcapsules produced by polymerisation



Magnification = 1000 X

Table 2

Skin and eye irritancy of two thiocarbamate herbicides

	Skin Irritation (rabbit)	Eye Irritation (rabbit)
EPTC + protectant Microencapsulated formulation	non-irritant	non-irritant
EPTC + protectant Emulsifiable concentrate	irritant	moderate irritant
Butylate + protectant Microencapsulated formulation	non-irritant	non-irritant
Butylate + protectant Emulsifiable concentrate	irritant	irritant

As a part of a general toxicological study of microencapsulation the toxicity of the capsule wall polymer was also evaluated. It appeared that this material is virtually non-toxic, with an acute oral LD 50 of greater than 9000 mg/kg and is non-irritating to the skin and eyes of rabbits. Ninety-days subchronic feeding tests in rats and dogs revealed no adverse effects when the animals were fed a diet containing up to 1.0% W/W of the capsule polymer.

BIOLOGICAL PROPERTIES

MATERIALS AND METHODS

A large number of maize trials were conducted throughout Western Europe (France, Germany, Holland, Spain and Italy) during 1979 and 1980 to evaluate microencapsulated formulations of EPTC + protectant and vernolate + protectant. The major objective was to determine whether soil incorporation could be delayed for a period of up to 24 h. after application, without loss of activity.

The tests were designed as randomized blocks with 3 - 4 replications and plot size varied from 16 - 25 m^2. The herbicides were sprayed at rates ranging from 2.88 - 5.76 kg ai/ha using a plot sprayer operating at a pressure of 2.5 - 3 bar and delivering 400 - 500 l/ha of water. Incorporation was carried out by means of rototillers, discs or harrows at 0, 8 and 24 hours after application. Herbicide activity was assessed by counting each weed species in four quadrats per replicate at 6 and 10 weeks after spraying and is given in Tables 3 - 5 as percent weed control.

The soil surface at most trial sites was predominantly dry during application. Air and soil temperatures ranged from 2 - 17° C. Maize hybrids included in the tests were: Atrea, Axia, Cosmos, Essor, Funk's G-4384, Dara, Buras LG 5, Circé LG 9, LG 11, Liza, Silor, Star 304 in France, Forla, Inraplus, Silor in Germany, Blizzard, Brutus, Fronica in Holland, Funk's First, Funk's Most, Funk's G-4288, NS-212 Capri in Italy, AE 701, Funk's G-44, Pioneer-3147 and PX-74 in Spain.

RESULTS

Mean data from thirty-six trials conducted throughout Western Europe are presented in Table 3. The emulsifiable concentrate formulation of EPTC + protectant gave good weed control when incorporated into the soil immediately after application. If, however, incorporation was delayed for 8 or 24 hours, EPTC was lost from the soil surface by evaporation and consequently weed control was poor. In contrast the microencapsulated formulation of EPTC + protectant was not affected by a delay in soil incorporation and performed well whether incorporated immediately after application or 24 hours later. It is also interesting to note that when incorporated immediately the microencapsulated formulation shows a higher level of herbicide activity than an equivalent rate of emulsifiable concentrate. Furthermore there is very little rate response between 2.88 kg ai/ha and 5.76 kg ai/ha of the microencapsulated material.

Similar results were recorded for vernolate + protectant (Table 4), but since vernolate is less volatile than EPTC the effects of delayed incorporation and microencapsulation are less pronounced.

Table 3 *

Activity of two formulations of EPTC + protectant against grass and broadleaved weeds in maize

Formulation	Dosage (Kg/Ha AI)	Delay in Incorporation (HRS) 0	8	24
1) 6E	3.60	85	76	68
6E	5.04	90**	79	73
6E	5.76	87	76	77
2) 3S	2.88	90**	89*	85
3S	3.60	90**	89*	86
3S	5.76	93**	92**	90**
36 trials	LSD (p = 0.01) = 4.50	LSD (p = 0.05) = 3.34		

1) Emulsifiable concentrate containing 720 g/1 EPTC
2) Microencapsulated formulation containing 360 g/1 EPTC

Weed species present: Amaranthus retroflexus, Anagallis arvensis, Chenopodium album, Lamium purpureum, Polygonum aviculare, Polygonum convolvulus, Polygonum persicaria, Galium aparine, Alopecurus myosuroides, Digitaria sanguinalis, Echinochloa crus-galli, Setaria verticillata, Setaria viridis.

Table 4 *

Activity of two formulations of vernolate + protectant against grass and broadleaved weeds in maize

Formulation	Dosage (Kg/Ha AI)	Delay in Incorporation (HRS) 0	8	24
1) 6.7E	4.02	86	85	73
2) 4S	2.88	85	87	77
4S	3.36	87	87	85
4S	4.02	92*	89*	87
7 trials	LSD (p = 0.05) = 2.77			

1) An emulsifiable concentrate containing 804 g/1 vernolate
2) A microencapsulate formulation containing 480 g/1 vernolate

Weed species present: Amaranthus retroflexus, Anagallis arvensis, Chenopodium album, Polygonum persicaria, Stellaria media, Veronica persica, Viola tricolor, Alopecurus myosuroides, Digitaria sanguinalis, Echinochloa crus-galli, Setaria viridis, Setaria verticillata.

* Activity in tables 3 and 4 expressed in percent weed control.

Table 5

Activity of two formulations of EPTC + protectant against annual grass weeds in maize 6 and 10 weeks after application

Formulation	Dosage (Kg/Ha AI)	Delay in Incorporation (HRS)	Percentage Weed Control 6 Weeks	10 Weeks
6E	3.60	0	96	88
3S	3.60	0	99	97
3S	3.60	8	99	95
3S	3.60	24	97	93
8 trials				

Weed species present: *Digitaria sanguinalis*, *Echinochloa crus-galli*, *Setaria verticillata*, *Setaria viridis*

In one series of trials weed control assessments were made six and ten weeks after application to determine the relative persistence of two EPTC formulations. Whilst the data shown in Table 5 are not conclusive, there is a suggestion that controlled herbicide release from a microencapsulated formulation will maintain weed control for a longer period than the current commercial product. These results are confirmed by laboratory studies which indicated that butylate (a related thiocarbamate) released from microcapsules, was present at slightly higher concentrations in the top 0 - 15 cm of soil for a period of 30 - 60 days following application, when compared with the emulsifiable concentrate.

DISCUSSION

The data presented in this paper demonstrate that microencapsulated formulations of the thiocarbamate herbicides, EPTC + protectant and vernolate + protectant will provide excellent weed control even when soil incorporation is conducted 24 hours after spraying. In practice, this advantage will undoubtedly allow the small and large scale farmer to make better use of equipment at the very critical time of seedbed preparation, herbicide application and drilling.

For the larger farmer or farming cooperative delayed incorporation offers the opportunity for aerial application. In the past, this method of application has not been feasible with the thiocarbamates since commercial formulations are volatile and require immediate incorporation. Thus a considerable amount of chemical would be lost by evaporation before the spray reached the soil surface. Even assuming satisfactory aerial application the large amount of cultivation equipment required to achieve immediate incorporation would be unpractical. The reduced volatility and the flexibility of a 24 hours delay in incorporation make the microencapsulated thiocarbamates much more suitable for aerial application.

Further fieldwork is planned to confirm the findings mentioned in this paper, and to confirm whether a reduction in herbicidal rate will be feasible.

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Proceedings 1980 British Crop Protection Conference - Weeds

BTS 44 584 - A GROWTH REGULATOR WITH EFFECTS ON SOIL WATER CONSERVATION

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Summary BTS 44 584 (S-2,5-dimethyl-4-pentamethylenecarbamoyloxyphenyl-SS-dimethylsulphonium p-toluenesulphonate) applied as a foliar spray to soybeans at 0.5 kg/ha acts as a growth retardant, reducing internode length and inducing a compact growth habit. Water loss via transpiration from treated plants is significantly reduced. Stomatal density is increased and pore size is reduced but responses to light are unaltered by treatment. The decrease in total water loss is related directly to the reduction in leaf area in plants treated with BTS 44 584.

Soybeans are particularly susceptible to water stress and it is concluded that BTS 44 584 may be a useful aid in the conservation of soil water.

Resume BTS 44 584 (S-2,5-dimethyl-4-pentamethylenecarbamoyloxyphenyl-SS-dimethylsulphonium p-toluenesulphonate) utilise en pulverisation foliaire sur soja a 0.5 kg/ha agit comme un retardateur de croissance, reduisant la longueur des entre-noeuds et induisant un comportement de croissance compacte. La perte d'eau par transpiration des plantes traitees est significativement diminuee. La densite des stomates s'accroit, la taille des pores diminue, mais les reponses a la lumiere sont inalterees. La diminution de perte en eau est correlee a la reduction de la superficie foliaire chez les plantes traitees avec le BTS 44 584.

Le soja est tres sensible au manque d'eau. Ce produit peut par consequent s'averer etre une aide precieuse pour conserver l'eau du sol.

INTRODUCTION

Several studies have demonstrated that in determinate and indeterminate varieties of soybean, BTS 44 584 significantly reduces height, may prevent lodging and increases yield (Garrod et al, 1979; Weiland and Stutte, 1979).

Retardants, through their potential influence upon cultural practices such as planting density and harvesting (Humphries, 1968) may enhance yield, but in soybeans positive responses of up to 20% to BTS 44 584 treatment, independent of similar effects on crop management also occur (Garrod et al 1979, 1980). The implication is that chemical treatment affects one or more of the major physiological and/or environmental parameters which determine yield. Consequently, any modification of the crops responses to environmental changes may be of considerable importance to the expression of this activity.

Soybeans, because of their high root resistance (Boyer, 1971) are particularly susceptible to water stress and in field grown soybeans, leaf water deficits capable of the inhibition of growth occur daily (Salter and Goode, 1967). Although soybeans may be more sensitive to a given level of duration of stress at one stage than at another, it is likely that yield is affected by the occurrence of internal plant stress at any stage of plant development. Relatively low stress levels may be expected to limit the early stages of leaf enlargement (Boyer, 1970) and reduce crop growth rate. Periods of drought during pod initiation and seed filling stages are reported to drastically reduce yield (Salter and Goode, 1967). A reduction in crop water loss at vegetative or reproductive stages by chemical treatment would result in an apparent increase in yield and would be subject to the duration of that effect providiing CO_2 assimilation was not limited by stomatal closure.

This paper describes the effects of BTS 44 584 on some aspects of the water relations of temperate soybeans and discusses the results with reference to the yield responses of field grown crops to similar treatments.

METHOD AND MATERIALS

Fiskeby V soybeans were germinated and grown in moist vermiculite and transferred at growth stage V_1 (Table 1. Fehr and Caviness, 1977) into hydroponic culture with half strength Hoaglands solution as nutrient. The culture medium was continuously aerated and replenished daily. Conditions were maintained at 28°-20°C, 65%-85% ± 4% RH, day and night temperatures and humidities respectively and a light intensity of 600 $\mu Em^{-2} sec^{-1}$ during a 12 h photoperiod.

Table 1

Description of growth stages

Stage no.	Description	Time from planting (days)
V_1 - V_n	1st node to nth node	
R_1	Beginning bloom	21
R_2	Full bloom	25
R_3	Beginning pod	
R_4	Full pod	30
R_5	Beginning seed	40
R_6	Full seed	48

At V_3, plants were sprayed to run-off with a 10^{-3}M solution of BTS 44 584 plus 1% Ethylan PB as wetter. Control plants were sprayed with water plus 1% Ethylan PB. For measurements of CO_2 and water vapour exchange, whole plants were enclosed in plexiglass chambers of 44.5 l capacity and illuminated from above to give a light intensity of 550 $\mu Em^{-2} sec^{-1}$ at plant height. Air drawn from outside, corrected to 28°C and 65% RH was passed through the chamber and was diffused and circulated within the chamber at 200 l min^{-1} using an electric fan. CO_2 exchange was measured using an infra-red gas analyser (Analytical Development Co. Ltd.) and water vapour exchange was measured with a capacitative hygrometer (Lee Dickens Co. Ltd), placed in circuit with the plant chamber. The flow rate was adjusted to give a CO_2 reduction between chamber inlet and outlet of not more than 20 ppm. Air temperature was monitored using a platinum resistance thermometer.

Determinations of CO_2 and water vapour exchange for each plant were made every minute until a steady state was reached, each series beginning at 9.00 a.m. At equilibrium, the CO_2 depletion and water losses were recorded and rates of net assimilation and transpiration calculated. Measurements were made from V1 to R4. At least three replicate plants per time treatment were used.

Leaf surface impressions of leaflets at each node on the main stem of treated and control plants were made using methods described previously (Sampson, 1961) and used for stomatal density and pore size determinations. Three replicates of twenty randomly chosen areas of leaf were examined per treatment. Leaf area was measured with an electronic planimeter (Li-Cor, Model Li-3000).

Root:shoot ratio was determined from samples of plants throughout the course of the experiment.

RESULTS

1. Transpiration rates

The different rates of transpiration per average unit area of leaf in treated and control plants in either light or dark periods were found to be nonsignificant from each other following statistical analysis due to high replicate variability (Table 2) although a rise in both rates was observed during development. Since the recorded figures represent an average leaf transpiration rate, this rise may reflect the influence of a more complete age range of leaves, and their respective rates of transpiration, on older plants, upon total water loss. Total water loss per plant was reduced in treated plants.

Table 2

Effect of 10^{-3}M BTS 44 584 upon the rate of transpiration of Fiskeby V soybeans in light and dark during development V3 to V4

1. LIGHT

	Average Transpiration Rate ($mgdm^{-2}h^{-1}$)					
GROWTH STAGE	V3	V6	R1	R2	R3	R4
Control	16.05(6.26)	13.25(1.77)	33.30(1.02)	33.62(0.99)	38.75(4.54)	38.90(8.76)
Treated	15.95(6.55)	9.75(4.19)	36.51(3.89)	34.70(3.11)	31.01(3.97)	27.37(3.54)

2. DARK

	Average Transpiration Rate ($mgdm^{-2}h^{-1}$)					
GROWTH STAGE	V3	V6	R1	R2	R3	R4
Control	2.29(1.11)	1.98(1.01)	4.69(2.00)	4.34(1.29)	5.35(1.30)	5.79(1.52)
Treated	2.69(1.28)	1.46(0.92)	5.00(0.54)	5.10(1.32)	2.26(2.00)	3.56(1.99)

Figures in brackets indicate 95% confidence limits.

2. Stomatal density and pore size

Stomatal density on leaves developed following treatment was higher ($P = 0.01$) than on control leaves (Table 3). However, the average pore size measured along the long axis was significantly smaller in treated leaves compared to equivalent control leaves ($P = 0.05$).

Table 3

Effect of 10^{-3}M BTS 44 584 upon stomatal density and pore size in leaves taken from node 6 of Fiskeby V soybeans

	Stomatal density No. mm^{-2}	Pore size μm
Control	139.00	13.85
Treated	214.67**	10.92*

*indicates significant differences P = 0.05

**indicates significant differences P = 0.01

3. Leaf area

Following application of BTS 44 584, leaf enlargement was inhibited (Table 4) such that at V_6, the leaf area of control plants was approximately 38% greater than that of treated plants ($P = 0.001$). The percentage difference was approximately 50% at R_2 ($P = 0.001$).

Table 4

Effect of 10^{-3}M BTS 44 584 upon leaf area development following foliar application to Fiskeby V soybeans at V3

	Leaf Area (cm^2)					
GROWTH STAGE	V3	V6	R1	R2	R3	R4
Control	283.32 (62.04)	1336.28 (17.53)	1134.78 (161.69)	1201.05 (40.22)	1103.81 (42.21)	1027.85 (52.20)
Treated	241.87 (46.91)	834.45*** (14.56)	634.82*** (71.14)	596.73*** (86.20)	754.29*** (29.34)	700.29*** (31.97)

Figures in brackets indicate 95% confidence limits.

***indicates significant differences P = 0.001

4. Root:shoot ratio

Root:shoot ratio decreased with time in both control and treated plants (Table 5). However, in treated plants, the duration of a high root:shoot ratio was significantly greater than in the control plants. Significant differences ($P = 0.05$) were maintained from V_5 to R_2.

Table 5

Effect of 10^{-3}M BTS 44 584 upon root:shoot ratio following foliar application to Fiskeby V soybeans at V_3

	Root:Shoot Ratio						
GROWTH STAGE	V1	V3	V5	R1	R2	R5	R6
Control	0.269	0.206	0.232	0.163	0.167	0.122	0.084
Treated	-	-	0.259*	0.261*	0.208*	0.110	0.085

*indicates significant differences P = 0.05

5. Net Photosynthesis

The average leaf net photosynthetic rate was significantly enhanced following treatment with BTS 44 584 (Table 6) and remained higher for the duration of the experimental period. A slight reduction in rate was observed at R_4. This is attributed to the onset of senescence of lower leaves particularly in control plants.

Table 6

Effect of 10^{-3}M BTS 44 584 upon average leaf net photosynthetic rate of Fiskeby V soybean

	Net Photosynthetic Rate ($mgCO_2dm^{-2}h^{-1}$)				
GROWTH STAGE	V1	V3	V6	R2	R4
Control	6.62	7.01	8.36	10.13	8.52
Treated	8.88	8.36	10.31*	16.89**	14.16*

*indicates significant differences P = 0.05

**indicates significant differences P = 0.01

DISCUSSION

The incorporation of mutual interference of evaporation from stomata and pore size factors (Verduin, 1949) in the interpretation of transpirational losses indicates that leaves formed subsequent to treatment are likely to lose water at a rate 1.24 times faster per unit area than equivalent control leaves. However, because of their drastically reduced area, total water losses from leaves on treated plants are reduced by 20% compared to those from control leaves. This correlates with values obtained for average leaf transpiration rates in treated and control tissue which were insignificantly different and augments the beneficial effects of the chemical upon the growth of the roots, compared to shoots. It has been suggested that the ratio of water absorbing surface to transpiring surface is probably more important than the actual leaf or transpiring surface since the inability of water absorption to match water loss will initiate internal water deficits (Kramer 1959). High root:shoot ratios correlate with a) high transpiration rates, even under normally stress-limiting conditions (Miller 1917), b) the maintenance of high turgidity (Slatyer, 1955) and c) increased yield (Jung, 1979). It is suggested that a high root:shoot ratio in soybeans is stimulated by treatment with BTS 44 584 and in conjunction with a low evaporative loss from the shoot aids soil water conservation and attenuates water stress. This effect is of particular importance in soybean development during which water stress and severe damage is usual at early reproductive stages and which corresponds to a period of high root: shoot ratio in treated plants. In addition, the development of early water stress may be aggravated by high crop transpirational losses. Retarded plants will reduce this loss and prolong non-stress conditions.

The advantage of a small leaf area to reduce water loss may be expected to be counteracted by the deleterious effects upon net assimilation. However, BTS 44 584 while active in decreasing leaf area, enhances net photosynthetic rate by an amount which may compensate for that loss. The mechanism of enhancement is under study and preliminary results suggest that alterations in leaf anatomy, particularly stomatal density, may be important in the reduction of resistances to CO_2 uptake.

In conclusion, BTS 44 584 when applied at V_3 at a retarding rate will reduce plant water loss for prolonged periods without inhibiting net photosynthetic rate and therefore has potential in soybeans as an aid to soil water conservation.

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NOTES

NC 20 484 A NEW SELECTIVE HERBICIDE FOR CONTROL OF CYPERUS spp AND OTHER WEEDS IN COTTON

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Summary 2,3-dihydro-3,3-dimethyl-5-benzofuranyl ethanesulphonate (NC 20 484) is a new pre-plant incorporated or pre-emergence herbicide discovered by Fisons Limited. It has been evaluated for selective control of annual and perennial weeds in cotton and many other crops including sugar cane, tobacco and rice. Trials in the U.S.A., S. Africa, Australia and Europe have shown that NC 20 484 provides excellent initial and residual control of Cyperus esculentus and C. rotundus, besides controlling a wide range of annual grasses and broad-leaved weeds at rates of 1.0-2.0 kg a.i./ha. NC 20 484 displays very little post-emergence activity.

NC 20 484 has been tested in mixtures or sequences with other selective herbicides to broaden the weed spectrum controlled, and provide season-long control of all the major weeds encountered in cotton and other tolerant crops.

Results from acute toxicology studies indicate that NC 20 484 has a low order of toxicity.

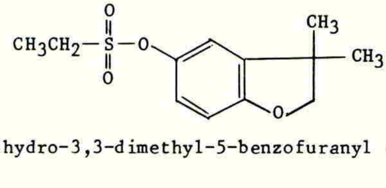
INTRODUCTION

The biological properties of NC 20 484 were first described by Ekins et al. at the Southern Weed Science Society of America's 33rd Annual Meeting in February 1980. The paper described the selectivity of the compound in cotton and other major crops pre- and post-emergence under U.S.A. conditions.

More than 250 trials have also been carried out by Fisons personnel and co-operators in the U.K., France, Austria, Spain, Italy, Israel, U.S.A., S. Africa, Australia, W. Germany and Colombia to determine further the efficacy and safety of NC 20 484 in cotton and a wide range of crops, including tobacco, sugar beet, soya beans, peanuts, beans, maize, sugar cane, ryegrass, sunflowers and orchard crops.

The chemical, physical and toxicological properties of NC 20 484 are summarised below:-

Structural formula



Chemical Name 2,3-dihydro-3,3-dimethyl-5-benzofuranyl ethanesulphonate

NC 20 484 is a crystalline solid which melts at 30°C. It is readily soluble in organic solvents and its solubility in water is 190 p.p.m. at 25°C.

Toxicology Acute oral and dermal studies indicate that NC 20 484 has a low order of toxicity.

Oral LD_{50}	active ingredient	Rat male	3536 mg/kg
		Rat female	2031 mg/kg
	EC 40 formulation	Rat male	6.96 ml product/kg
		Rat female	7.13 ml product/kg
Dermal LD_{50}	EC 40 formulation	Rat male/female	7 ml product/kg

Mode of uptake The main route of uptake by monocotyledonous plants is predominantly by the emerging shoot as it grows through the treated soil layer. In broad-leaved species root uptake is more important.

Foliar absorption takes place in both groups of plants but the level of herbicidal activity is generally low. Addition of surfactants or non-phytotoxic oils does not significantly increase foliar activity.

METHOD AND MATERIALS

Small plot screening and larger-scale replicated trials have been carried out during 1979 and 1980. A variety of equipment has been used to spray the herbicide, ranging from hand-pump knapsack to CO_2 powered equipment, mostly applied in a volume of 200 l/ha of water and 1.8-2.0 bar pressure. Incorporation, where necessary, has been by rotavation, discing and rolling, or fixed-tine cultivation.

The formulation of NC 20 484 used in all trials was an emulsifiable concentrate containing 400 g/litre of active ingredient.

Herbicidal efficacy as % overall weed control or % control of individual species was visually assessed in treated plots compared with untreated controls. Safety to crops was evaluated by % vigour and % stand ratings compared to controls.

RESULTS

COTTON TOLERANCE Glasshouse and field trials over 4 years have shown cotton to be very tolerant of pre-plant incorporated or pre-emergence applications of NC 20 484. Summarised data of cotton vigour and stand ratings are presented in Table 1 from replicated trials in 1979 and 1980.

Table 1
% Cotton vigour reduction and % stand reduction from 1979 and 1980 cotton experiments

Dose kg a.i./ha		Mean % vigour reduction				Mean % stand reduction	
		Early*		Late*			
		1979	1980	1979	1980	1979	1980
NC 20 484	1.0	14 (33)	1 (20)	5 (14)	2 (10)	3 (15)	1 (16)
NC 20 484	2.0	26 (32)	7 (20)	9 (12)	6 (15)	14 (14)	3 (14)
perfluidone	2.0-3.0	26 (16)	11 (3)	10 (9)	- (-)	9 (10)	- (-)
norflurazon	2.0-3.0	15 (3)	13 (18)	2 (3)	7 (14)	5 (4)	4 (12)
fluometuron	1.0-2.0	6 (13)	1 (18)	1 (5)	2 (15)	5 (4)	1 (19)

*Early - Assessment at 3-6 weeks after spraying
*Late - Assessment at 7-10 weeks after spraying
Number of sites in parenthesis.

The data at 3-6 weeks assessment shows that some cotton vigour reduction can occur at rates of 1.0-2.0 kg a.i./ha of NC 20 484, but stand is on average not appreciably affected. Over the 2 years, results are better than the standard grass/broad-leaved herbicides evaluated.

Vigour ratings at 7-10 weeks showed considerable recovery from these early effects.

Varietal tolerance of cotton Over 19 common cotton varieties have been included in these trials with no indication of varietal susceptibility to NC 20 484. Direct comparisons of the U.S.A. varieties in screening trials showed no differential response.

WEED CONTROL From the earliest screening trials in 1977, *Cyperus* has consistently been one of the most susceptible weed species to NC 20 484. The results from 1979 and 1980 cotton trials in the U.S.A., Greece and South Africa are summarised in Table 2.

Table 2
Pre-emergence control of *Cyperus* spp early (3-6 weeks) and late season (7-10 weeks)

Dose of herbicide (kg a.i./ha)		% *Cyperus esculentus* control		% *Cyperus rotundus* control	
		Early*	Late*	Early*	Late*
NC 20 484	1.0	93 (11)	69 (6)	67 (44)	61 (25)
NC 20 484	2.0	98 (9)	88 (10)	78 (40)	72 (24)
NC 20 484	4.0	96 (9)	89 (6)	86 (18)	78 (15)
Norflurazon	2.0-3.0	38 (7)	50 (10)	43 (24)	47 (11)
Perfluidone	2.0-3.0	75 (1)	78 (2)	45 (17)	44 (13)

*Early - Assessment 3-6 weeks from application
*Late - Assessment 7-10 weeks from application
Number of sites in parenthesis.

At 1.0-2.0 kg a.i./ha NC 20 484 provides good to excellent control of *Cyperus* spp., particularly *C. esculentus*. In both years of evaluation the compound has displayed distinct improvements over the standard herbicides on these difficult to control sedge species. The residual activity of NC 20 484 shows particular advantages in controlling late-emerging shoots from dormant nutlets.

NC 20 484 also controls a wide range of important annual grasses and broad-leaved weeds that occur in cotton.

Overall control of these species is presented in Table 3 as a mean of 1979 and 1980 results over all soil types:-

Table 3

% Overall weed control early and late season

Dose of herbicide (kg a.i./ha)		3-6 week assessment	7-10 week assessment
NC 20 484	1.0	74 (42)	68 (31)
NC 20 484	2.0	82 (39)	80 (30)
NC 20 484	4.0	87 (17)	84 (16)
norflurazon	2.0-3.0	59 (27)	59 (17)
perfluidone	2.0-3.0	73 (15)	68 (13)
fluometuron	1.0-2.0	55 (35)	41 (24)
trifluralin	0.75-1.0	51 (17)	26 (9)

Number of sites in parenthesis.

For adequate season-long control over all soil types, 2.0 kg a.i./ha of NC 20 484 is required. Higher rates do not greatly improve the overall level of activity but it must be stressed that 4.0 kg a.i./ha was mainly applied in trials on heavy soil types, containing greater than 25% clay content. In practice, the rate of NC 20 484 must be adjusted in order to determine the correct dose of NC 20 484 to apply according to soil type. Table 4 has been prepared from 1979 and 1980 data:-

Table 4

% Overall weed control according to soil type at 3-6 week assessment

Dose of NC 20 484 in kg a.i./ha	Light Soil (LS-VFSL)	Medium soil (ZL-ZyL)	Heavy soil (ZyCL-C)
0.5	61 (3)	55 (1)	28 (4)
1.0	83 (8)	76 (11)	71 (23)
2.0	89 (6)	84 (12)	78 (21)
4.0	93 (3)	89 (2)	87 (14)

Number of sites in parenthesis.

0.5 kg a.i./ha of NC 20 484 has failed to give adequate overall weed control in these trials. However in limited trials on light soils in California during 1979 this rate has completely controlled *Cyperus esculentus*.

1.0-2.0 kg a.i./ha are the preferred rates of application : for good selectivity 1.0 kg a.i./ha is recommended on light soils and 2.0 kg a.i./ha on medium to heavy soils. On very heavy soils with greater than 35% clay content or organic matter in excess of 5%, higher rates of 3.0-4.0 kg a.i./ha are required. These rates have proved safe to cotton.

Other factors which may influence the activity of NC 20 484 include soil moisture and incorporation.

Soil moisture Since it is not essential for moisture to move NC 20 484 down into the soil where it can be taken up by root absorption, its performance is less affected by weather conditions than most pre-emergence herbicides. However, in 6 trials comparing irrigation versus very dry conditions in the U.S.A., Greece and the U.K., some soil moisture (on average 7-12 mm. of precipitation) proved necessary to activate NC 20 484 particularly in controlling *Cyperus spp.* as their shoots emerged through the treated soil layer.

Soil incorporation In 24 trials over 2 years, comparing pre-plant incorporated versus surface pre-emergence applications, incorporation did not prove necessary provided adequate soil moisture was present. Incorporation only improved the performance of NC 20 484 under very dry conditions, and should therefore be considered for dry areas where no irrigation is available and natural rainfall is limited.

Incorporation depth varied in these trials between 2.5 and 10 cm., but comparison studies have shown that the actual depth of incorporation does not greatly affect activity of NC 20 484 on *Cyperus* or other weeds.

Control of individual weed species From trials on cotton and all other crops evaluated the following grasses and broad-leaved weeds are shown to be highly susceptible to NC 20 484:-

At 1.0 kg a.i./ha NC 20 484 controls:-

Acalypha alopecuroides
Alopecurus myosuroides
Anagallis arvensis
Boerhaavia erecta
Brachiaria platyphylla
Capsella bursa-pastoris
Chenopodium bontei
Cyperus esculentus
Desmodium tortuosum
Digitaria sanguinalis
Echinochloa colonum
Echinochloa glabrescens
Eleusine africana
Eleusine indica
Euphorbia spp.
Galinsoga ciliata
Galium aparine
Lamium amplexicaule
Mercurialis annua
Myosotis arvensis
Panicum dichotomiflorum
Physalis longifolia
Poa annua
Polygonum lapathifolium
Portulaca oleracea
Raphanus raphanistrum
Richardia brasiliensis
Setaria spp.
Silene alba
Sinapis arvensis
Sorghum halepense (seedling)
Sonchus oleraceus
Spilanthes ocyimifolia
Stellaria media
Tripleurospermum spp.
Urtica urens
Veronica persica

At 2.0 kg a.i./ha NC 20 484 controls in addition the following weeds:-

Amaranthus spp.
Anoda cristata
Bidens pilosa
Bromus tectorum
Chenopodium album
Commelina benghalensis
Cyperus rotundus
Galeopsis tetrahit
Mollugo verticillata
Panicum fasciculatum
Polygonum aviculare
Polygonum pensylvanicum
Polygonum persicaria
Richardia scabra
Schkuhria pinnata
Sida spinosa
Solanum nigrum
Trianthema portulacastrum
Viola spp.

Resistant species include:-

Abutilon theophrasti
Ambrosia artemisiifolia
Avena fatua
Datura stramonium
Polygonum convolvulus
Senecio vulgaris
Sesbania bispinosa
Sorghum halepense (rhizome)
Xanthium spp.

Post-emergence activity on grass and broad-leaved weed species is poor.

Mixtures and sequences for broad-spectrum weed control It can be seen that some broad-leaved weeds are not controlled by NC 20 484. Hence a broader spectrum of activity can be obtained by using mixtures or sequences of NC 20 484 with other cotton herbicides. The most commonly used herbicides, trifluralin and fluometuron have been evaluated in mixtures over two seasons in Texas, Greece and S. Africa (Table 5).

Table 5
% Cotton vigour reduction and % overall weed control in NC 20 484 mixture trials 1979/1980

Pre-plant incorporated treatments (doses in kg a.i./ha)

	NC 20 484			NC 20 484 + trifluralin			trifluralin	
	1.0	2.0	4.0*	0.5+ 0.75	1.0+ 0.75	1.0+ 1.0*	0.75	1.0
% crop vigour reduction	3 (13)	8 (16)	14 (6)	2 (2)	4 (4)	6 (5)	2 (8)	1 (10)
% overall weed control	73 (11)	86 (12)	81 (4)	92 (2)	92 (4)	85 (5)	53 (8)	35 (10)

Pre-emergence treatments (doses in kg a.i./ha)

	NC 20 484			NC 20 484 + fluometuron				fluometuron		
	1.0	2.0	4.0*	1.0+ 0.75	1.0+ 1.5	1.5+ 1.5	2.0+ 0.75*	0.75	1.5	2.0
% cotton vigour reduction	5 (23)	13 (25)	12 (5)	10 (15)	11 (4)	13 (7)	12 (4)	2 (9)	6 (14)	1 (8)
% overall weed control	73 (22)	84 (24)	84 (5)	95 (7)	90 (4)	87 (8)	90 (4)	60 (11)	61 (13)	58 (8)

*Mainly applied on heavy-textured soils.
Number of sites in parenthesis.

Both trifluralin pre-plant incorporated and fluometuron pre-emergence have spectra of weed activity complementary to NC 20 484. Mixtures have thus shown excellent grass and broad-leaved weed control, even at reduced doses of both herbicides. In most experiments, a mixture with 1.0 kg a.i./ha of NC 20 484 has proved adequate for the majority of soil types.

Mixtures with dinitramine, prometryne and pendimethalin have also shown promising results in 1980 trials.

NC 20 484 can also be used in sequence with other herbicides in many different ways. For example, NC 20 484 used alone pre-plant incorporated, can be followed by fluometuron pre-emergence for broader-spectrum activity on weeds. Pre-emergence applications of NC 20 484, with or without fluometuron, can also be followed by MSMA for additional grass control. Late-fall (autumn) or winter applications of NC 20 484 alone or in admixture with trifluralin applied pre-plant incorporated on dormant *Cyperus rotundus* 2 months prior to cotton planting has given excellent weed control.

TOLERANCE OF NC 20 484 IN CROPS OTHER THAN COTTON NC 20 484 displays selectivity in a wide range of major world crops, as summarised in Table 6.

Table 6

Crops tolerant of NC 20 484

Crop	Maximum dose of NC 20 484 tolerated (kg a.i./ha)
Pre-plant incorporated or pre-emergence	
Maize, peas, sugar beet and peanuts	0.5
Potatoes, dry and paddy rice and field beans (Vicia spp.)	1.0
French, navy, haricot, dry beans (Phaseolus spp.) and sunflowers	2.0
Sugar cane and transplanted tobacco	4.0
Post-emergence	
Annual and perennial ryegrass, dry and paddy rice, peanuts, maize, peas, millet, sorghum and nectarine	1.0
Sugar beet and transplanted tobacco	2.0
Sugar cane, peach, plum, apricot, citrus*, apple*, and grapes*	4.0

* Including young transplants and established crops.

The post-emergence safety of NC 20 484 in annual crops is listed for situations where weeds such as Cyperus may germinate after crop emergence.

NC 20 484 is not tolerated by canteloupe, cucumber, tomatoes, spinach, lentils, onions and oilseed rape pre- or post-emergence.

Apart from cotton, NC 20 484 is being evaluated for Cyperus spp. control in tobacco, beans, sugar cane and other plantation crops. Mixtures with other selective herbicides are being evaluated.

LEACHING PROPERTIES/SOIL PERSISTENCE OF NC 20 484 Experiments using soil columns with surface treatment of NC 20 484 followed by 200 mm. of precipitation water over 8 days have resulted in leaching to a depth of 40-140 mm for light soils, 60-120 mm for medium and 0-80 mm for heavy soil types. Analytical soil residue studies have shown that NC 20 484 does not accumulate at depths lower than 75 mm under field conditions.

Texas and N. Carolina soils treated with 2.24 and 4.48 kg a.i./ha of NC 20 484 have been shown to degrade the chemical by 50% within 10-39 days and by 90% within 34-129 days.

Field bio-assays in Greece, S. Africa, the U.K. and the U.S.A. have shown that a rate of 2.0 kg a.i./ha applied pre-emergence to cotton has proved safe to following crops of wheat when sown 8-9 months after application even without soil disturbance. Four experiments in S. Africa were disced or ploughed after cotton harvest and sown to winter wheat by farmers 7-8 months after 2.0 or 4.0 kg a.i./ha of NC 20 484 was applied in the spring with no effect on the wheat. Following crops of tomatoes (2 trials), sugar cane (1 trial), brassicas (2 trials), green peppers (1 trial) and french beans (1 trial) have also been shown to be safe.

DISCUSSION

Cyperus spp., (C. rotundus and C. esculentus) have many times been described as the world's worst weeds. (Holm 1969) and have been shown to be present in all the major cotton-growing areas as well as predominating in sugar cane and rice growing areas (Holm and Herberger 1970).

Many pre-emergence residual herbicides have been evaluated in recent years to provide selective control of Cyperus spp. in a growing crop. Many, however, have limitations due to poor residual efficacy, crop phytotoxicity or residual effects on following crops.

From the evidence of field trials referred to in this paper, it is clear that NC 20 484 has proved selective in cotton and other major crops for the control of Cyperus esculentus and C. rotundus. Many other important grasses and broad-leaved weeds are also controlled.

The experimental results suggest that NC 20 484 can be used in 3 main types of programme:-

1. Pre-plant incorporated alone or in mixtures with other ppi herbicides such as trifluralin. Applications should preferably be made just prior to cotton planting or 1-2 months before planting on dormant Cyperus.

2. Pre-emergence surface following pre-plant incorporated herbicides. Either alone or in mixtures with surface-applied grass and/or broad-leaved weed herbicides such as fluometuron.

3. Pre-emergence surface applied either alone or in mixtures, followed by post-emergence herbicide applications.

Many other variations are possible and can be developed to suit local requirements and herbicide availability.

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PROGRESS IN THE DEVELOPMENT OF THE SELECTIVE APPLICATION OF HERBICIDES TO CONTROL RUMEX OBTUSIFOLIUS IN GRASSLAND

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Summary A 1% solution of glyphosate in 3% w/v calcium alginate was applied in 20 ml amounts onto a single leaf or divided between every leaf of Rumex obtusifolius (Broad-leaved dock) plants in a grass sward. Satisfactory control of docks was achieved even when only one leaf was treated. After initial sward damage, grass recovery was most successful when only one leaf of each dock was treated. This was confirmed in a second study which also showed that grass damage was caused by contact with treated dock leaves rather than by movement of the herbicide from the roots of treated plants. The technique of applying glyphosate mixed in alginate onto a small area of dock foliage achieves effective weed control without lasting sward damage and is of considerable practical interest.

INTRODUCTION

The selective application of aqueous herbicide solutions, which exploits the difference in height between crop and weed, has been used in sugar beet crops (Vigoureux, 1976). In later work at the Weed Research Organization Rumex obtusifolius (Broad-leaved dock) was controlled by leaf applications of 10% glyphosate (27.8% w/v Roundup commercial product) in alginate solution (Oswald, 1978). Transitory damage to grass surrounding treated dock plants occurred but the treatments had little long-term effect on grass yields.

Two experiments which investigate this effect further, are now discussed. In the first of these, glyphosate concentration was varied and gels were applied to only one leaf or all leaves on dock plants. A second study investigated whether damage was caused by herbicide transfer from treated foliage or from the roots.

METHOD AND MATERIALS

Experiment 1

The experiment was laid out at Begbroke Hill on a sward sown on 19 May 1976 to a mixture of perennial ryegrass, white clover and R. obtusifolius. Small amounts of Poa spp., Holcus lanatus and Festuca rubra were also present. During 1976, 50 kg/ha N + 25 kg/ha P_2O_5 + 25 kg/ha K_2O was applied in split applications while in 1977 and 1978 a total of 100 kg/ha N + 25 kg/ha P_2O_5 + 25 kg/ha K_2O was given as split spring and autumn applications. After establishment the sward was grazed throughout each summer and autumn by young beef animals with cutting for silage in June.

There were 7 replicates of varying size depending on the distribution and frequency of docks. Each plot consisted of 7 plants which were chosen for uniformity in size and age. The total area of the experiment was 572 m^2.

The grass was in flower and approximately 10 cm high at the time of treatment with taller clumps near dung pats. Docks were 15-25 cm high with some plants flowering. Thus there was a grass/dock height differential of 5-15 cm.

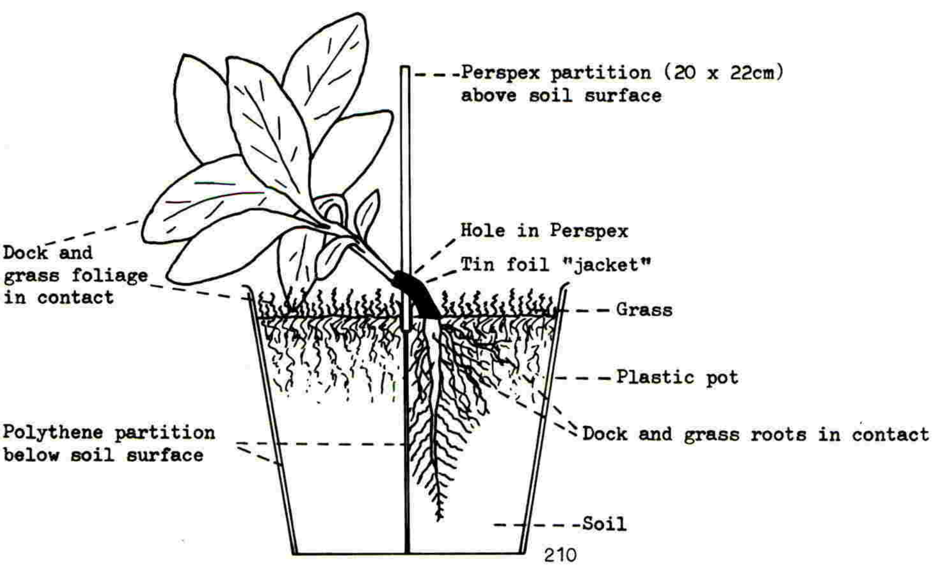
The solutions of glyphosate acid (Table 1) were prepared as described elsewhere (Oswald, 1978). The mixtures were made up on 28 July 1978, 24 h before application when 20 ml amounts were placed onto either one leaf or divided between all the leaves on a dock plant. Treated plants were identified by plastic rings of different colours attached to the stems.

The treated docks were inspected 10, 20, 30 and 60 days after treatment and scored for amounts of green material present compared to untreated plants. Scoring was from 0 (no green material visible) to 9 (equal to untreated control). Two people scored independently, both scores being recorded. The docks were harvested at ground level on 25 September 1978 and 10 July 1979 using hand shears. The grass growing within a 30 cm x 30 cm area round each dock plant was similarly harvested. The cut material was weighed separately and placed in an oven at 100°C for at least 6 h before weighing.

Experiment 2

The main objective was to determine whether grass damage was caused by contamination from treated dock foliage or from root contact. Plastic pots of 25 cm diameter were filled with sandy loam soil and divided below the soil surface into two halves with polythene sheet (Fig. 1). These were placed in a greenhouse maintained at 14-18°C with supplementary light. Perennial ryegrass cv. Melle seed was then sown into each half pot on 16 February 1978 and allowed to establish a good shoot and root system. One dock plant, from a number sown on the same date and grown on in the greenhouse, was transplanted into one half of each pot and its shoot trained to grow through a hole in a sheet of perspex, placed above the soil surface, and into the other half of the pot. At the time of treatment each dock plant had an average of 19 leaves. The grass, which had previously been cut on 7 occasions to a height of 5 cm, was again cut immediately before treatment to 2 cm.

Fig. 1 Experiment 2. Treatment method



Solutions were prepared and applied as in experiment 1. A 10% w/v solution of glyphosate was mixed with 3% alginate and applied in 20 ml amounts to either one leaf or divided between all leaves on each plant. The treatments were replicated three times and are shown in Table 2.

After treatment, plants were watered at grass level so that herbicide would not run off dock foliage onto the grass below.

Grass from both treated and untreated half pots was harvested on 22 August 1978. The cut material was dried and weighed as in experiment 1.

RESULTS

Experiment 1

Effects on docks

No green leaf was present 30-40 days after treatment (Fig. 2). Desiccation was fastest when all the leaves were treated.

At the first harvest two months after treatment even the lowest concentrations of glyphosate (1%) greatly reduced dry weights (Table 1). Differences between the various concentrations did not reach significance. Applying the treatments to only a single leaf was as effective as treating all the leaves. One year later there was no sign of regrowth from any of the herbicide treated plots.

Effects on grass

The yield of grass growing around treated dock plants was reduced by all glyphosate treatments at the first harvest (Table 1). Yields were lower when all leaves on the docks were treated. Grass yields had largely recovered after 12 months although recovery was poorer when all dock leaves had been treated instead of a single leaf.

There was little difference between different herbicide concentrations but a regression analysis indicated that falling yields were associated with increasing concentrations (Fig. 3). At the first harvest, this relationship was independent of whether the treatments were applied to all or one dock leaf but, at the second harvest, the effect showed only when all the leaves were treated.

Experiment 2

All the docks were dead when the grass was harvested 8 weeks after treatment. There was no effect on grass dry weight when only the roots were in contact with treated dock plants (Table 2). Grass growing beneath treated plants was only damaged when all the leaves were treated.

DISCUSSION

Experiment 1 confirms that selective applications of glyphosate in alginate can effectively control Broad-leaved dock in grassland. Established plants were controlled for at least 12 months after treatment when glyphosate equivalent to 0.2 g a.i. was applied to a small area of foliage; overall herbicide cover was unnecessary.

The control was better than is usually achieved by conventional spray applications, where dock regrowth usually occurs during the year following treatment (Frame and Harkess, 1972; Oswald and Elliott, 1970, Oswald and Haggar, 1976).

Damage to grass was temporary and confined to a small area in the immediate vicinity of treated weed plants. When conventional sprays are used, all the sward may be damaged (Courtney, 1970; Oswald and Elliott, 1970; Oswald and Haggar, 1976). Sward damage, as a proportion of the whole area, might have been even less had a greater sampling area been used.

The results of experiment 2 demonstrate that damage to grass was due solely to transfer of herbicide from treated dock leaves. Glyphosate does not appear to move from the roots of treated dock plants. Although it is difficult to see what can be done to stop dying weed foliage from collapsing onto the sward, the treatment of a minimum area of foliage with a minimum concentration of herbicide would reduce contamination.

The study also indicates an extremely economical method of using herbicides in grassland. To control the 56 dock plants in the experiment area of 572 m^2 by conventional herbicide spray with 2-3 kg ha^{-1} a.i. would require from 114-172 g. of active ingredient. To control these plants with 1% (0.2 g) glyphosate in alginate required only 11.2 g. This amount could be reduced further if lower concentrations were possible.

This technique allows the use of a non-selective, but effective herbicide in a situation where this was hitherto impossible. Even lower concentrations of glyphosate now need to be evaluated, together with other herbicides which are more commonly applied in grassland.

It is also important to identify the appropriate time to employ this technique. Obviously there must be a minimal difference in height between the weed and the grass crop. A study is underway at the Weed Research Organization involving periodic measurements of dock and grass growth under grazing and hay or silage utilisation systems. Other tall growing weeds in grassland, including thistles, nettles, rushes and tussock grass are also being investigated.

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Table 1

Experiment 1. Effects of different concentrations of glyphosate applied in alginage onto one or all leaves of dock plants in a grass sward on 28 July 1978

	Harvested dry wt.								
	Docks (g/plant)			Grass (g/30 cm^2)					
Glyphosate	14 Sept. 1978			14 Sept. 1978			23 July 1979		
conc. (%)	one	all	Mean	one	all	Mean	one	all	Mean
0	8.8	11.6	10.2	41.4	40.3	40.8	19.3	16.5	17.9
1	2.0	2.1	2.1	31.5	21.6	26.6	24.7	20.1	22.4
2	0.6	1.3	0.9	28.2	26.2	27.2	23.3	13.3	18.3
4	2.4	2.6	2.5	25.7	16.8	21.2	18.4	11.8	15.1
6	0.3	0.6	0.5	28.6	12.8	20.7	18.3	11.9	15.1
8	0.1	2.4	1.3	23.0	24.0	23.5	21.3	10.5	15.9
10	2.2	1.8	2.0	22.6	20.7	21.6	25.8	12.6	19.2
12	1.3	1.2	1.2	27.9	20.4	24.2	24.7	11.6	18.1
Mean	1.31	1.7		26.8	20.4		22.4	13.1	
S.E. Means	1.27		1.66	1.52		2.85	1.25		1.35

Table 2

Experiment 2. The effects of glyphosate applied in alginate solution on grass growing in shoot contact and root contact with docks grown in pots

	Grass dry wt (g/pot)	
Rumex treatment	Shoot contact	Root contact
Untreated	5.9	7.4
One leaf treated	6.4	9.0
All leaves "	2.4	11.1

S.E. diff. between dock treatments = 1.14

" grass ± docks = 1.27

Fig. 2

Experiment 1. The effects of different concentrations of glyphosate in alginate solution on green material of treated dock plants

Scorch 0 = No green material present
9 = No visible effect (as control)

—— One leaf smeared
--- All leaves smeared

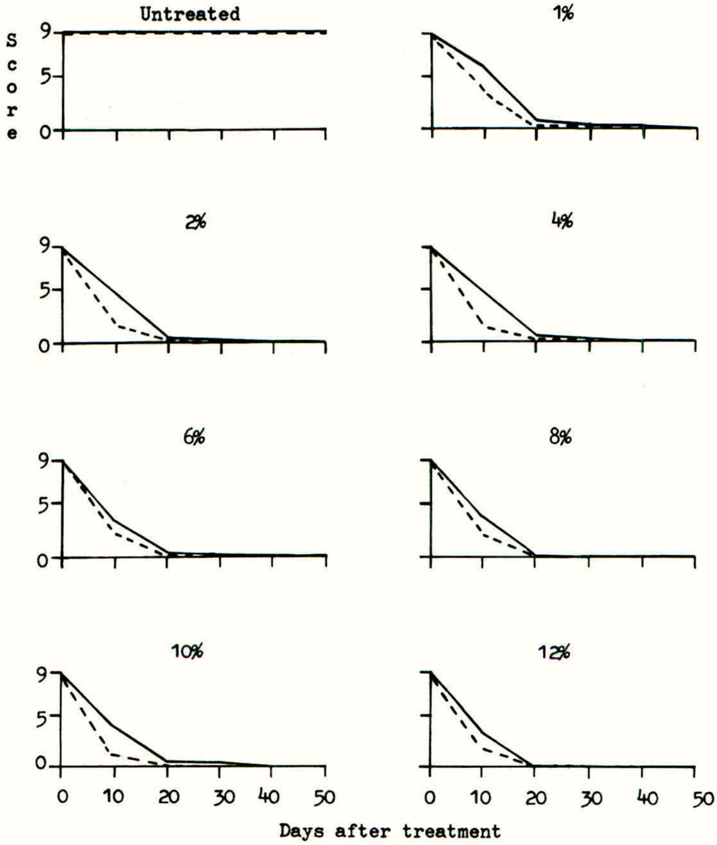
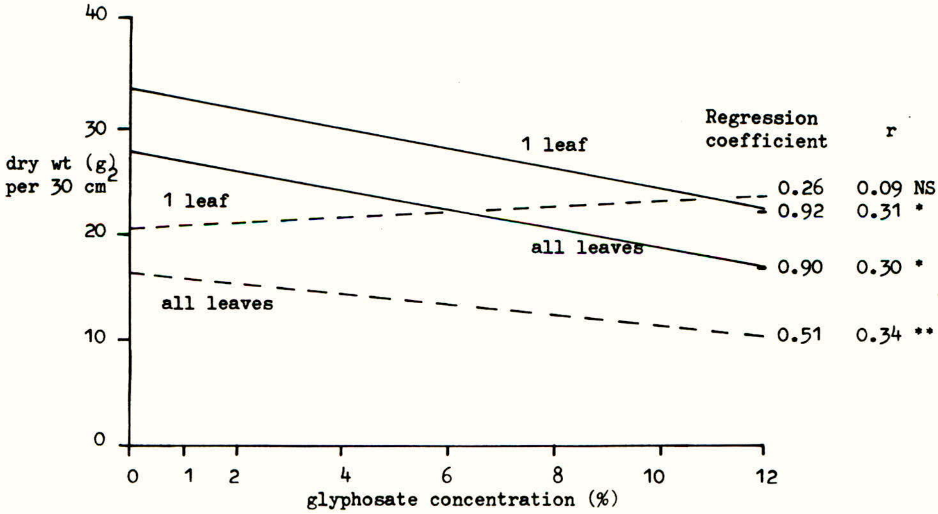


Fig. 3

Experiment 1. Relationship between glyphosate concentration and dry weight of grass harvested 2 (——) and 12 (---) months after treatment on 28 July 1978



NOTES

UBI-S734 : A NEW HERBICIDE FOR GRASS AND NUTSEDGE CONTROL

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Summary UBI-S734, 2-[(1-(2,5-dimethylphenyl) ethyl] sulfonyl) pyridine-1-oxide, is a new soil applied herbicide which has shown promise for the control of grasses and nutsedges in most dicotyledonous crops. In glasshouse and field trials UBI-S734 applied at between 0.375 and 2 kg a.i./ha has shown good control of Agropyron repens, Avena fatua, Cyperus esculentus, Echinochloa crus-galli, Eleusine africana and Digitaria sanguinalis. Sugarbeet, brassicas, large seeded legumes, sunflowers and potatoes were tolerant of rates of 2 kg a.i./ha.

INTRODUCTION

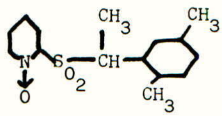
UBI-S734 is a new soil applied herbicide which has been tested in the U.S.A. since 1977 and Europe since 1979. U.S.A. screening results (Bell and Plant, 1979) indicated that most dicotyledonous crops including cotton, soyabeans, sunflowers, peanuts, potatoes and sugarbeet were tolerant of the herbicide. The susceptible weed spectrum covered grasses and nutsedges with a partial control of some dicotyledonous weeds. Results (Bell, Hoffman, 1980; Mcrenyolds, et al,1979; Harvey and Jansen, 1979; Murphy and Morrow, 1980; Saunders and Talbert, 1980; Selleck and Greider, 1980) showed control of Agropyron repens, Avena fatua, Digitaria spp, Echinochloa crus-galli, Panicum spp, Poa annua, Setaria spp, Cyperus esculentus and Cyperus rotundus with partial control of Chenopodium album and Amaranthus retroflexus.

Of the various application methods tested, generally pre-plant incorporated, whether by mechanical means or irrigation, proved more effective than pre-emergence applications. Post-emergence applications proved to be ineffective. A major emphasis of the work in the U.S.A. has been to determine the lowest effective rate of UBI-S734 for controlling annual and perennial grasses and nutsedges, particularly C.esculentus, in soyabeans and cotton. As a result of this work an experimental programme was initiated in 1979 in Europe and South Africa and data from various trials in these areas is presented in this paper. The physical, chemical and toxicological properties of UBI-S734 are summarised below.

Chemical and Physical Properties

Chemical name: 2-[(1-(2,5-dimethylphenyl) ethyl] sulfonyl) pyridine-1-oxide

Chemical structure:



Molecular weight: 291

Physical form: white crystalline solid

Formulation: 75% w.p. or 48% flowable

Solubility of technical material:
(g/100 g of solvent at $20^{o}C$)

water	- 0.2	cyclohexanone	- 8.1
dimethylformamide	- 21.8	toluene	- insoluble
dimethylsulfoxide	- 14.8	butanol	- insoluble

Toxicology

Broad scale investigations on the toxicity of UBI-S734 are currently in progress. Results from acute oral studies indicate that UBI-S734 is a compound of low toxicity.

	technical material	75% w.p. formulation
Acute oral LD_{50} (rats)	5200 mg/kg	5000 mg/kg
Acute dermal LD_{50} (rabbits)	2000 mg/kg	> 2000 mg/kg
Skin irritation (rabbits)	mild	slight
Eye irritation (rabbits)	mild to moderate	mild
Ames mutagenicity	negative	-

METHODS AND MATERIALS

1. Effect of soil type on activity of UBI-S734 in the glasshouse on *Lolium perenne* and *Avena fatua* (Table 1)

Tins of air dry soil of different types were sprayed with knapsack Van der Weij sprayer with the appropriate rate of UBI-S734 at a volume of 300 l/ha. The treated soil (4 replicates) was incorporated, by shaking, to the full 8 cm depth of the tin. Three 6 cm pots of soil were taken from each tin and sown with 10 *Lolium perenne* seeds and one 9 cm pot of soil from each tin was sown with five *Avena fatua* seeds. The sowings were carried out on the same day as treatment. The surviving plants were counted and fresh shoot weights taken two months after sowing.

2. Effect of depth of incorporation (Table 2)

Spraying and incorporation of UBI-S734 on a scl soil (ADAS textural scale) were carried out as above. The incorporation of 1 kg a.i./ha surface applied to a depth of 3 cm gave a concentration of UBI-S734 in the soil of 1.1 ppm. Layers of this, and soil containing 0.55 ppm, were placed at various depths within the pots. Seeds of *Avena fatua* were sown at either 2 or 4 cm depth. Overhead watering was given little but often to reduce possible leaching affects. Counts and fresh shoot weights were determined 9 weeks after sowing.

3. Control of *A.repens* in potatoes (Table 3)

The trial was of randomised block design with 4 replicates per treatment. Soil type was lfs with cation exchange capacity (CEC) 7.3. UBI-S734 and EPTC were sprayed on 4.5.79. The EPTC plots were incorporated within five minutes of spraying using two passes of tractor-mounted tandem discs penetrating to 15 - 20 cm. Potatoes (cv. Pentland Squire) were planted on 9.5.79 and the pre-emergence applications were made on 25.5.79. 49 cm rain fell within 6 days of the pre-emergence applications.

4. Transplanted flue-cured tobacco (Table 4)

Two methods of application were used in this trial. (A) after the ridges had been made the chemical was applied overall and within 30 minutes incorporated into the ridge, using a Garrat implement, to a depth of 3 cm. (B) the chemical was applied as an overall application to the flat soil surface before ridging and incorporated to a depth of 5 - 10 cm. The trial was of split plot randomised block design with 3 replicates. The product was applied by knapsack sprayer through 8003 flat fan nozzles in 200 l water/ha. The air temperature @ spraying was 33°C. 50 mm rainfall fell within two days of application. The variety was T.L.38.

5. Crop screens (Table 5)

Two screening trials were carried out on sandy clay loan (CEC 17.1) and loam (CEC 12.6) soils and 2 additional trials on sugarbeet on loamy very fine sand (CEC 7.1) and clay (CEC 41.3) soils. UBI-S734 was applied ppi incorporated to 6 - 8 cm by rotary cultivation and pre-emergence using a Van der Weij knapsack sprayer in a volume of 200 l/ha. All treatments were replicated four times. Assessments of crop emergence and vigour were made.

Table 1

Effect of soil type on the activity of UBI-S734 in the glasshouse against *Lolium perenne* (L.p.) and *Avena fatua* (A.f.)

	fresh weight as % of untreated									
soil type:*	lvfs		scl		sicl		c		peat	
UBI-S734 kg a.i./ha	L.p.	A.f.	L.p.	A.f.	L.p.	A.f.	L.p.	A.f.	L.p.	A.f.
0.5	0	3.5	0.3	8.6	0.3	12.3	1.0	23.9	108.7	95.5
1.0	0	0	0.2	3.3	0.2	1.6	0.7	0	69.5	101.6
2.0	0	0	0.2	0.3	0	1.0	0	0	16.6	72.4
untreated wt. g	10.9	3.1	6.6	3.1	5.9	3.1	5.9	3.1	6.1	3.2
soil % organic matter	1.8		3.8		3.0		6.7		57.5	
soil cation exchange capacity	7.1		17.1		14.0		41.3		119.0	

Lolium perenne was more susceptible to UBI-S734 than was *Avena fatua*. The affect of increasing clay content was reflected in the increase in % fresh weight of the *A.fatua* treated with UBI-S734 0.5 kg/ha. The high organic (peat) soil considerably reduced the activity of UBI-S734 particularly against the *A.fatua*.

* ADAS textural classification

Table 2

Effect of depth of incorporation (placement) on the activity of UBI-S734 against Avena fatua grown in a sandy clay loam soil

	Placement depth cm	UBI-S734 Conc. in soil ppm	UBI-S734 Equivalent rate surface applied kg a.i./ha	Fresh wt. as % reduction over untreated sowing depth *A.fatua* 2 cm	4 cm
1.	Surface	-	0.50	55	26
2.	Surface	-	1.00	64	44
3.	0 - 2	0.55	0.125	7	7
4.	0 - 2	1.10	0.25	0	4
5.	2 - 4	0.55	0.125	52	29
6.	2 - 4	1.10	0.25	77	74
7.	4 - 8	0.55	0.25	71	64
8.	4 - 8	1.10	0.50	71	67
9.	0 - 4	0.55	0.25	81	59
10.	0 - 4	1.10	0.50	94	78
11.	0 - 8	0.55	0.50	83	93
12.	0 - 8	1.10	1.00	93	97

The shallow sown *A.fatua* were more susceptible than the deeper sown, to UBI-S734 surface applied (pre-emergence) and at all depths of placement except where incorporation was throughout the pot (0 - 8 cm).

Incorporation gave a greater reduction in fresh weight than did the surface application. For example 0.25 kg/ha incorporated to 0 - 4 cm gave 81% and 59% reduction for the 2 cm and 4 cm depth sowings compared with 64% and 44% achieved by 1.0 kg/ha surface applied.

The results show that the greatest reduction in fresh weight occurred when UBI-S734 surrounded the seed. The reduction was less when the UBI-S734 was adjacent or below the seed and least when it was above the seed.

Table 3

Control of Agropyron repens in Potatoes

	Treatment	Application	rate kg a.i./ha	% reduction in shoot no. of *A.repens*	+ metribuzin 1.05 kg a.i./ha post-em
1.	UBI-S734	ppi	0.5	58	80
2.	UBI-S734	ppi	1.0	65	93
3.	UBI-S734	ppi	2.0	98	98
4.	UBI-S734	ppi	4.0	87	92
5.	UBI-S734	pre-em.	0.5	55	82
6.	UBI-S734	pre-em.	1.0	82	88
7.	UBI-S734	pre-em.	2.0	70	74
8.	UBI-S734	pre-em.	4.0	96	96
9.	UBI-S734	post-em.	1.0	0	34
10.	EPTC	ppi	4.5	40	81
11.	metribuzin	post-em.	1.05	61	-
12.	untreated shoot no./m row			33.1	

At this site 61 mm of rain fell in the month following the pre-emergence application of UBI-S734. This was probably sufficient to maximise the activity of the pre-emergence treatments making them similar in efficacy to the ppi treatments.

EPTC performed poorly in this trial and all rates of UBI-S734 gave improved control of *A.repens* over the EPTC. A rate of 2 kg a.i./ha ppi was needed to give good control. 1 kg a.i./ha post-emergence gave no control.

The addition of metribuzin greatly improved the control of *A.repens* by all treatments, particularly that given by the lower rates of UBI-S734.

Table 4

Weed control with UBI-S734 in Tobacco in South Africa (57 days after treatment)

Weed Control & Crop Phytotoxicity (1 - 9, where 1 = 100% weed & 0% crop control)

Rate kg a.i./ha	0.375		0.572		0.75	
Incorporation method	A	B	A	B	A	B
Cyperus esculentus	2	1	2	1	2	1
Echinochloa crus-galli	1	1	2	1	1	1
Eleusine africana	3	1	2	1	2	1
Digitaria sanguinalis	3	1	3	1	2	1
Galinsoga parviflora	6	3	5	3	5	2
Convolvulus arvensis	6	2	5	2	5	2
Crop phytotoxicity	1	4	1	4	1	5

UBI-S734 at 0.75 kg a.i./ha gave the best control of *C.esculentus* and annual grasses, although there was little difference between this rate and the lowest rate of 0.375 kg a.i./ha.

Method of incorporation affected the degree of weed control. Incorporation prior to ridging (method B) gave superior weed control to incorporation after ridging (method A) particularly where the broad leaved weeds are considered. Both methods gave commercially acceptable control of the grass weeds. Tobacco phytotoxicity occurred as a stunting, later outgrown, when incorporation was prior to ridging (B). Incorporation post ridging (A) had no adverse affects on the tobacco.

Table 5

Summary of Crop Tolerance for UBI-S734 as a mean of 1979 sites in U.K.

Crop	No. sites	pre-plant incorporated kg a.i./ha			pre-emergence kg a.i./ha		
		0.5	1.0	2.0	0.5	1.0	2.0
Sugarbeet	4	9	9	8	9	9	7
Brassicas	2	9	9	9	9	9	9
Pea	1	9	9	9	9	9	9
Broad bean	1	9	9	9	9	9	9
Dwarf bean	1	9	9	9	9	9	9
Carrot	2	9	9	7	9	8	9
Sunflower	2	9	9	9	9	9	9
Potato	2	9	9	9	9	9	9

Phytotoxicity scale 1 - 9, where 1 = 100% crop kill & 9 = healthy

DISCUSSION

From glasshouse tests it can be seen that for best results UBI-S734 should be incorporated to place it in contact with the grass seeds. Other data (Bell and Hoffman, 1980) supports this conclusion for rhizomatous grasses and nutsedge tubers. Pre-emergence applications were successful when incorporated by considerable rainfall as shown by the trial on potatoes (Table 3). This indicates the main site of uptake being in the roots and the region of the seed with no above ground uptake. Bell (1980) has shown that Echinochloa crus-galli seed soaked in 5 ppm UBI-S734 solution for 4 hours and then planted in untreated soil gave 30% germination only. After 8 hours the control was 70%, after 24 hours 85% and after 48 hours 95%. Although UBI-S734 uptake by seeds constitutes one method of control, seedling roots will continue to pick up available UBI-S734 under field conditions.

In common with most residual herbicides, soil type had a considerable effect on the activity of the UBI-S734. Although there was a trend of reduced activity according to increase in clay content, the effect of high organic matter was more important in reducing herbicide activity. Suggested rates of use are 0.75 - 1.5 kg a.i./ha for control of annual grasses in light and heavy soils respectively.

Since UBI-S734 is primarily active against grasses and nutsedges a companion herbicide will usually be necessary for broad leaved weed control. Unfortunately few commercial herbicides for broad leaved weed control work well when incorporated. Current work on sugar beet is evaluating UBI-S734 in combination with chloridazon, lenacil or metamitron. Trials are also in progress on potatoes, peas, beans, oil seed rape, cotton, peanuts, soyabeans, tobacco and sunflower using various combinations with commercially available broad leaved herbicides.

Based on field evaluations to date UBI-S734 offers the promise of becoming a broad spectrum herbicide covering annual and perennial grass weeds as well as nutsedges.

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EFFECT OF FORMULATION TECHNOLOGY ON THE RELEASE OF STARCH ENCAPSULATED EPTC

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Summary. Laboratory studies of starch encapsulated formulations of EPTC consistently indicate that these new formulations offer opportunities for delayed incorporation without appreciable loss of EPTC activity. These formulations may be modified by surface coating which imparts controlled-release characteristics. This new formulation technology could be employed for herbicides that are not only highly volatile but those readily leachable in the soil and/or subject to photodecomposition on the soil surface.

INTRODUCTION

The ability to slow or control the release of herbicides applied to the soil has long been considered a desirable formulation characteristic by weed scientists. The development of encapsulation by entrapment within a starch matrix (Shasha et al 1976) represents a technical and economically feasible approach (Stout et al 1979). Recent studies indicate that herbicide release from starch encapsulated formulations of EPTC and butylate can be greatly modified based on the selection of the starting starch xanthate and oxidant used in the formulation process (Schreiber et al 1978). Also, the release characteristics determined are closely related to the surface and internal structure of the granule (Schreiber and White, 1980).

Many thiocarbamate herbicides, because of their volatility, must be immediately incorporated into the soil particularly under moist soil conditions at time of application or shortly after (Gray and Weierich 1965). The objectives of this study were to determine the potential of starch encapsulated formulations over the emulsifiable concentrate formulation of EPTC in regard to delay of incorporation and whether a formulation modification would offer truely controlled-release.

METHOD AND MATERIALS

Formulation preparations. The general technique involves the formation of a starch xanthate and the crosslinking of the starch xanthate by an oxidant in the presence of EPTC to give the corresponding xanthide. Details of the preparation of starch encapsulated (SE) formulations SE-60, SE-61, and SE-59 are given by Schreiber et al (1978). Briefly, these formulations represent fast, moderate and slow release characteristics, respectively, based on changes in the starting xanthate and the oxidants used in crosslinking. SE-77 and SE-25 were prepared from starch xanthate and crosslinked with H_2O_2 and H_2SO_4 as oxidants. SE-25 was modified by coating the granules with pregelatinized wheat and corn starch. This latter procedure produced granules that contained round globules of pregelatinized starch on their surface, covering the surface pores reported by Schreiber and White (1980).

Exposure study I. The emulsifiable concentrate of EPTC and SE-60, SE-61 and SE-59 were surface applied at 6.72 kg/ha to 10 cm^2 plastic petri dishes containing 150 g of either air dry soil or soil at 16% moisture by weight. The petri dishes were allowed to remain uncovered for 0, 4, 24, or 48 h before they were bioassayed using pregerminated oat seeds according to the method of Horowitz (1966). The 24 and 48 h exposure dishes were watered daily to maintain moisture levels. The experiment was conducted in the laboratory at 22 C and was replicated 4 times. Shoot growth was measured 72 h after bioassay was initiated and data were compared to a standard curve to determine the kg/ha of EPTC remaining.

Exposure study II. A similar study was conducted using the emulsifiable concentrate and SE-25. Exposure periods were extended to 72 h and three initial concentrations were used, 6.72, 3.36 and 1.68 kg/ha. In this study only moist soil was used and all soils were kept moist by daily watering. This study was replicated 3 times and repeated twice. Measurements were made as in study I.

Exposure study III. Appropriate amounts of SE-77, SE-25 and a commercial 10G formulation equivalent to 6.72 kg/ha of EPTC were mixed with 6.58 kg of air-dried silt loam in a V-shaped soil mixer for 5 min. An equivalent rate of the emulsifiable concentrate of EPTC was sprayed to soil and immediately mixed. One hundred and fifty g of the soil from each treatment were placed in petri dishes and moistened to field capacity. One batch was bioassayed immediately and 3 batches, corresponding to exposures of 7, 14 and 35 days, were allowed to remain uncovered. Soils were kept at 16% moisture until bioassayed. This study was replicated 3 times and repeated twice. Measurements were made as in study I.

RESULTS

No significant EPTC loss was measured due to exposure time from surface application for either the emulsifiable concentrate or the SE formulations when applied to dry soil (Table 1). However, significant losses did occur at 24 and 48 h when applied to wet soil. This occurred in all formulations but with greater losses in the emulsifiable concentrate formulation and the fast release SE-60 formulation.

Table 1

Concentration remaining (kg/ha) from initial application of 6.72 kg/ha

Moisture regime	EPTC formulation	0-h	4-h	24-h	48-h
Dry	untreated	0 A*	0 A	0 A	0 A
	e.c.	4.80B*	4.80B	3.10B	5.00B
	SE-60	4.75B	3.94B	2.10B	3.94B
	SE-61	3.94B	3.94B	2.10B	3.94B
	SE-59	3.94B	3.10B	3.10B	4.80B
Wet	untreated	0 A	0 A	0 A	0 A
	e.c.	3.08B	3.08B	0.50B	0.28B
	SE-60	3.08B	2.60B	0.70B	0.31B
	SE-61	2.60B	3.94B	1.43C	1.43C
	SE-59	3.94B	4.80B	2.10C	1.82C

*Values in column within moisture regime and each exposure time followed by same letter are not significantly different at 5% level Duncan's Multiple Range Test.

The addition of a pregelatinized coat on the SE formulation (SE-25) significantly reduced the loss of EPTC from the soil surface at all concentrations used and up to 72 h of exposure (Table 2) compared to the emulsifiable concentrate. These data also indicate that the rate of loss from the emulsifiable concentrate formulation was more rapid at higher concentrations than at lower concentrations. Relatively little loss occurred from the SE-25 formulation regardless of initial concentration.

Table 2

Concentration remaining (kg/ha) after five exposure periods

Exposure time	EPTC formulation	6.72 kg/ha	3.36 kg/ha	1.68 kg/ha
0-h	untreated	0 A*	0 A	0 A
	e.c.	6.50B*	3.05B	1.40B
	SE-25	6.72B	3.36B	1.62B
4-h	untreated	0 A	0 A	0 A
	e.c.	3.08B	2.10B	1.43B
	SE-25	6.72C	3.36C	1.61C
24-h	untreated	0 A	0 A	0 A
	e.c.	1.61B	0.84B	0.60B
	SE-25	5.60C	2.52C	1.68C
48-h	untreated	0 A	0 A	0 A
	e.c.	0.98B	0.56B	0.28B
	SE-25	6.72C	3.36C	1.19C
72-h	untreated	0 A	0 A	0 A
	e.c.	0.56B	0.56B	0.18B
	SE-25	5.60C	3.36C	1.30C

*Values in column within exposure time and initial concentration followed by same letter are not significantly different at 5% level Duncan's Multiple Range Test.

Data shown in Table 3 indicate that only SE-25 shows controlled release over a period of 35d. The emulsifiable concentrate, 10G (commercial granule), and SE-77 all showed initial high concentration levels which gradually declined significantly over the same period. The higher concentrations of the emulsifiable concentrate when incorporated into the soil compared to the rapid losses when exposed on the soil surface can be noted when data in Table 3 are compared to data presented in Tables 1 and 2.

Table 3

Concentration remaining (kg/ha) from initial incorporated application of 6.72 kg/ha

EPTC formulation	0-day	7-day	14-days	35-days
e.c.	4.48A*	2.24A	1.12B	0.43C
10G	5.75A	4.48A	1.40B	1.21B
SE-77	4.48A	3.36A	1.27B	0.84C
SE-25	1.23A	1.40A	1.40A	1.23A

*Values in row followed by same letter are not significantly different at 5% level Duncan's Multiple Range Test.

DISCUSSION

The formulation of a highly volatile herbicide such as EPTC in a starch encapsulated granule can offer the user an option for delayed incorporation that is not feasible under most field conditions with the emulsifiable concentration. Work by Coffman and Gentner (1980) indicate similar advantages for the herbicide trifluralin. The data also indicate that slight modifications in SE formulation techniques can extend the stability of the herbicide EPTC even under the most favorable conditions for volatility loss on the soil surface. The addition of a pregelatinized coat on the surface of SE formulations of EPTC not only reduces substantial the loss from volatility but offers for the first time an indicated controlled release characteristic. Full season control should be possible.

Since the starch encapsulation of herbicides involves an entrapment within a starch matrix, it is also possible to entrap more than one pesticide within the same granule. This may be two or more herbicides, a herbicide and any other pesticide, or herbicide with protectants.

The data in Table 3 also point out a phenomenon that has concerned weed scientists for many years. That is the initial high concentrations that are immediately available from commercial emulsifiable concentrate formulations that often determine crop selectivity. The formulation SE-25 not only exhibited controlled release but the concentration level was low enough to possibly modify crop susceptibility yet high enough for adequate weed control.

This new formulation technology could be employed for herbicides that are not only highly volatile but readily leachable in the soil and/or subject to photodecomposition.

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NOTES

S-3552[N'-4-(4-METHYLPHENETHYLOXY)PHENYL-N-METHOXY-N-METHYLUREA] - A NEW SELECTIVE POSTEMERGENCE HERBICIDE FOR USE IN SOYBEANS

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Summary S-3552[N'-4-(4-methylphenethyloxy)phenyl-N-methoxy-N-methylurea] is a new selective post-emergence herbicide for use in soybeans. S-3552 exhibited excellent selectivity between soybeans and broadleaf weeds by over-the-top application. S-3552 showed potent herbicidal activity against such troublesome broadleaf weeds as Xanthium strumarium, Ipomoea purpurea, Abutilon theophrasti. Datura stramonium, Ambrosia spp. Euphorbia helioscopia etc. The herbicidal spectrum of S-3552 is quite broad and covers most of the common and troublesome broadleaf weeds in soybean fields of not only the United States but also Brazil. S-3552 is weaker against grassy weeds. S-3552 is weaker by pre-emergence application. The performance of S-3552 under greenhouse as well as field conditions is described.

INTRODUCTION

S-3552[N'-4-(4-methylphenethyloxy)phenyl-N-methoxy-N-methylurea] is a new selective postemergence herbicide for use in soybeans. S-3552 is characterized by a broad herbicidal spectrum against broadleaf weeds and by excellent selectivity to soybeans when applied by postemergence over-the-top application.

This paper presents basic information on herbicidal activity and soybean selectivity of S-3552 under greenhouse as well as field conditions.

METHODS AND MATERIALS

Greenhouse tests

Postemergence activity - Seeds of thirteen species of weeds and soybeans were sown in soil placed in a 33 X 25 X 10 cm^3 container, and kept in the greenhouse at about 25 ^oC. At 17 days after seeding, a test herbicide solution was sprayed over the top of the plants at a volume of 500 litres per hectare. At 15 days after treatment, herbicidal activity and soybean phytotoxicity were evaluated by a 0 to 5 rating system (0 = no effect, 5 = complete kill). At the time of treatment soybeans were at 1.5 trifoliate stage, and weeds were at 1 to 4 leaf stages.

Preemergence activity - After seeds of weeds and soybeans were sown in the same way as described above, a test herbicide solution was sprayed over the surface of soil at 1500 litres per ha. The plants were grown in the greenhouse at about 25 ^oC. At 3 weeks after treatment, herbicidal activity and soybean phytotoxicity were evaluated in the same way as described above.

Herbicidal spectrum by postemergence application - Various species of weeds were treated with S-3552 and herbicidal activity was evaluated. The method was essentially the same as described for the preemergence test.

Field trial

Trial was conducted in a randomized complete block design with three replications. Plot size was 2 m^2. The field was located at Katano, Osaka, Japan. At 28 days after seeding, a test herbicide solution was sprayed over the top of test plants at a volume of 500 litre per ha. The test solution contained 0.1 % wetting agent. At 12 days after treatment, aereal parts of test plants were cut off and their fresh weights measured. Herbicidal activity and soybean phytotoxicity were evaluated on the basis of percentage of the fresh weight of a treated plant relative to that of the untreated control..

Open-air tests

Seeds of weeds and soybeans were sown in soil placed in a 33 X 25 X 10 cm^3 container, and kept in the open air. At 2 to 4 weeks after seeding, a test herbicide solution was sprayed over the top of test plants in the same way as described for the field trial. At 2 to 3 weeks after treatment, herbicidal activity and soybean phytotoxicity were evaluated in the same way as described for the field trial. The results given are averages of 7 to 15 tests per weed species.

RESULTS

Greenhouse tests

S-3552 showed both potent herbicidal activity and high soybean selectivity by postemergence over-the-top application(Table 1). Herbicidal symptoms were of photosynthetic inhibition. S-3552 was far more effective against broadleaf weeds than against grassy weeds. No phytotoxicity to soybeans was observed at the dosage rates tested.

S-3552 showed much weaker preemergence activity compared with its postemergence activity(Table 2).

S-3552 exhibited a broad herbicidal spectrum against broadleaf weeds(Table 3). Most of the common and troublesome broadleaf weeds in the soybean fields of the United States and Brazil were found to be sensitive to S-3552. On the other hand, grassy weeds, *Cyperus* spp. and *Commelina* were more resistant to S-3552.

Field trial

S-3552 showed excellent herbicidal activity at 0.4 kg ai/ha against six broadleaf weeds tested which are among the major troublesome weeds in soybean fields in the United States(Table 4). Soybeans(cv. Ogden) suffered from slight growth inhibition at 1.5 kg ai/ha, but soon recovered from it. At the dosage rate below 0.7 kg ai/ha, S-3552 showed no phytotoxicity to soybeans.

Open-air tests

As shown in Table 5, most of the troublesome broadleaf weeds in the U. S. soybean fields were completely killed or suppressed by 0.75 kg ai/ha of S-3552. At 1.0 to 2.0 kg ai/ha, S-3552 slightly inhibited growth of soybean plants. But, field trials of longer duration showed that soybeans could fully recover from this level of growth inhibition.

DISCUSSION

S-3552 is characterized by excellent selectivity between soybeans and broadleaf weeds by postemergence application, and by its potent herbicidal activity against a wide range of broadleaf weeds, including those which are difficult to control by conventional preemergence herbicides, such as *Xanthium*, *Ipomoea*, *Abutilon*, *Datura*, *Ambrosia*, and *Euphorbia*. S-3552 is weaker against grassy weeds.

One system for weed control in soybean fields will be to apply a preemergence herbicide first for grass control and then apply S-3552 postemergence for the control of remaining broadleaf weeds. Another system will be to apply a mixture of a postemergence grass herbicide and S-3552 for simultaneous control of grasses and broadleaf weeds by a single treatment. The latter system is interesting in light of broad herbicidal spectrum of S-3552 against broadleaf weeds.

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Table 1

Herbicidal activity by postemergence application

Test plant	Herbicidal activity					
	S-3552 50WP			bentazon		
	kg ai/ha			kg ai/ha		
	1.0	0.5	0.25	1.0	0.5	0.25
Digitaria sanguinalis	2	1	0.5	0.5	0	0
Echinocloa crus-galli	2	1	0.5	2	1.5	0.5
Setaria viridis	3	2.5	2	0	0	0
Agropyron repens	2	1	0.5	0	0	0
Sorghum halepense	2	1.5	1	0	0	0
Amarathus patulus	5	5	5	3	2	1
Portulaca oleracea	5	5	4	5	5	4
Sinapis arvensis	5	5	5	5	5	5
Ambrosia artemisi-folia	5	5	5	5	5	5
Datura stramonium	5	5	5	5	5	5
Abutilon theophrasti	5	5	5	5	5	5
Ipomoea purpurea	5	4	4	4	2	1
Xanthium strumarium	5	5	4	5	5	5
Glycine max (soybean)	0	0	0	0	0	0

Table 2

Herbicidal activity by preemergence application

Test plant	Herbicidal activity			
	S-3552 50WP		alachlor	
	kg ai/ha		kg ai/ha	
	2.0	1.0	4.0	2.0
Digitaria sanguinalis	1	1	5	5
Echinocloa crus-galli	0	0	5	5
Setaria viridis	0	0	5	5
Agropyron repens	0	0	1.5	1
Sorghum halepense	0	0	3.5	3
Amaranthus patulus	3.5	2	5	5
Portulaca oleracea	2	1	5	5
Sinapis arvensis	1.5	0	3	2
Ambrosia artemisi-folia	0	0	3	2
Datura stramonium	0	0	2.5	1
Abutilon theophrasti	0	0	0	0
Ipomoea purpurea	0	0	3	2
Xanthium strumarium	0	0	0	0
Glycine max (soybean)	0	0	0	0

Table 3

Herbicidal spectrum of S-3552 by postemergence application

Group I	*Polygonum* spp., *Mollugo verticillata*, *Portulaca oleracea*, *Chenopodium album*, *Amaranthus patulus*, *Amaranthus retroflexus*, *Papaver rhoeas*, *Sinapis arvensis*, *Sesbania exaltata*, *Acalypha* sp., *Euphorbia helioscopia*, *Abutilon theophrasti*, *Oenothera* sp., *Ipomoea purpurea*, *Datura stramonium*, *Solanum nigrum*, *Bidens* spp., *Ambrosia artemisi-folia*, *Ambrisia trifida*, *Xanthium* spp., *Helianthus anuus*, *Asclepias syriaca* *Berreria alata*, *Acanthospermeum* sp.
Group II	*Cassia obtusifolia*, *Sida spinosa*, *Convolvulus arvensis*
Group III	*Commelina communis*, *Cyperus* spp., most of the gramineous weeds

Note: Groups I and II were killed by 0.25 to 0.5 and 0.75 to 1.5 kg ai/ha of S-3552, respectiviely, and Group III was not killed at 1.5 kg ai/ha under greenhouse conditions.

Table 4

Field trial of S-3552 as a postemergence herbicide for use in soybeans

Test plant	Stage		Herbicidal activity and crop tolerance									
			S-3552 50WP kg ai/ha					bentazon kg ai/ha				
	Leaf	Height (cm)	1.5	1.0	0.7	0.4	0.2	1.5	1.0	0.7	0.4	0.2
Glycine max (cv. Ogden)	3-4 (trif)	15-25	G	E	E	E	E	E	E	E	E	E
Xanthium strumarium	6-7	15-18	E	E	E	E	G	E	E	E	E	E
Ipomoea purpurea	4-9	10-30	E	E	E	E	F	E	E	G	G	F
Datura stramonium	4	10	E	E	E	E	E	E	G	E	E	E
Abutilon theophrasti	5-6	10	E	E	E	E	E	E	E	E	E	E
Ambrosia trifida	6-9	8-15	E	E	E	E	G	E	E	E	E	E
Amaranthus patulus	8-12	10-13	E	E	E	E	E	P	P	P	P	P

Note: Herbicidal activity and soybean tolerance were evaluated on the basis of percentage of the fresh weight of remaining aereal parts relative to that of the untreated control. For herbicidal activity, E, G, F and P denote that 0-10, 11-30, 31-50 and more than 50 % remained, respectively. For crop tolerance, E and G denote that more than 90 and 89-70 % remained, respectively.

Table 5

Trials in the open air of S-3552 as a postemergence herbicide for use in soybeans

Test plant	Leaf stage	Herbicidal activity and crop tolerance									
		S-3552 50WP					bentazon				
		kg ai/ha					kg ai/ha				
		2.0	1.5	1.0	0.75	0.5	2.0	1.5	1.0	0.75	0.5
Glycine max	1-2-3 (trif)	G	G	G	E	E	G	E	E	E	E
Ipomoea purpurea	2-4-7	G	G	G	G	F	F	F	F	P	P
Xanthium strumarium	3-4-6	E	E	E	E	G	E	E	E	E	G
Abutilon theophrasti	2-4-6	E	E	E	E	G	E	E	E	E	G
Amaranthus patulus	3-5-7	E	E	E	E	E	P	P	P	P	P
Datura stramonium	2-3-5	E	E	E	E	E	E	E	E	E	E
Ambrosia trifida	4-6-8	E	E	E	E	E	E	E	E	E	P
Solanum sp.	3-4-5	E	E	E	E	E	G	F	P	P	P
Helianthus anuus	3-4-5	E	E	G	E	G	E	E	E	E	G
Grasses	3-4-6	P	P	P	P	P	P	P	P	P	P

Note: The rating system of herbicidal activity and crop tolerance was the same as that described for Table 4.

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THE EFFECT OF DPX 4189 ON BIOCHEMICAL PROCESSES IN ISOLATED LEAF CELLS AND CHLOROPLASTS

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Summary Time- and concentration studies were conducted to determine the effect of DPX 4189 on photosynthesis, respiration, RNA synthesis, protein synthesis and lipid synthesis using isolated single leaf cells of *Phaseolus vulgaris*. Appropriate ^{14}C-substrates and product purification procedures were used for each process prior to liquid scintillation counting. The most sensitive process studied, photosynthesis, was inhibited by 5×10^{-4} M DPX 4189 by 91% after 120 min whereas inhibition of RNA synthesis, protein synthesis, lipid synthesis and respiration was 67%, 59%, 64% and 26% respectively.

The effect of DPX 4189 on a Mg^{+2}-dependent ATPase that is activated by light in the presence of dithiothreitol and phenazine methosulphate, as well as on oxygen evolution was also determined in isolated chloroplasts. DPX 4189 did not effect ATPase activity but inhibited oxygen evolution at concentrations of 5×10^{-4} M and 10^{-4} M by 39% and 32% respectively.

INTRODUCTION

During the past few years several techniques have been developed for the isolation of metabolically active cells from higher plants. These cells are capable of performing normal biochemical processes like photosynthesis, respiration, RNA synthesis, protein synthesis and lipid synthesis (Francki *et al*. 1971; Jensen *et al*. 1971; Ashton *et al*. 1977). It has been shown that these cells can be utilized to study the effect(s) of a particular herbicide on a variety of biochemical processes.

The objective of the present investigation was to study the effect of the new herbicide DPX 4189 [2-chloro-N(4-methoxy-6-methyl-1,3,5-triazine-2-yl) aminocarbonyl benzene-sulfonamide] on different biochemical processes utilizing single leaf cells. The processes investigated were those which have been most frequently reported to be influenced by herbicides in plants i.e. photosynthesis, respiration, RNA synthesis, protein synthesis and lipid synthesis (Ashton & Crafts, 1973). The effect of DPX 4189 was also determined on the light-induced ATPase activity as well as on oxygen evolution of isolated chloroplasts.

METHOD AND MATERIALS

Material. Beans (*Phaseolus vulgaris* L. var. Top Crop) were grown in moist Perlite at room temperature ($23^{o} \pm 2^{o}C$). Light with an intensity of 6 500 lux at the level of the primary leaves was supplied by a combination of fluorescent and incandescent lights; a 16-h light and 8-h dark regime was employed.

Isolation of cells. Mesophyll cells were isolated from 7-day-old leaves according to the method of Ashton *et al*. (1977) using a maceration medium consisting of 0.7 M sorbitol, 0.3% potassium dextran sulphate and 0.5% Macerase adjusted to pH 5.8. The released cells were centrifuged for 2 min at 60 x g and then washed in a medium containing 0.65 M sorbitol and several inorganic ions. After centrifugation for another 2 min at 60 x g, the cells were made to a desired volume with incubation medium containing 0.625 M sorbitol, the above inorganic ions and 50 mM MES buffer adjusted to pH 5.8.

Isolation of chloroplasts. Chloroplasts were isolated essentially by the method of Avron (1960) at $4^{o}C$. Chloroplasts were isolated from 9-day-old leaves by homogenization in a Waring Blender in 150 ml homogenizing medium containing 0.4 M sucrose, 0.05 M KH_2PO_4-K_2HPO_4 buffer (pH 7.3), 0.01 M KCl and 0.02 M sodium D-iso-ascorbate. The homogenate was squeezed through two layers of cheese cloth and centrifuged for 2 min at 500 x g, after which the supernatant was transferred and recentrifuged for 7 min at 1 000 x g. The pellet was suspended in 150 ml homogenizing medium (from which sodium D-iso-ascorbate was omitted) with a final pH of 6.5.

Chlorophyll determination. The chlorophyll content of the isolated cells and chloroplasts was determined according to the method of Vernon (1960).

Time- and concentration course studies with isolated cells. These studies were conducted to determine the effect of DPX 4189 on photosynthesis, respiration, RNA synthesis, protein synthesis and lipid synthesis using appropriate ^{14}C-substrates and product purification procedures as described previously (Ashton *et al*. 1977). The rates of the processes studied were measured by determining the amount of radioactivity incorporated or released from $NaH^{14}CO_3$ (photosynthesis), D-glucose-U-^{14}C (respiration), uracil-2-^{14}C (RNA-synthesis), L-leucine-U-^{14}C (protein synthesis) and 1,2-^{14}C-sodium acetate (lipid synthesis). Radioactive products were isolated prior to liquid scintillation counting, and their radioactivity was determined in toluene containing 0.4% PPO and 0.01% POPOP.

Isolated cells were exposed to DPX 4189 with final concentrations of 5×10^{-4} M, 10^{-4} M, 10^{-5} M, 10^{-6} M and 10^{-7} M respectively in 1% ethanol (in the final volume) in the incubation medium. Samples were collected at 15, 30, 60 and 120 min intervals.

Oxygen evolution. Oxygen evolution by isolated chloroplasts was determined with a Gilson respirometer according to the method of Vishniac (1957). The reaction mixture (2.2 ml) consisted of 0.02 M $K_3Fe(CN)_6$, 0.01 M $FeNH_4SO_4$, 0.05 M $K_2C_2O_4$, 0.02 M KH_2PO_4-K_2HPO_4 buffer, 0.0067 M KCl and 0.2 M sucrose adjusted to pH 6.5; 0.4 ml chloroplasts and 0.05 ml herbicide solution (with a final concentration of 5×10^{-4} M, 10^{-4} M, 10^{-5} M, 10^{-6} M and 10^{-7} M respectively) in 1% ethanol in the final volume. All reactions were carried out at $15^{o}C$ with constant shaking. Oxygen evolution was determined for 20 min.

ATPase activity. ATPase activity of the chloroplasts was determined according to the method of Alsop & Moreland (1975). The reaction mixture (4 ml) contained (in μ moles): Tris-HCl (pH 8.0) 50, $MgCl_2$ 10, sucrose 1 800, dithiothreitol 30, phenazine methosulphate 0.1, 1.2 ml chloroplasts and 0.1 ml herbicide solution (with a final concentration of 5×10^{-4} M, 10^{-4} M, 10^{-5} M, 10^{-6} M and 10^{-7} M respectively) in 1% ethanol in the final volume. The reaction vessels were illuminated by a photoflood lamp with an intensity of 70 000 lux. All reactions were carried out at 25°C. After a 5-min illumination period, 7.5 μ moles ATP was added and the reaction medium allowed to proceed in the dark for 10 min, after which it was stopped by the addition of 1 ml 10% TCA. The precipitated protein was removed by centrifugation, and the inorganic phosphate in the supernatant was determined spectrophotometrically (Merck, 1970).

All the above assays were repeated three times and the data presented are the average of these assays.

RESULTS

1. Time- and concentration course studies with isolated cells.

These results are presented in Table 1. Although all data were calculated as cpm/mg chlorophyll, these values were converted to per cent of the control (no herbicide present) for ease of comparison. Time-course experiments showed that in general, linear responses to DPX 4189 were obtained with respect to all the processes studied.

Photosynthesis. It is evident that the lower levels of DPX 4189 (10^{-7} M, 10^{-6} M and 10^{-5} M) had little effect on $^{14}CO_2$ fixation whereas the higher concentrations (10^{-4} M and 5×10^{-4} M) inhibited this process; after 120 min photosynthesis was inhibited by 23% and 91% respectively.

Respiration. Except for the highest concentration (5×10^{-4} M) DPX 4189 had little effect on respiration. DPX 4189, at a concentration of 5×10^{-4} M, inhibited this process by 26% after 120 min.

RNA synthesis. Low levels of DPX 4189 (10^{-7} M, 10^{-6} M and 10^{-5} M) had no pronounced effect, whereas 10^{-4} M and 5×10^{-4} M resulted in an inhibition of about 19% and 67% respectively after 120 min.

Protein synthesis. Except for the highest concentrations used (i.e. 10^{-4} M and 5×10^{-4} M) DPX 4189 had no effect on this process. DPX 4189 at concentrations of 10^{-4} M and 5×10^{-4} M inhibited protein synthesis by 29% and 59% respectively after 120 min.

Lipid synthesis. Low levels of DPX 4189 (10^{-7} M) stimulated lipid synthesis to a small extent whereas the higher concentrations (10^{-4} M and 5×10^{-4} M) inhibited this process; after 120 min the inhibition by 10^{-4} M and 5×10^{-4} M DPX 4189 amounted to about 48% and 64% respectively.

2. Studies with isolated chloroplasts.

Oxygen evolution. (Table 2). It is evident that 10^{-7} M DPX 4189 stimulated oxygen evolution by 24% whereas concentrations of 10^{-6} M and 10^{-5} M had no effect on this process. The higher levels of DPX 4189 applied i.e. 10^{-4} M and 5×10^{-4} M inhibited oxygen evolution by 32% and 39% respectively.

ATPase activity. (Table 3). DPX 4189 had no significant effect on ATPase activity.

Table 1

Effect of DPX 4189 on biochemical processes in isolated mesophyll cells

Concentration (M)	^{14}C-activity (cpm/mg chl) Expressed as % of 120 min control — Incubation period: 15 min	30 min	60 min	120 min
Photosynthesis				
0	12,0	26,0	51,6	100
5×10^{-4}	6,2	9,5	10,5	9,2
1×10^{-4}	12,9	25,4	48,2	77,1
1×10^{-5}	12,3	26,5	50,1	93,4
1×10^{-6}	13,2	24,0	52,8	98,3
1×10^{-7}	12,7	24,2	51,9	98,2
Respiration				
0	19,8	32,3	49,9	100
5×10^{-4}	16,3	24,3	37,2	73,8
1×10^{-4}	16,6	24,9	48,9	86,7
1×10^{-5}	17,8	28,5	47,9	98,3
1×10^{-6}	18,0	26,0	48,1	97,5
1×10^{-7}	18,9	28,6	47,1	98,6
RNA synthesis				
0	18,7	27,5	49,8	100
5×10^{-4}	19,5	26,4	26,5	33,0
1×10^{-4}	17,6	28,3	45,2	81,0
1×10^{-5}	18,1	28,8	48,2	98,1
1×10^{-6}	17,8	27,9	47,9	98,9
1×10^{-7}	18,2	30,1	48,8	99,4
Protein synthesis				
0	15,7	25,6	51,8	100
5×10^{-4}	13,5	9,2	22,8	41,1
1×10^{-4}	14,1	20,6	35,3	71,1
1×10^{-5}	15,1	24,6	49,1	98,2
1×10^{-6}	15,6	25,2	50,9	98,9
1×10^{-7}	16,2	24,8	51,6	99,1
Lipid synthesis				
0	19,0	30,8	52,6	100
5×10^{-4}	12,6	21,0	29,7	35,7
1×10^{-4}	11,0	22,4	25,8	41,5
1×10^{-5}	16,8	28,5	49,0	95,9
1×10^{-6}	18,2	31,1	53,4	115,9
1×10^{-7}	16,9	30,6	61,4	107,4

Table 2

Effect of DPX 4189 on oxygen evolution by isolated chloroplasts

Concentration (M)	Oxygen evolution (μl/mg chl/h)
0	333,4
5×10^{-4}	203,3
1×10^{-4}	226,7
1×10^{-5}	323,4
1×10^{-6}	330,1
1×10^{-7}	413,4

Table 3

Effect of DPX 4189 on the ATPase activity of isolated chloroplasts

Concentration (M)	P_i released (μg/mg chl/h)
0	167,3
5×10^{-4}	168,1
1×10^{-4}	167,3
1×10^{-5}	168,1
1×10^{-6}	167,3
1×10^{-7}	168,1

DISCUSSION

It is evident that the single-cell technique can be used to determine the effect of a herbicide on different biochemical processes simultaneously. As shown by Ashton *et al*. (1977) this technique can be used to localize the most sensitive metabolic processes involved in the action of a herbicide.

The present study shows that the primary effect of DPX 4189 in isolated leaf cells is on photosynthesis as indicated by its inhibition caused by the higher concentrations of the herbicide. DPX 4189 (at 5×10^{-4} M) also inhibited other metabolic processes, but to a much lesser extent. From this it is concluded that these processes may not be affected directly but only indirectly through the inhibition of photosynthesis, which probably provides most of the energy needed for their activities. However, the possibility that DPX 4189 directly affects more than one metabolic process simultaneously can not be excluded.

The present study showed that DPX 4189 does not affect the light-induced ATPase activity of the chloroplasts.

From the present results it would seem evident that DPX 4189 inhibits photosynthesis via the light-dependent part of the photosynthetic process by inhibiting PSII-mediated oxygen evolution. At present work is underway to determine the effect of DPX 4189 on electron transport in PSII and PSI in isolated chloroplasts.

Although it was found that DPX 4189 mainly inhibits photosynthesis in isolated leaf cells, this affect was only obtained when very high concentrations (i.e. 10^{-4} M and 5×10^{-4} M) of the herbicide were used.

Previous work with isolated leaf cells has shown that herbicides which primarily inhibit photosynthesis e.g. monuron, diuron and atrazine exhibit this effect at much lower concentrations e.g. 10^{-6} M (Ashton et al. 1977; De Villiers & Marais, 1979). From this it is concluded that inhibition of photosynthesis is probably not the primary mode of action of DPX 4189.

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LIGHT REFLECTANCE CHARACTERISTICS OF WEED AND CROP LEAVES AS EFFECTED BY PLANT SPECIES AND HERBICIDES

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Summary The results of spectrophotometric measurements in the .5 to 2.5 µm waveband showed that the leaves of none of 16 different plant species had exactly the same light reflectance. In the visible region of the light, the smallest reflectance differences with the highest standard deviations were obtained. The largest inter-species differences and the highest reflectances were measured at the near-infrared reflectance plateau, represented by λ= .80 µm. The differences in this region are mainly caused by specific mesophyll arrangements.

2,4-D and atrazine increased the reflectance of bean leaves in the visible and the water absorption wavebands of the light and caused a reduction at the near infrared plateau. These reflectance changes indicated a decreasing chlorophyll concentration and diminished water content and a gradually collapsed mesophyll, respectively. No reaction was observed for corn leaves.

Resumé Les résultats des mesures spectrophotométriques dans les bandes d'ondes de 0,5 à 2,5 µm, ont montré que les feuilles d'aucunes des 16 éspèces différentes ont reflêté la lumière exactement de la même facon. Dans les secteurs visibles de la lumière, les différences de la réflexion les plus petites avec les plus hautes déviations standard on été obtenu. Les plus grandes différences interspécifiques et les plus hautes réflexions ont été mesuré sur le plateau de réflexion de l'infrarouge proche, représenté par λ = 0,80 µm. Les raisons prédominantes pour les différences dans ce secteur sont des arrangements spécifiques du mésophylle.

2,4-D et atrazine augmente la réflexion des feuilles de fêves dans les bandes d'ondes de la lumière visible et d'absorption de l'eau. De même, les produits provoque une réduction dans le plateau de l'infrarouge proche. Ces changements de réflexions indiquent une concentration chlorophyllienne que devient de plus en plus faible et un contenu diminu en eau et le mésophylle collable successivement, respectivement. Les feuilles de mais n'ont pas donné de réaction.

INTRODUCTION

Reflectance and transmittance of light at a plant leaf have been explained on the basis of critical reflection at the cell wall/air interface of the spongy mesophyll tissue (Willstätter & Stoll, 1913; Woolley, 1971; Sinclair et al., 1973; Gausman & Allen, 1973; Gausman, 1974; Bunnik, 1978). Sinclair et al. (1973) hypothesized that leaf reflectance results from the diffuse characteristics of cell walls. Light reflectance of a leaf is generally reduced over all wavelengths between .4 or .5 to 2.5 µm when the leaf is infiltrated with a liquid (Woolley, 1971). Most of the reflectance, therefore, originates internally and is reduced when the cell wall/air interfaces are eliminated.

Near infrared (.75 to 1.35 µm) light reflectance usually increases with an increase in the number of intercellular air spaces (Gausman et al., 1970) because light is scattered when passing from hydrated cell walls with a refractive index of 1.47 (Woolley, 1971) to intercellular air with a refractive index of 1.0. Internal refractive index discontinuities among cellular constituents are also responsible for some of the near infrared light reflectance of a leaf (Woolley, 1971; Gausman, 1973). Generally, in this wavelength region the reflectance of leaves with compact mesophylls is lower as compared to leaves with porous mesophylls (Gausman & Allen, 1973). Near infrared reflectance is comparatively high because of the lack of light absorbing materials.

The effective absorption coefficient of a typical leaf is a superposition of the absorption coefficients of chlorophyll and pure liquid water. In the 1.35 to 2.50 µm waveband, the relative amounts of absorption and reflectance are mainly determined by leaf water content (NAS, 1970, Bunnick, 1978).

The basic principles outlined in the previous paragraphs show that factors affecting the anatomical structure or pigment resp. water content of a leaf are also effecting its reflectance properties (for details see Bowden, 1974; ASP, 1978; Gausman et al., 1978).

The first of our objectives was to investigate species specific effects on the reflectance of leaves of different crop and weed species in order to discriminate them by their spectral reflectance properties. The second part of this investigation was concerned with the effect of herbicides on the spectral reflectance of leaves to see whether or not this nondestructive electro-optical technique (Myers & Allen, 1968) can be applied successfully in detecting herbicide effects on plants.

METHOD AND MATERIALS

Effect of plant species on reflectance

Five fully expanded and healthy-appearing leaves were collected from the middle part of each of 16 field grown plant species in the shooting stage: Aegopodium podagraria L., Atriplex patula L., Chenopodium album L., Cirsium arvense (L.) Scop., Fallopia convolvulus (L.) A. Leove, Galeopsis tetrahit L., Lapsana communis L., Polygonum amphibium L., P. lapathifolium L., Sinapis arvensis L., Sonchus arvensis L., Tussilago farfara L., Urtica dioca L., maize, potato, sugar beet. Immediately after excision, leaves were put in plastic bags to minimize dehydration and stored on ice. Spectral reflectance factors and water-content were measured and the leaf anatomy was investigated.

Spectral reflectance of the upper (adaxial) surfaces of single leaves was measured by means of a Zeiss PMQ-II spectrophotometer equipped with a reflectance attachment over the .5 - 2.5 µm wavelength interval. The instrument was calibrated against a $BaSO_4$ standard. To avoid changes in the leaf's properties during the measurement, the time of measurement was reduced by selecting 13 wavelengths between .50 to 2.50 µm. Three wavelengths were selected in the chlorophyll absorption and reflectance region (.50, .55 and .66 µm), four on the near infrared plateau (.75, .80, 1.10 and 1.45 µm) and three in the water absorption bands (1.45, 1.95, 2.50 µm) with the corresponding reflectance peaks at 1.65 (incl. 1.85) and 2.25 µm respectively. Statements about reflectance differences between species are based on the mean values of the data under consideration of their standard deviation.

Water content of leaves was determined on a dry weight basis. For anatomical studies, tissue pieces were sampled from the centre of leaves, fixed in formalin-acetic acid-alcohol, dehydrated in a tertiary butanol series, embedded in paraffin, stained, transversally microtomed at 12 µm thickness, mounted on glass-slides, and photographed.

Effect of herbicides on reflectance

This part of our study was carried out at the USDA laboratory at Weslaco, Texas, USA. Seeds of the two test species, beans (Phaseolus vulgaris) and maize (Zea mays), were sown in a mixture of one part perlite to 200 parts of a sandy clay loam contained in plastic pots and thinned to two plants per pot before application. A 10-20-5 NPK fertilizer was added to the mixture to give the equivalent of 67 kg/ha of N. All pots were surface irrigated with equal amounts of rain water.

Maize and beans were sprayed with a hand sprayer at the five and two (true) leaf stage, respectively. The total spray volume was equivalent to 252 l/ha. Control plants were sprayed with distilled water. The other treatments were .72 l/ha a.i. 2,4-D amine and 1.44 l/ha a.i. atrazine. There were five replications.

A Beckman Model DK-2 A spectrophotometer, equipped with a reflectance attachment, was used to measure total diffuse reflectance on the upper (adaxial) surfaces of plant-attached single leaves over the .50 - 2.50 µm waveband. Data were corrected for decay of the $BaSO_4$ standard to give absolute radiometric data. The measurements were taken daily beginning just before the plants were sprayed and up to 8 days after treatment for each plant. The results are given as reflectance curves. Reflectance data were analyzed for variance, using the LSD at p .05 to test differences between the control and each of the herbicide treatments. In addition the water content was determined and the leaf anatomy was investigated on the last day.

RESULTS

Effect of plant species on reflectance

Regardless of the plant species, green, healthy leaves showed in general the same reflectance characteristic (Fig. 1). But within this general pattern there were qualitative and quantitative interspecies differences. These differences were quite small in the visible region of the spectrum. Larger differences could be observed at the near infrared reflectance plateau and the reflectance peaks at 1.65 and 2.25 µm following the 1.45 and 1.95 µm waterabsorption bands. The leaf water content is also different for the different plant species (e.g. sugar beet 91 %, Fallopia convolvulus 86 %, Urtica dioica 84 %).

The largest inter-species differences were obtained at the .80 µm wavelength on the near infrared reflectance plateau (Fig. 2). Here also the standard deviation of the means was lower than in the visible light. Therefore this wavelength was selected for discrimination purposes between the plant species. To the species with the lowest reflectance belonged Aegopodium podagraria, maize, and Urtica dioica. Species with a high reflectance were Tussilago farfara, Polygonum amphibium and P. lapathifolium. Along with these reflectance differences different mesophyll arrangements were observed.

Effect of herbicides on reflectance

Over the entire measurement period, no herbicide effects of any significance could be detected for maize, neither visually nor spectrophotometrically. Beans, however, reacted very sensitively to both herbicides. Already 2 days after treatment differences between the reflectance of untreated and herbicide treated leaves were obtained (Fig. 3 a). At this time no visible differences between treated and untreated leaves could be observed.

Eight days after the herbicides were applied the differences in reflectance between untreated and treated leaves increased (Fig. 3 b). At this time, marked visible effects had appeared. At the .55 µm wavelength (chlorophyll reflectance peak) reflectance of treated leaves was 50 and 46 % higher than of control leaves for the 2,4-D and atrazine treatments, respectively. The reflectance at the .80 µm wavelength, which is strongly affected by the mesophyll structure, was 12 % lower for the 2,4-D treatment and 7 % lower for the atrazine treatment, compared to control leaves. At the water absorption region of the spectrum, especially atrazine treated leaves had a significantly higher reflectance (35 % at 2.20 µm) than control leaves. The corresponding water-content was 85 %, 67 %, and 87 % for control, atrazine, and 2,4-D treated leaves, respectively.

DISCUSSION

Even though the plant species tested had in general the same spectral reflectance pattern some qualitative and quantitative reflectance differences were observed for different species. Differences in the visible region are largely due to different chlorophyll concentrations as Thomas & Gausman (1977) have demonstrated. But in this region the standard deviation of the mean reflectance factors was highest, which indicates the dependence of the chlorophyll concentration on environmental conditions. These circumstances limit the use of the reflectance data of this region for the discrimination of plant species.

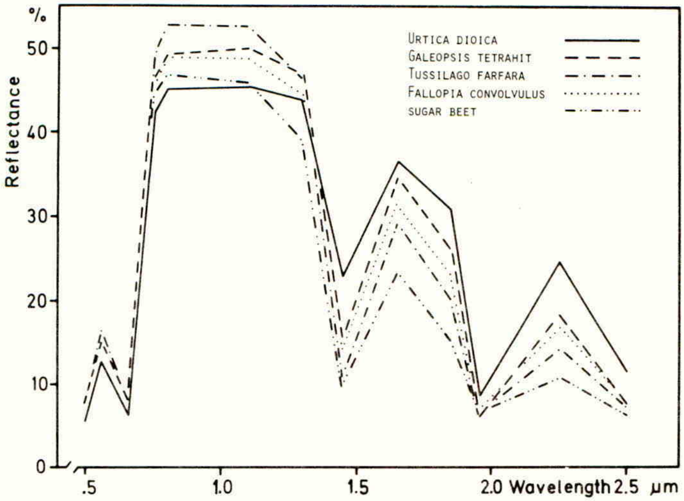

Fig. 1

Spectral reflectance of leaves of five plant species

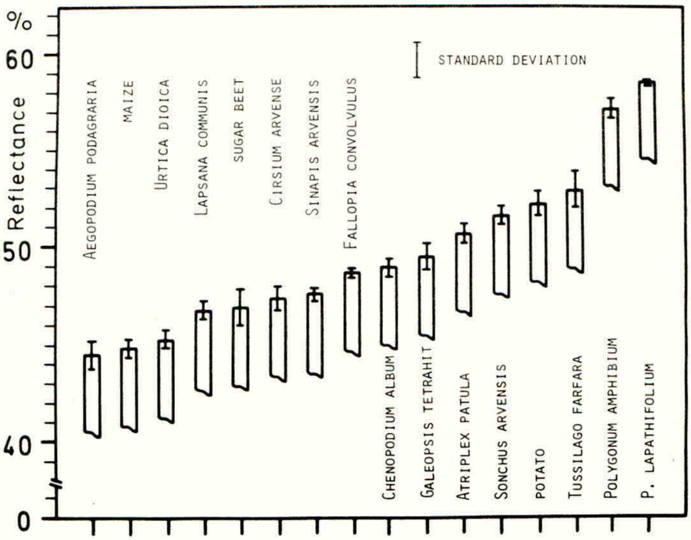

Fig. 2

Spectral reflectance of leaves of 16 plant species at $\lambda = .8\ \mu m$

The same problems arise with the evaluation of the reflectance factors in the water absorption bands. Although the differences in reflectance between the species were quite large at the time of measurement, they are not very useful to distinguish between plant species, as they largely depend on the actual water content of the plant and therefore on the enviromental conditions. These reflectance factors can, however, be used to estimate the water content of a plant's leaf and of the plant itself. The negative correlation between reflectance (at 1.65 and 2.20 µm wavelength) and water-content of a leaf is highly significant (Walter et al., unpublished data).

The differences between the species at the near infrared reflectance plateau (.75 - 1.35 µm), represented by the reflectance at the .80 µm wavelength, were largely caused by specific mesophyll

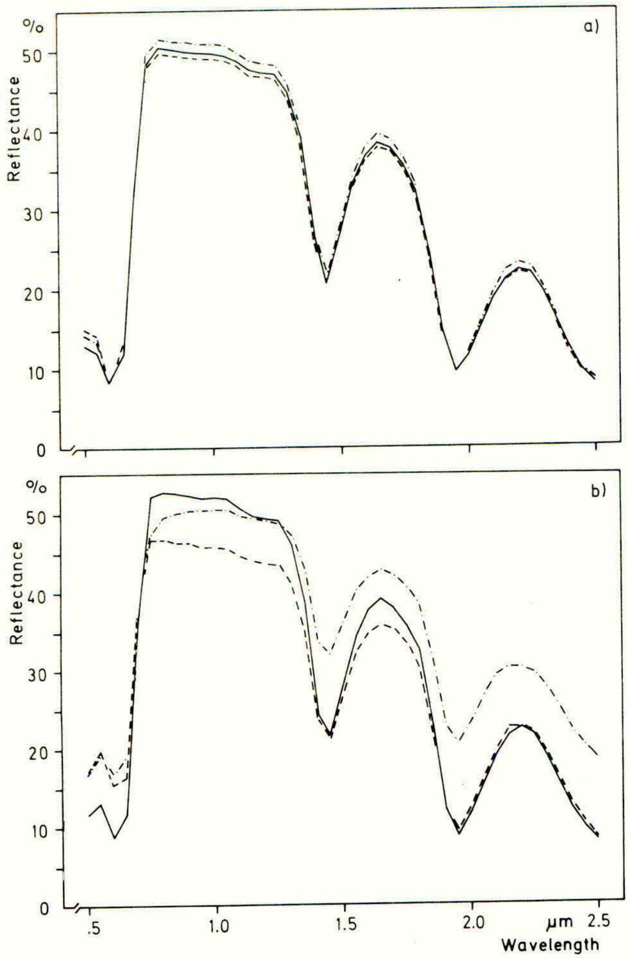

Fig. 3

Effect of 2,4-D and atrazine on the reflectance of bean leaves; a: 2 days, b: 8 days after treatment;

untreated ————

2,4-D – – – – –

atrazine –·–·–·–·

arrangements of the respective species. This is confirmed by several authors (Woolley, 1971; Gausman & Allen, 1973; Menges et al., 1980). Low reflectance values were associated with a more densely packed and compact mesophyll structure (e.g. Aegopodium podagraria, Urtica dioica, maize) whereas high reflectance values were obtained for plant leaves with a very finely divided mesophyll containing many cell wall/air interfaces (e.g. Tussilago farfara, Polygonum amphibium and P. lapathifolium).

In view of the close relation between the more or less constant species specific mesophyll arrangement and the light reflectance at the near infrared reflectance plateau (e.g. .80 µm), this spectral region could be used to distinguish plant species by their spectral reflectance . A practical application of these reflectance differences would be the aerial reconnaissance for weeds in a crop as it is mentioned by Menges (1979), who could clearly recognize weed species within an onion field by using aerial photography with colour infrared film. Information like this may also allow us to locate areas of weed populations, monitor their spread (Gausman et al.,1977), outline areas for weed control and supervise the areas or fields sprayed with herbicides (Young et al.,1976).

The last mentioned practical application possibly seems quite realistic as plants which are susceptible to certain herbicides change their reflectance characteristics quite drastically following the treatment with these herbicides. This is evident if we compare the effect 2,4-D and atrazine had on the reflectance of corn and beans. For the bean plants which are susceptible to both herbicides, effects which are not detectable visually could be found from the changes in reflectance comparing untreated and treated leaves.

Both herbicides affected the chlorophyll concentration in bean leaves and therefore increased the reflectance in the visible region of the light. The decreased reflectance at the near infrared reflectance plateau is due to the gradually collapsing mesophyll which decreases the number of air spaces (cell wall/air interfaces) and thus the reflectance potential. The increased reflectance in the water absorption bands following the treatment with atrazine is caused by the lower water content of the leaf. Again the negative relation between the water content of a leaf and its reflectance in the water adsorption region is obvious. So this nondestructive electro-optical measuring technique could also be used as a laboratory method to detect herbicide effects or stress in general (Gausman et al.,1978) on plants.

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