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MEFLUIDIDE (MBR 12325) - A NEW CONCEPT IN WEED CONTROL WITH A PLANT GROWTH REGULATOR

J.W. Bushong, D.W. Gates and T.P. Sullivan

3M Company, Agrichemicals Project, Saint Paul, Minnesota 55101 U.S.A.

Summary Mefluidide (formerly MBR 12325), with the trade name EMBARK Plant Growth Regulator/Herbicide, has shown promise in agriculture and horticulture by inducing a variety of responses in numerous plant species. Mefluidide acts as a regulator in that it retards turf growth and suppresses seedhead formation for 3-8 weeks after application. The compound also acts as a sugar cane ripener, increasing sucrose levels by an average of 20%, retards growth of many ornamental species, and is effective in controlling the formation of suckers in tobacco. Mefluidide acts as a post-emergence soybean herbicide by selectively killing and/or suppressing many grassy and broadleaf weeds. It is particularly active on *Sorghum halepense* and *Sesbania exaltata*. The toxicological data available to date indicate that mefluidide is not persistent in the environment and will not present a health hazard to man, wildlife, or domestic animals.

INTRODUCTION

Mefluidide, an experimental plant growth regulator/herbicide from the 3M Company, shows promise in a number of situations in which plant growth regulation can be advantageous. The potential commercial uses of this compound as a new tool for more efficient agricultural and horticultural production are quite diverse because of the various responses which we have observed for numerous plant species.

Mefluidide (formerly tested as MBR 12325) has been given the trade name EMBARK Plant Growth Regulator/Herbicide by the 3M Company. This compound has been granted a temporary permit by the U. S. Environmental Protection Agency for evaluation on turfgrasses in 1976.

CHEMICAL AND PHYSICAL PROPERTIES

Mefluidide, *N*-[2,4-dimethyl-5-[[(trifluoromethyl)sulfonyl]amino]phenyl]acetamide, is a relatively non-volatile, high-melting, crystalline white solid, which dissolves only slightly in water, but is quite soluble in organic solvents such as methanol and acetone. The compound is acidic (pK_A 4.6) and is stable to heat and moisture. Being acidic, it readily forms salts, some of which are very soluble, with inorganic and organic bases. Mefluidide is formulated as a diethanolamine salt solution containing 0.48 kg a.i. (4S) or 0.24 kg a.i. (2S) per 1.

BIOLOGICAL PROPERTIES

Grass Growth Retardation and Seedhead Suppression

Mefluidide has proved to be effective in retarding grass growth in turf. When the compound is applied uniformly to many warm and cool-season grasses, mowing is not required for 3-8 weeks after application of the compound. Mefluidide retards grass growth and suppresses seedhead formation yet allows the grass to maintain a healthy appearance.

In a 30-day trial with bermudagrass (*Cynodon dactylon*) turf, mowing 3 days after application was the best treatment for maximum retardation. Turf mowed 14 days after treatment also showed good retardation however. At the end of the 30-day period the 14-day treatment showed retardation for only 16 days, whereas the 3-day treatment retarded grass growth for 27 days. It appears that mowing turf 3 days after treatment provides a "shock" to the grass, thus accentuating the effect of the chemical.

Chemical Ripening of Sugar Cane

Mefluidide looks extremely promising as a chemical ripening agent for increasing sucrose content in sugar cane (*Saccharum officinarum*). In numerous trials conducted in Hawaii and throughout the world, sucrose content has been significantly increased. Mefluidide is active on the major cane varieties and when applied as a foliar spray 7-12 weeks prior to harvest, the sucrose content has been increased by an average of 20% in tests conducted by the sugar industry.

Weed Suppression in Soybeans

Mefluidide applied post-emergence at the 2-5 trifoliate stage to soybeans at a rate of 0.28-1.12 kg a.i./ha has selectively killed, suppressed growth, and/or inhibited seed formation of many grassy and broadleaf weeds. Although mefluidide does not kill the weeds in most instances, it suppresses growth, thus reducing their ability to compete. Some of the more susceptible weeds have been *Sorghum halepense*, *Sesbania exaltata*, *Xanthium pennsylvanicum*, and *Ipomoea* spp.

Mefluidide was applied post-emergence at the 4-5 trifoliate stage to soybeans (*Glycine max*, var. Bragg) in fields with heavy infestations of *Sorghum halepense*. The percentage of *S. halepense* control and soybean injury was determined at 17 and 49 days after treatment (Table 1). Mefluidide gave 100% control at all rates 17 days after treatment. Soybean injury increased during this time. At 49 days after treatment, *S. halepense* control continued to be excellent (93-98%) and crop injury was not evident at 0.28 and 0.56 kg a.i./ha. Crop injury was reduced at 49 days because new growth occurred during the interval of 17-49 days after treatment with the compound.

Table 1

Effect of mefluidide on Sorghum halepense and soybeans (Glycine max var. Bragg) when applied post-emergence to the soybeans at the 4-5 trifoliate stage

Application rate (kg ai/ha)	Days after application: 17		49	
	% Weed control	% Crop injury	% Weed control	% Crop injury
0.28	100	10	97	0
0.56	100	17	93	0
1.12	100	27	98	17

Collinston, Louisiana

In a similar experiment, mefluidide was applied post-emergence at the 4-5 trifoliate stage in combination with a surfactant (Sterox NJ). S. halepense control and soybean injury were determined at 16 and 75 days after treatment and yield was determined at the termination of the experiment (Table 2). Mefluidide gave 75%, 85%, and 95% S. halepense control respectively 16 days after treatment with slight crop injury and 65%, 75% and 78% control 75 days after treatment. No crop injury was noted at this time. Yield increases ranged from 12-29% compared to the untreated check.

Table 2

Effect of mefluidide on Sorghum halepense and soybeans (Glycine max var. Hill) when applied post-emergence to the soybeans at the 4-5 trifoliate stage

Application rate (kg ai/ha)	Days after application: 16		75		Yield (kg/ha)
	% Weed control	% Crop injury	% Weed control	% Crop injury	
Unweeded check	0	0	0	0	2290
0.45	75	10	65	0	2829
0.67	85	15	75	0	2964
0.90	95	17	78	5	2559

Stoneville, Mississippi

Post-emergence application of mefluidide has also shown promise for controlling Sesbania exaltata in soybeans. Applied over-the-top of 2-5 trifoliate soybeans at 0.28 to 0.56 kg a.i./ha, mefluidide plus surfactant gave 50-90% suppression or kill of S. exaltata up to 25 cm tall. Terminal and axillary bud kill resulted in the lack of growth for several weeks and in some cases for the entire growing season.

Other Growth-Regulating Properties

Mefluidide appears to modify plant growth and development of the apical meristem and for many plants this action may induce other meristematic regions of the plant to develop. This growth can be inhibited by using higher concentrations.

In tobacco (Nicotiana tabacum), axillary bud suppression (tobacco sucker control) has been observed from applications of 50 to 150 ppm sprayed to runoff.

Excellent growth suppression of woody ornamentals has been exhibited using mefluidide. Plants that have responded to foliar applications include azalea (Rhododendron spp.), juniper (Juniperus spp.), holly (Ilex rotundifolia), privet (Ligustrum spp.), prune (Prunus spp.) and peach (Prunus persica).

Mefluidide applied to privet (Ligustrum spp.) at a rate of 3.36 kg a.i./ha after trimming gave 90-day suppression of axillary meristems.

Mefluidide also acts as an excellent herbistat/herbicide on Avena fatua and Helianthus californicus in safflower (Carthamus tinctoria).

TOXICOLOGY

In order to help ensure that mefluidide may be safely applied in the enviroment, the fate of this compound in plants, animals, soil, and water has been thoroughly investigated.

Oral toxicity of mefluidide for mice and rats is 1920 mg/kg and > 4000 mg/kg respectively. Dermal toxicity is > 4000 mg/kg in rabbits. On a subacute basis, the no-effect level obtained from a 90-day feeding study was 6000 ppm.

Mefluidide is unstable in the soil and will leach when applied to moist soil followed by ample rainfall. Its half-life in soil is less than one week and the compound is susceptible to photodecomposition in solution but is relatively stable on soil surfaces.

Acute and subacute toxicology metabolism, and residue data gathered to date suggest that the compound will not be a hazard to man and his environment.

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THE USE OF A METOXURON PREPARATION, SAN 7102, FOR DESICCATION OF DIFFERENT CROPS

P. Corpataux and A. Henauer
Sandoz Ltd, CH-4002 Basle, Switzerland

Summary SAN 7102, based on metoxuron, has proved to be an interesting desiccant for use in hemp, potatoes and tomatoes. The advantage of this new product lies in its very low toxicity to man, wildlife, and to fish. It is not toxic to bees. Another advantage is the rapid degradation of this compound after application.

This paper gives an overall view of the field results available and provides indications for its optimal use. SAN 7102 can be used profitably at 1·6 - 2·4 kg a.i./ha and at a minimum spray volume of 300 l/ha (ground application), or at about 30 l/ha (aerial application) for haulm-killing in ware and industrial potatoes. It is also currently used in hemp crops, at a rate of 3·2 kg a.i./ha SAN 7102 + 4 l. white oil in dry regions, but without the adjuvant under humid conditions. In tomatoes SAN 7102 at 2·4 kg a.i./ha can be used with good effect to reduce interfering foliage and to shorten the harvesting period in machine- and hand picked late-season cultivars.

INTRODUCTION

In recent times, defoliation/desiccation has become an important task in crop farming and constitues an essential step in the various stages of food production, both in facilitating harvesting, and accelerating or synchronising maturation. The smaller the quantity of interfering foliage, the easier it is to use harvesting machines in crops such as hemp, potato, sunflower and tomato.

The manifold application possibilities for defoliants/desiccants have led to the development of a whole range of such preparations, only very few of which, however, meet the more important requirements. Although many of the substances in use today have high biological activity, they are not able to fulfil the requirements with respect to their possible effect on man, animals, soil and quality of the produce. The growing concern for high quality and protection of the environment has made it necessary to consider not only the biological effectiveness of a preparation, but to a greater extent also its toxicological properties, environmental and residue behaviour and influence on quality.

In this paper we shall deal mainly with the use of SAN 7102 in potato, hemp and tomato.

TERMINOLOGY

Various methods are now being used for the chemical destruction of green plant material. According to the mechanism of action, we destinguish between defoliants and desiccants. Since these terms are often confused, we shall briefly explain their meaning and, at the same time, indicate into which class we have placed SAN 7102.

Defoliation: Premature induction of the abscission mechanism by means of certain chemicals (e.g. ethylene).

Desiccation: Destruction of the green plant material by means of dehydrating substances, or by those affecting plant metabolism. We distinguish:

fast desiccants, e.g. diquat, DNOC
slow desiccants, e.g. SAN 7102.

MATERIAL AND METHODS

The desiccant SAN 7102 contains metoxuron, a substance developed by Sandoz Ltd, is available in a 80 % w/w wettable powder formulation.

The physical, chemical and toxicological properties of metoxuron, and its use as a herbicide in winter wheat and carrots, have been known for some time (Berg, 1968). Summarizing, we would like to mention only that the active ingredient is practically non-toxic to mammals, fish and bees, also that it is safe with respect to residues in the harvested crop, and that it degrades rapidly in the soil.

Potato

The results presented in this paper are mainly from field trials in Holland; observations made in other countries and those noted during routine applications were also taken into consideration. The plot size was usually 20 m^2, in which there were three rows of potatoes. The layout was that of randomized blocks with four or five replicates. For assessing the yield, the middle row of the plots was harvested. As a rule, the desiccation was measured as a percentage and the effect on the leaves and stems was recorded separately.

Hemp

At the suggestion of A. Gimesi, from the Plant Protection Institute in Budapest, SAN 7102 was first used in 1969 in the hemp-producing area of Hungary, and then later in Czechoslovakia, Bulgaria and Rumania. Today, it is used successfully as a desiccant in these countries. The introductory trials were carried out under the auspices of the hemp-processing industry, together with the Plant Protection Institute and also the hemp Institutes. During the cours of these trials, the following aspects were studied: dosage, timing of application, fibre quality, yield characteristics and the influence of climatic factores. In 1974, trials were carried out by the Agricultural Institute at Osijek and the PLK Dakovo in Yugoslavia.

Tomato

Plot trials in Italy, 1974. There were four trials with three replicates and a plot size of 10 m^2. Two trials were with cv. Roma VF and one trial each on cv. No. 1350 and 1439. Applications were made with a knapsack sprayer, using a spray volume of 1000 l/ha. Ethephon (PGR), which is in commercial use, was used for comparison.

Field trial in Italy, 1975. There were fifteen trials in early and late-ripening tomatoes, with application dates at the end of July and at the beginning of September respectively. The spray volume was 600 l/ha. The same comparison product was used as in these plot trials.

RESULTS AND DISCUSSION

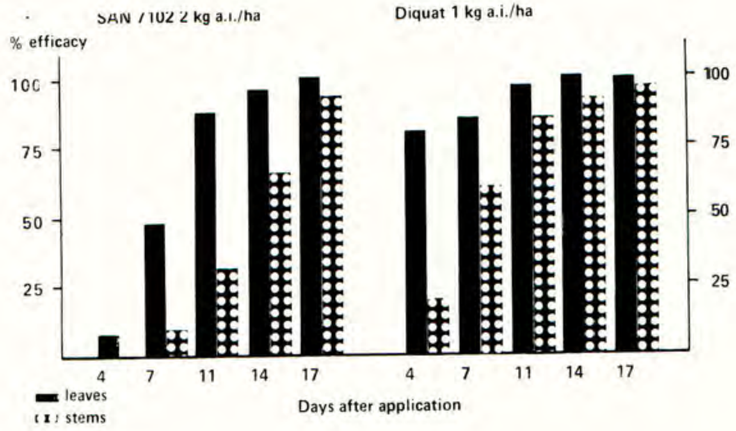
Potatoes

Effect and mode of action.

Fig. 1 summarizes all the results obtained during 1971 - 75 on cv. Bintje with 2 kg a.i./ha of SAN 7102. It is clear that SAN 7102 required 17 days in order to destroy the stems and leaves satisfactorily. In comparison, 1 kg a.i./ha of diquat (more costly) required 11 days to obtain the same result.

Figure 1

Effect and mode of action of SAN 7102 in comparison with diquat applied to potatoes cv. Bintje. Average figures of 35 trials 1971 - 75



Time of application.

Table 1

Influence of the time of application of 2 kg a.i./ha SAN 7102 on the speed of action in potatoes cv. Bintje. Average values from three plot trials (Holland 1974).

Date of treatment	Desiccation (%) Leaf/Stem					
	Days after treatment					
	0	4	7	10	14	18
19/20.8.74	0/0	0/0	33/1	80/20	92/42	98/71
29/30.8.74	7/0	27/3	49/13	82/46	97/65	99/80
5/6. 9.74	30/10	69/32	84/49	99/80	100/89	100/96

Table 1 lists results from trials performed on three different application dates. They show that if the application took place early, i.e. when the potato plants were still fully active, the onset of action of SAN 7102 was delayed. The closer the treatment was to the time of natural maturing, the quicker was the onset of action. We believe, however, that a certain number of fully functioning leaves must be available for SAN 7102 to act as an inhibitor of photosynthesis.

Yield. When assessing the yield of potatoes after using SAN 7102 in comparison with the important standard preparation diquat the following results were obtained. In 13 yield trials in Holland, SAN 7102 was applied 4 - 5 days before diquat; no significant differences in yield were found between the two preparations. In a further series of three trials in 1974, SAN 7102 was applied 7 days before diquat; in one of the trials, a statistically significant yield reduction of 6 % was obtained with SAN 7102.

Application technique. We noticed that the mode of action is influenced mainly by the distribution of the spray, and less by the amount of preparation used. The lower the spray volume, the higher are the requirements for its optimal distribution. SAN 7102 can be applied with ground spray equipment of a minimum capacity of 200 l/ha. For treating potato plants, which are still very active, 500 l/ha appears optimal. Excellent results were obtained with 33 l/ha by aerial application.

Influence on the discoloration of the vascular bundle and the point of abscisson of a tuber.

Table 2

Influence of SAN 7102 on the brown coloration of tubers in comparison with that of diquat and sodium arsenite. Average values from eight trials on potatoes cv. Bintje. (Sweden and Norway 1975)

Product	(kg a.i./ha)	% of tubers with discoloration			
		none	slight	medium	strong
SAN 7102	2.0	92.5	6.5	0.5	0.5
Diquat	0.8	50.0	34.5	10.5	5.0
Na-Arsenit*	20 l.	79.6	18.2	2.2	0
Untreated		89.5	10.2	0.3	0

* formulated product

Effect on weeds. In comparison with standard preparations, SAN 7102 had in general a less pronounced and slower effect on weeds present in fields of potatoes near to harvest. Good results were obtained against *Chenopodium album*, *Setaria glauca*, *Polygonum lapathifolium*, *Tripleurospermum maritimum* ssp. *inodorum* and *Stellaria media*, and the level of effectiveness against these weeds was comparable to that of diquat. Insufficient effect was noted mainly against *Senecio vulgaris*, *Urtica urens*, *Lolium multiflorum*, *Agropyron repens* and *Cirsium arvense*.

Tomatoes

Small plot trials.

Table 3

Desiccation effect of SAN 7102 on tomatoes, 15 days after application. Average values from four trials. (Italy 1974)

Treatment	Dose (kg a.i./ha)	% of foliar surface burnt	Number of fruites (%)		
			Mature	Rose	Green
Untreated	-	19.2	45.5	26.1	28.3
SAN 7102	2.4	65.2	59.0	28.8	12.2
SAN 7102	3.2	72.2	64.0	25.1	10.9
Ethephon	1.44	45.9	68.4	22.5	9.0

Table 4

Effect of SAN 7102 on the yield of tomatoes cv. Roma VF harvested 25 days after application. (Italy 1974)

Treatment	Dose kg a.i./ha	Mature fruit q/ha	Green fruit q/ha	Total q/ha	Relative yield of mature fruit
Untreated	-	663	127	790	100
SAN 7102	2.4	823	77	900	123
SAN 7102	3.2	781	54	835	118
Ethephon	1.44	687	75	762	103

At rates of 2.4 and 3.2 kg a.i./ha, SAN 7102 caused approximately 70 % desiccation of the leaves (Table 3). The fact that it did not give 100 % desiccation 15 days after application, is considered as an advantage. The slow, but incomplete desiccation allowed the plants to retain the still-growing fruit for a certain time, thereby permitting the storage of more nutrients. This was reflected in yields (Table 4) approximately 20 % higher than that obtained with ethephon. This standard preparation was comparable to SAN 7102 in respect of the number of fully matured fruits, but the yield was less.

Under the trial conditions, SAN 7102 showed the following additional advantages compared to the standard:

- SAN 7102 has the secondary effect of accelerating maturation by slowly reducing the live foliage, and thus should be applied to the leaves only. With ethephon, the fruits must be wetted completely and especially in very bushy plants, this can be achieved only with a special application technique.

- The desiccation effect leads to a better drying out of the plants which reduces the incidence of diseases.
- A good and safe effect is obtained at temperatures below 15°C; the standard works only at higher ambient temperatures.
- During harvest, the interfering foliage dries out to a large extent, so that the fruits are more visible and accessible. Thus, the picking rate can be increased from 70 - 80 kg/h per person in an untreated field up to 200 - 300 kg/h in SAN 7102-treated fields.

Routine application. Treatment of the early cv. New Yorker at the end of July gave unsatisfactory results. Even with only 0.8 kg a.i./ha of SAN 7102 there was a full effect on the plants, yet the yield was no higher than that of the untreated plots or those treated with the standard. Treatment of late cultivars at the beginning of September had a good effect, and the positive results of the plot trials (Table 3) were confirmed.

Hemp

The chemical desiccation of hemp has been tested for some time already, using diquat, paraquat, DNOC, dinoseb and other substances, mainly with the aim of changing completely to mechanized harvesting and of improving the fibre quality by reduction of fungal infection. However, this operation has frequently failed because such products damaged the fibres (Gimesi & Bocsa, 1972). In trials carried out by A. Gimesi, metoxuron destroyed the leaves without affecting the quality of the hemp fibres. However, the success of desiccation of hemp with SAN 7102 depends on various factors, which we shall consider below.

Table 5

Desiccation effect of SAN 7102 in hemp plant. (Yugoslavia 1974)

Days after apllic.	Treatments (26.7.74)	Dose kg a.i./ha	Desiccation (%) Plants Total	Plants Male	Plants Female	Part of Plants Top	Part of Plants Middle	Part of Plants Foot
5	SAN 7102	3.2	36	52	22	81	27	4
5	SAN 7102 + white oil	3.2 5 l.	50	61	39	94	39	12
12	SAN 7102	3.2	80	90	66	100	93	48
12	SAN 7102 + white oil	3.2 5 l.	96	100	91	100	100	87

Table 5 shows the speed of action of SAN 7102 on the hemp leaves; 12 days after application of 3·2 kg a.i./ha of SAN 7102, a sufficient desiccation effect was noted. The white oil adjuvant had a positive effect mainly on female plants and on the leaves of the lower regions of the plants.

The time of application is determined on the basis of the technical maturity (TM), that stage of development of which both yield and fibre quality are at their best. The optimum date of application of SAN 7102 is usually fixed by the specialists of the hemp industry. The personal experience and the know-how of the specialists responsible for this is of great importance. Additional criteria are the degree of pollination of the flowers, the cultivar, the growing conditions, and the appearance of the crop. It is now customary to apply SAN 7102 at 7 - 12 days before the technical maturity. Treatments carried out too early show a very good desiccation effect, but the yield tends to be influenced adversely. Treatments, too late, will not desiccate the hemp plants to the desired extent, and then the addition of white oil can improve the results.

For the application of SAN 7102 in dry areas, the following measures have proved to be useful:

- Application in the morning and evening hours, when the higher air humidity facilitates the absorption of the active substance by the plant.
- Addition of white oil to SAN 7102.
- Choice of optimum time of application, i.e., not too late.

CONCLUSIONS

Potatoes

The results of five years' trials with SAN 7102 have demonstrated that it can be applied with ground spray equipment at 1.6 - 2.4 kg a.i. /ha, using a minimum volume of 300 l/ha or, in the case of air spraying, a volume of 30 l/ha.

It will not always be possible to replace conventional desiccants by SAN 7102, mainly because of its insufficient effect on weeds, and because it acts too slowly in Phytophthora-infested potato fields. However, these two aspects have lost much of their importance, because weed control and measures to prevent tuber rotting are now usually part of normal practice in potato production. The advantages of SAN 7102 as a potato desiccant, in comparison with conventional products, can be summarized as follows: toxicological safety, rapid decomposition in the soil, no influence on wildlife, no influence on tuber quality, small risk of damage due to drift, economical in use, non-corrosive, minimum risk to the applicator, and capable of application from aircraft.

Tomatoes

SAN 7102 provides rapid foliage desiccation and improves the uniformity of fruit ripening when applied at 2.4 kg a,i,/ha. Due to its desiccating effect, the rate of fruit picking and consequently the yield of mature fruits, is increased. Moreover, the incidence of diseases is reduced, because the whole plant dries off quite quickly.

Hemp

SAN 7102 is a desiccant for hemp, and has no adverse effect on the fibre quality. The time of treatment must be adapted to the maturity stage of the hemp plant, because SAN 7102, like all other desiccants, adversely affects further growth. Treatment is usually carried out 7 - 12 days before technical maturity. In this crop, the only suitable application method is by aeroplane or by helicopter. At the optimum application time and under favourable humid and warm climatic conditions, the optimum rate is 3.2 kg a.i./ha. If a late date of application is chosen, or in dry weather,addition of 4 l. of white oil improves the result.

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BAS 461 00 H, A HERBICIDE SELECTIVE IN RICE

E. Eysell, B.-H. Menck, J.C. van de Weerd and B. Würzer

BASF Agricultural Research Station, Limburgerhof, F.R. Germany.

Summary A new herbicide, O-(methylaminosulphonyl)-glycolic acid hexamethylene amide, was tested for the control of grasses, sedges and certain broadleaf weeds in rice. BAS 461 00 H (w.p.) and BAS 461 01 H (granule) were the two formulations compared. The field tests considered in this report were located throughout the rice-growing areas in Southern and Western Europe.

The most successful results were obtained when BAS 461 00 H was sprayed post-emergence into drained fields or prior to flooding, and when flooding started again after 24 to 36 h. Another method of application which was equally successful was to put BAS 461 01 H post-emergence into the irrigation water. Among the weed species controlled were Echinochloa crus-galli, Alopecurus geniculatus, Sagittaria trifolia, Eleocharis acicularis, Scirpus juncoides, Cyperus difformis, Alisma spp. and Butomus umbellatus.

Combinations of BAS 461 00 H with several other rice herbicides were tested in the greenhouse. Among those which resulted in enhanced weed control were bentazone, 98 941 (BASF), propanil and butachlor.

INTRODUCTION

Weeds in direct-seeded flooded rice are controlled by herbicides, for example benthiocarb, butachlor, molinate or propanil. These materials are effective against grasses and other important species in rice but there are deficiencies in performance in some rice-growing areas: e.g. poor control of broadleaf weeds by benthiocarb, butachlor and propanil; no effect of propanil on sedges; good control of grasses, broadleaf weeds and sedges by molinate but no acceptable control of Cyperus difformis; phytotoxicity to seeded rice of benthiocarb and butachlor; need for special water management to avoid adverse effects on the growth of rice after application of propanil. The approach of BASF in overcoming some of these disadvantages in weed control was the development of O-(methylaminosulphonyl)-glycolic acid hexamethylene amide, which is selective in rice and effective against grasses, sedges and broadleaf weeds.

In 1976, 90 field trials were conducted by BASF personnel in Italy, Spain and Portugal to confirm the results of greenhouse and small-plot field tests. The complementary, synergistic or antagonistic effects between the new compound and other herbicides were studied in a research programme in progress at the BASF Agricultural Research Station, Limburgerhof. The results to date of the field trials and the greenhouse testing of combinations are presented in this paper.

FIELD TRIALS WITH BAS 461 00 H

Materials and methods

The chemical, physical and toxicological properties of the compound have already been published by Fischer et al. (1975).

In 1976 a total of 90 trials was conducted by researchers and field personnel of BASF in Italy, Spain and Portugal. BAS 461 00 H (65% w.p.) was sprayed with an air-pressurized knapsack sprayer to direct-seeded rice as a pre-seeding soil surface (1 and 3 days prior to seeding), pre-seeding water surface (1 and 3 days prior to seeding), post-seeding pre-emergence soil surface (1 and 3 days after seeding), post-seeding pre-emergence water surface (2 and 3 days after seeding) or post-emergence application (applied at the 1-, 2-, 3- or 4-leaf stages of both rice and *Echinochloa crus-galli*).

The plots were drained 24 h prior to spraying and 24-36 h after application they were flooded. In model trials at the BASF Agricultural Research Station, Utrera, Spain, the water depths were 0, 1, 5 and 10 cm while in field trials the depth of water was the same as in agricultural practice. In some field trials regulation of the water level was achieved by plastic tubes mounted on the dykes, enabling depths of 3, 8 and 12 cm to be obtained. No change of water took place during 6 days after application. BAS 461 01 H (9% granule) was distributed by hand to plots maintained at 0, 3, 5 and 10 cm water levels. Benthiocarb and molinate were applied as reference compounds according to local recommendations.

All experiments were of randomised block design with three or four replications. Weed control and effects of the treatments on the development of rice (cv. Italpatna, Bahia, Podan, Sequial, Moscardo, Girona) were evaluated using the BBA scoring system on a 1-9 scale, where 9 was total crop damage or no weed control. Ratings were taken at various times and 23 out of the 90 trials were harvested.

Results

Weeds controlled

Commercially acceptable control of *Echinochloa crus-galli* was obtained with 3.2 and 3.6 kg/ha a.i. of the granule (9% a.i.) formulation and 2.6 and 2.9 kg/ha a.i. of the w.p. formulation (65% a.i.). *Echinochloa crus-galli* was killed when treated at the 1- up to early 4-leaf stage. Weeds controlled in rice by BAS 461 00 H are listed in Table 1; its effectiveness against other weed species has been described elsewhere (Fischer et al, 1975).

Table 1

Weed control with BAS 461 00 H in paddy rice

Weeds controlled	% weed control			
	BAS 461 00 H (w.p.) (kg/ha a.i.)		BAS 461 01 H (granule) (kg/ha a.i.)	
	2.6	2.9	3.2	3.6
Echinochloa crus-galli	75->95	>95	80->95	>95
Alopecurus geniculatus	70	90-95	70	90-95
Sagittaria trifolia	50	65	50	65
Eleocharis acicularis	90	90	75-95	85-95
Scirpus juncoides	90	>95	95	>95
Cyperus difformis	60-90	95	95	>95
Alisma spp.	90	90	95	95
Butomus umbellatus	90	95	95	>95

Effect of timing of application on weed control and crop safety

It was learned from the experiments that the pre-seeding soil surface (PSA), pre-seeding water surface (PWA), post-seeding pre-emergence soil surface (POPSA), post-seeding pre-emergence water surface (POPWA) applications of the w.p. all controlled Echinochloa crus-galli which germinated within 10 to 25 days after seeding; seedlings germinating later were not controlled (Table 2).

Table 2

Control of Echinochloa crus-galli with BAS 461 00 H applied at different times prior to and after seeding

Chemical	Dose (kg/ha a.i.)	Application time*	% control (days after seeding) 10	25	60	90
BAS 461 00 H (w.p.)	2.9	PSA	50	40	10	0
		PWA	95	50	10	0
		POPSA	80	35	5	0
		POPWA	70	30	5	0
BAS 461 01 H (granule)	3.6	PSA	50	30	0	0
		PWA	90	40	5	0
		POPSA	85	35	0	0
		POPWA	60	30	5	0
Molinate	4.0	as in local practice	90	40	10	0
Benthiocarb	3.0		90	35	5	0

* For explanation see text

Weed control from seeding to heading of rice was observed when BAS 461 00 H and BAS 461 01 H were applied post-emergence at the 1- to the 4-leaf stage of both E. crus-galli and crop. Applications to later developmental stages of E. crus-galli did not control this species.

Crop tolerance

There were no adverse effects on the rice crop when:

1. 2.6 and 2.9 kg/ha a.i. of BAS 461 00 H or 3.2 and 3.6 kg/ha a.i. of BAS 461 01 H were applied as pre-seeding soil surface or post-seeding soil surface treatments, respectively;

2. the treated rice was irrigated at emergence of the crop. All other applications of both formulations after crop emergence with water depths greater than 3 cm were also safe to the crop (Table 3).

Table 3

The growth of direct-seeded rice when treated with BAS 461 00 H and BAS 461 01 H at different times prior to and after seeding with irrigation depth of 5 cm or more within 24-36 h after application

Chemical	Dose (kg/ha a.i.)	Application time*	Effect on rice: Height at flowering (% reduction from control)	Effect on rice: Yield (% of control)
BAS 461 00 H (65% w.p.)	2.9	PSA	10	100
		PWA	15	100
		POPSA	10	106
		POPWA	10	104
BAS 461 01 H (9% granule)	3.6	PSA	15	100
		PWA	15	100
		POPSA	15	108
		POPWA	10	109
Molinate		applied according to local practice	0	108
Benthiocarb			0	104
Control			0	4.2 t/ha

* For explanation see text

In all trials a kind of growth-regulating activity was observed, expressed as darker green leaves and 10 to 15% shorter plants at flowering. No difference in lodging was observed in any of the treated plots as compared with the controls. Yields were taken from 23 out of 90 trials, and the mean yields from treated plots were the same as those of control plots treated with commercial standards (Table 3). Both BAS 461 00 H and BAS 461 01 H at 5, 7 and 9 kg/ha a.i. were safe on rice treated at the 3-leaf stage under flooded conditions and when the w.p. was sprayed on drained rice flooded 24 h after application.

BAS 461 00 H IN HERBICIDE MIXTURES

Objectives

It is a common practice to mix individual biologically active materials in order to broaden the herbicidal activity of the compounds. Mixtures are also checked for synergistic effects and more recently, possible antagonistic effects have been investigated in order to find potential antidotes.

Bearing these objectives in mind, BAS 461 00 H was combined with numerous commercial or experimental rice herbicides. Greenhouse trials were conducted in order to obtain guidelines for future research and some preliminary results are presented.

Materials and methods

Rice (cv. Semilla) and certain weed species occurring in rice fields (Ammannia coccinea, A. auriculata, Cyperus esculentus, E. crus-galli, Sesbania exaltata) were grown in plastic pots containing 300 cm^3 loamy sand with 1.5% organic matter. The seeds were planted shallowly, and were thus readily exposed to at least part of the applied herbicides.

Sprouting tubers of Cyperus esculentus were transplanted. Ammannia coccinea and A. auriculata were propagated by cuttings and used for post-emergence treatments. The plants were quite uniform within an individual trial, but variations between tests in plant size, growth stage or age of the cuttings gave rise to some variation in the results.

The herbicides were applied as single compounds and as tank mixtures. The pre-emergence applications were made immediately after seeding or transplanting. The plants were treated post-emergence when they had reached a height of 5 to 15 cm, bearing 2 to several true leaves depending upon species and method of propagation. The herbicides were suspended, emulsified or dissolved in water and sprayed by means of atomising nozzles within a chamber. Doses are expressed as kg/ha a.i.

The test plants were grown in a greenhouse at a temperature of 25-40 °C. The soil was kept wet after the plants had rooted, but the pots were not flooded. The trials were maintained for approximately 4 weeks. A scale of 0 (no effect) to 100 (no germination or complete shoot kill) was used for evaluation.

Results

Results from individual trials have been collated in tables 4-6. BAS 461 00 H was included in all tests and its performance demonstrated variation between trials attributable to growth stage of the test plants and environmental conditions, even though these were controlled to some extent. The timing of the evaluation also had some impact on the ratings assigned, since some materials like the diphenylethers acted very rapidly compared with BAS 461 00 H. It was also sometimes difficult to find the proper time of application for the mixtures as compared with the recommendations for the individual compounds.

The main points of interest which emerged are:-

1. The mixtures of BAS 461 00 H plus bentazone, or plus 98 941 (BASF, 3-isopropyl-1H-(pyridino-(3,2-e)-2,1,3-thiadiazin-4-one-2,2-dioxide) broadened the spectrum of weeds controlled. The mixtures caused less phytotoxicity to the rice crop than BAS 461 00 H used by itself. Although bentazone and 98 941 (BASF) are chemically related compounds, they affected Cyperus esculentus and Sesbania exaltata in a rather different manner (Table 4).

2. The addition of hormone-type herbicides to BAS 461 00 H also helped to extend the weed species controlled, and the herbicidal effect was also increased, as shown by the results for Echinochloa crus-galli. Simultaneously the crop injury increased (Table 4).

3. Concerning pre-emergence treatments, only the mixture of BAS 461 00 H plus butachlor gave positive results; none of the others showed any promise (Table 5).

4. BAS 461 00 H and propanil complemented each other when applied together post-emergence. The fast-acting performance of propanil was well allied with the residual activity of BAS 461 00 H (Table 5). Other mixtures occasionally provided limited improvements in weed control, but frequently showed inherent phytotoxicity to the rice crop (Table 6).

Table 4
Weed control by mixtures of BAS 461 00 H plus hormone type herbicides bentazone and related compounds

Chemicals	Rate kg/ha a.i.	% injury (0, no effect; 100, shoots or planted killed) Rice	Ammania spp.	Cyperus esculentus	E. crus-galli	Sesbania exaltata
BAS 461 00 H	2.0	10	30	65	30	100
	2.5	10	50	85	30	0
	3.0	10	90	95	40	40
2,4,5-T	0.5	0	50	0	0	30
	0.75	0	65	0	0	30
	1.5	0	95	0	0	90
2,4-D	0.25	0	95	0	10	0
	0.75	0	95	0	10	0
	1.5	10	95	10	20	0
2,4,5-TP	0.25	0	90	0	0	50
(Silvex)	0.75	0	95	0	0	60
	1.5	0	95	0	10	60
BAS 461 00 H	1.5 + 0.5	20	95	70	55	30
+ 2,4,5-T	2.0 + 0.5	20	95	70	60	45
	2.0 + 1.0	15	95	70	60	55
BAS 461 00 H	1.5 + 0.5	20	95	60	55	10
+ 2,4-D	2.0 + 0.5	20	80	60	60	10
	2.0 + 1.0	15	95	60	60	10
BAS 461 00 H	1.5 + 0.5	10	95	60	60	25
+ 2,4,5-TP	2.0 + 0.5	20	95	60	65	40
(Silvex)	2.0 + 1.0	20	95	60	60	70
BAS 461 00 H	0.5	10	60	45	80	0
	1.0	20	70	60	85	10
	2.0	20	90	60	85	50
	3.0	25	90	70	90	50
bentazone	0.5	0	100	0	0	0
Na-salt	1.0	0	100	20	0	10
	2.0	0	100	50	0	20
98 941 (BASF)	0.5	0	100	0	0	65
	1.0	0	100	0	0	65
	2.0	0	100	0	0	70
	3.0	0	100	0	0	100
BAS 461 00 H	0.75 + 0.25	10	95	70	85	20
+ bentazone	1.0 + 0.5	15	100	75	90	60
Na-salt	1.0 + 1.0	10	100	75	75	40
	1.5 + 1.5	15	100	75	80	50
	0.5 + 2.0	0	100	65	70	70
BAS 461 00 H	0.75 + 0.25	0	85	70	75	70
+ 98 941	1.0 + 0.5	0	100	70	75	75
(BASF)	1.0 + 1.0	10	95	65	80	65
	1.5 + 1.5	10	100	70	80	70
	1.5 + 0.5	10	90	70	80	80
	0.5 + 2.0	0	100	70	75	60

Table 5

Weed control by mixtures of BAS 461 00 H and other rice herbicides applied pre- or post-emergence

Chemicals	Rate kg/ha a.i.	% injury (0, no effect; 100, shoots or plants killed) Rice	*Ammannia* spp.	*Cyperus esculentus*	*Echinochloa crus-galli*
BAS 461 00 H	0.5 + 1.0	0 (0,0)*	100 (80,50)	60 (55,0)	60 (55,45)
+ propanil	1.0 + 0.5	5 (0,0)	100 (90,10)	75 (60,0)	75 (75,30)
post-em.	0.75 + 0.75	0	100	65	75
BAS 461 00 H	0.75 + 0.75	0	75	65	80
+ benthiocarb	1.0 + 0.5	15 (0,0)	70 (90,0)	75 (60,0)	60 (75,50)
post-em.	1.0 + 2.0	10 (0,0)	70 (90,40)	75 (60,0)	65 (75,70)
	2.0 + 1.0	10 (10,0)	75 (95,20)	70 (70,0)	85 (75,60)
BAS 461 00 H	0.75 + 0.75	10	95	75	65
+ oxadiazon	1.0 + 0.5	10 (0,15)	90 (90,50)	75 (60,0)	75 (75,20)
BAS 461 00 H	0.75 + 0.75	0	80	85	75
+ butachlor	1.0 + 1.0	15 (0,0)	80 (90,10)	85 (60,0)	90 (75,10)
post-em.	0.75 + 0.25	5	80	75	80
BAS 461 00 H	0.75 + 0.75	5	95	55	60
+ bifenox	0.5 + 1.5	0 (0)	95 (80,95)	60 (55,20)	20 (55,0)
post-em.	1.0 + 1.5	10 (0,10)	95 (90,95)	70 (60,20)	65 (75,0)
	1.5 + 1.0	5	100	90	70
BAS 461 00 H	0.5 + 0.5	10 (0,0)	-	60 (80,0)	80 (50,60)
+ benthiocarb	1.0 + 0.5	20 (0,0)	-	95 (90,0)	80 (60,60)
pre-em.	1.0 + 2.0	20 (0,10)	-	95 (90,0)	80 (60,100)
	2.0 + 1.0	10 (20,0)	-	90 (90,0)	100 (80,80)
BAS 461 00 H	0.5 + 1.0	15 (0,15)	-	60 (80,0)	95 (50,60)
+ oxadiazon	0.75 + 0.25	20	-	60	85
pre-em.	0.75 + 0.75	20	-	90	95
	1.0 + 0.5	20 (0,0)	-	90 (90,0)	95 (60,40)
BAS 461 00 H	0.5 + 1.0	15 (0,10)	-	95 (80,0)	90 (50,60)
+ butachlor	0.75 + 0.25	15	-	95	90
pre-em.	1.0 + 0.5	20 (0,5)	-	100 (50,25)	90 (60,40)
	1.0 + 1.0	20 (0,10)	-	100 (90,0)	95 (60,60)
BAS 461 00 H	0.5 + 1.5	29 (0,10)	-	95 (80,0)	60 (50,0)
+ bifenox	0.75 + 0.75	10	-	95	60
pre-em.	1.0 + 1.0	15 (0,0)	-	95 (90,0)	60 (60,0)
	1.5 + 1.0	20 (5,0)	-	95 (90,0)	65 (60,0)

* ( ) corresponds to % injury of the chemicals applied alone.

Table 6

BAS 461 00 H combined with other rice herbicides applied as post-emergence treatments

Chemicals	Rate kg/ha a.i.	% injury (0, no effect; 100, shoots or plants killed)			
		Rice	Ammannia spp.	Cyperus esculentus	Echinochloa crus-galli
Trial A					
BAS 461 00 H + swep	0.75 + 0.25	0	50	70	65
	1.0 + 1.0	25 (10,0)*	50 (60,0)	70 (65,0)	70 (70,0)
	2.0 + 1.0	40 (25,0)	60 (70,0)	80 (70,0)	70 (75,0)
BAS 461 00 H + drepamon	0.75 + 0.25	25	60	70	75
	2.0 + 1.0	50 (25,0)	60 (70,80)	75 (70,0)	90 (75,45)
BAS 461 00 H + simetryne	0.75 + 0.25	25	50	65	70
	1.0 + 0.5	35 (10,0)	95 (60,60)	70 (65,30)	90 (70,90)
	1.5 + 0.5	45	95	75	90
Trial B					
BAS 461 00 H + nitrofen	0.75 + 0.25	20	55	50	95
	1.0 + 0.5	25 (0,10)	50 (25,60)	60 (50,40)	95 (60,95)
	2.0 + 0.5	20	60	60	95
BAS 461 00 H + MO 500	0.75 + 0.25	20	40	60	90
	1.0 + 0.5	30 (0,20)	30 (25,30)	65 (50,30)	90 (60,90)
	1.5 + 1.0	40 (5,35)	60 (30,50)	70 (50,40)	90 (60,95)

* ( ) corresponds to % injury of the chemicals applied alone.

Reference

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CL 11.344 - A NEW SELECTIVE HERBICIDE FOR USE IN CEREALS AND MAIZE

A.Diskus, R.Schönbeck, E.Auer and E.Kloimstein

Chemie Linz AG, P.O.Box 296, A-4021 Linz, Austria

Summary CL 11.344, a new non-dyeing contact herbicide, selective in cereals and maize, offers promising possibilities for the control of hard-to-kill weeds such as *Galium aparine*, *Galeopsis tetrahit*, *Galeopsis speciosa*, *Lamium purpureum*, *L.amplexicaule*, *Veronica hederifolia*, *V.persica* and *Lapsana communis*. Depending on weed species, dose rates between 1.0 and 1.5 kg a.i./ha are considered to give broad-spectrum weed control in both summer and winter cereals.

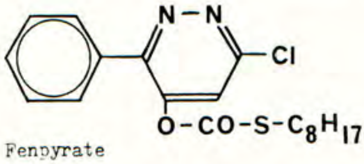
In maize CL 11.344 gives control of grasses such as *Echinochloa crus-galli*, *Digitaria sanguinale*, *D.filiformis* and *Setaria viridis* up to the 3-leaf stage and *Panicum miliaceum* up to the 5-leaf stage. Provided that the product is applied at the correct leaf stage of these grasses 1.0 kg a.i./ha has proved to be sufficient. Being a contact herbicide without any activity via the soil, weed control by CL 11.344 avoids problems of soil moisture, sorption capacity and/or carry over of residues which may occur with pre-emergence herbicides.

INTRODUCTION

A new type of biologically active compound has been found among derivatives of 3-phenyl-pyridazines. As reported by Auer *et al.* (1974) herbicidal activity of 3-phenyl-pyridazines is closely correlated with the presence of a halogen (chlorine, bromine) at position 6 and a hydroxy-, methoxy- or acetoxy- group at position 4. Compounds of this type show herbicidal activity on a range of dicotyledonous weeds with selectivity in cereals and maize. This has been established in greenhouse and field trials.

Variations in position 4 by preparing esters of 3-phenyl-6-chloro-4-hydroxy-pyridazine have resulted in compounds of much higher activity as compared to the free hydroxy compound. The carbonothioic-acid alkyl-esters of 3-phenyl-6-halogeno--4-hydroxy-pyridazine have proved to be especially promising. Though there is a series of highly active compounds available within that range of derivatives, the carbonothioic-acid-O-(6-chloro-3-phenyl-4-pyridazinyl)-S-n-octyl-ester is considered to represent an optimal structure as regards herbicidal potency, crop tolerance and stability. This compound has therefore been selected for further development.

PHYSICAL AND CHEMICAL PROPERTIES

Chemical name	Carbonothioic-acid-O-(6-chloro-3-phenyl--4-pyridazinyl)-S-n-octyl-ester
Chemical structure	
Common name (proposed)	Fenpyrate
Chemie Linz Code	CL 11.344
Molecular weight	378.91
Melting point	27°C
Appearance	Brown oily liquid
Specific gravity	1.555 at 20°C
Flash point (open cup)	200°C
Viscosity (technical material)	336 cst at 20°C 11.1 cst at 80°C
Volatility	Practically non-volatile
Solubility	Water 90 ppm, highly soluble in organic solvents
Formulation	Wettable powder (50 % w/w)

TOXICOLOGY

Broad-scale investigations on the toxicity of CL 11.344 are in progress. Results from acute oral studies indicate that fenpyrate is a compound of low toxicity

LD 50 acute oral in mg/kg bodyweight

	mice		rats	
	male	female	male	female
CL 11.344 (technical)	>10,000	>10,000	1800	2100
CL 11.344 (50 % w.p.)	>10,000	>10,000	8700	8100

METHODS AND MATERIALS

In field trials the size of the replicated plots was 20 m^2 (cereals) or 40 m^2 (maize) and sprays were applied with a pneumatic plot sprayer equipped with a 4-m spray boom. Spraying pressure and velocity were adjusted to give 400 litres of water per hectare. Weed control was evaluated either by visual ratings (cereal trials) or by counting the weeds within square units (maize trials). The results have been transferred to a score from 1 - 9, representing the levels of weed control according to the E.W.R.C.scheme. A 50 % w.p. of CL 11.344 was used in all the experiments.

CEREALS

A series of field trials was conducted with CL 11.344 in both summer and winter cereals during 1974 and 1975 covering the main cereal growing areas of Austria (Table 1)..

Table 1

Survey of field trials programme 1974-75

Cereal crop	Cultivars included	No. of trials
Spring barley	Martha, Union	8
Oats	Petkuser weiß, Flämings Silber, Tiger	9
Winter barley	Dunja	20
Rye	Petkuser kurz, Schlägler alt	9
Winter wheat	Extrem, Stabil, Diplomat, Lentia, Linzerbraun, Jubilar, Danubius, Multiweiß	40

RESULTS

As shown in Table 2, CL 11.344 gives control of a range of hard-to-kill weeds including Galium aparine, Galeopsis spp., Lamium spp. and Veronica spp.

Comparing the results of 1974 and 1975 in Table 2 it is surprising to find that the mean scores differ even where they are based on quite a large number of trials (see Galium aparine, Lamium purpureum, L.amplexicaule, Matricaria recutita, Myosotis arvensis, Veronica spp. and Stellaria media). There is a strong indication the very different weather conditions in 1974 and 1975 are the answer. While in 1974 there was a very dry spring in most parts of Austria, 1975 was an extremely wet spraying season. As we learnt from two trials in 1975, application of CL 11.344 (50 % w.p.) followed by heavy rainfall immediately afterwards resulted in excellent weed control, especially control of Galium aparine. On the other hand, dry and unfavourable growing conditions are known to cause slow herbicidal activity of CL 11.344.

Level of weed control is, apart from other factors, dependent on weed species and growth stage. While Galium aparine, Lamium spp., Galeopsis spp. and Lithospermum arvense can be controlled even at advanced stages (Galium aparine up to 8 leaves, Galeopsis spp. up to 6 leaves, Lamium spp. and Lithospermum arvense up to the bud stage), most other weeds should be sprayed at an earlier stage, preferably at the 4-(true) leaf stage.

Spraying in dry and hot weather may cause some slight burning of the cereal leaves, but this is outgrown by the crop within a week or so.

Table 2

Results from field trials with CL 11.344 in cereals

Weeds	Mean scores for weed control (No. of trials) 1974		1975
kg a.i./ha	1.0	1.5	1.5
Anthemis arvensis	6.5 (1)	2.5 (2)	2.7 (3)
Centaurea cyanus	5.5 (1)	3.0 (4)	2.4 (7)
Chenopodium album	-	-	1.0 (3)
Chenopodium polyspermum	-	-	1.0 (3)
Delphinium consolida	3.2 (2)	1.8 (3)	1.0 (1)
Galeopsis speciosa	-	3.0 (4)	1.0 (1)
Galeopsis tetrahit	-	3.0 (4)	1.4 (8)
Galinsoga parviflora	-	-	1.0 (2)
Galium aparine	4.0 (17)	2.3 (35)	1.6 (35)
Lamium purpureum, L.amplexicaule	2.2 ([illegible])	1.9 (13)	1.0 (5)
Lapsana communis	-	-	1.0 (6)
Legousia speculum-veneris	-	-	2.0 (1)
Lithospermum arvense	-	-	1.5 (3)
Matricaria recutita	6.2 (3)	5.0 (7)	1.7 (9)
Myosotis arvensis	5.5 (1)	5.2 (2)	2.0 (18)
Papaver rhoeas	6.0 (2)	5.2 (2)	7.0 (4)
Polygonum aviculare	-	-	6.0 (3)
Polygonum convolvulus	5.0 (3)	2.4 (7)	2.6 (11)
Raphanus raphanistrum	-	-	5.0 (4)
Sherardia arvensis	-	-	2.0 (2)
Sinapis arvensis	-	-	4.5 (4)
Stellaria media	4.7 (11)	4.1 (8)	1.6 (21)
Veronica spp.	3.3 (11)	3.0 (16)	1.2 (10)
Vicia spp. (annual)	-	2.0 (1)	2.0 (4)
Viola tricolor	6.4 (4)	6.3 (7)	6.2 (3)

MAIZE

In greenhouse screening CL 11.344 has been found to give control of some hard-to-kill grasses such as Echinochloa crus-galli, Digitaria sanguinale, D.filiformis, Setaria viridis and Panicum miliaceum, some of which are resistant to atrazine at economic rates. The compound has to be applied after the emergence of the weeds when the grasses are in their 2-3 leaf stage (Panicum miliaceum up to the 5-leaf stage). From the 4-leaf stage onwards (beginning of tillering) there is an increasing tolerance of Echinochloa crus-galli, Setaria viridis and Digitaria spp. to CL 11.344.

During 1974 and 1975 a programme of 17 field trials has been conducted to establish these observations under various environmental conditions.

As can be seen in Table 3, CL 11.344 offers a way for the control of grassy weeds, some resistant to atrazine, as a post emergence spray. Maize possesses a high degree of tolerance to CL 11.344, so application date is dependent only on the development stage of the grassy weeds.

RESULTS

Table 3

Results from field trials with CL 11.344 for the control of grassy weeds

Herbicide kg a.i./ha	% control of Echinochloa crus-galli	Digitaria spp.	Setaria viridis	Panicum miliaceum
Atrazine 1.0	31 - 100	no control	34 - 66	no control
Atrazine 1.0 + Paraffinic oil 5.0 l/ha	94 - 100	no control	80 - 100	no control
CL 11.344 1.0	75 - 100	80 - 100	92 - 100	82 - 100
CL 11.344 1.5	80 - 100	85 - 100	95 - 100	90 - 100

DISCUSSION

CL 11.344 represents a new type of selective non-dyeing contact herbicides for use in cereals and maize. The range of activity comprises primarily annual dicotyledonous weeds, but CL 11.344 also controls grassy weeds of the Echinochloa, Setaria and Digitaria type. Considering the tolerance of cereals, maize and other grasses to CL 11.344, it is surprising to find that these grassy weeds are sensitive. This is why CL 11.344 offers a new approach for the control of these weeds in maize in a post-emergence spray, thus avoiding the problems of soil moisture and sorption capacity when using pre-emergence herbicides of high persistence.

As a rule, the herbicidal effect needs a longer period to become evident compared to dinitrophenols or hydroxybenzonitriles. Weed control effectiveness is dependent on temperature and humidity of the air as well as on weed species and stage of growth. Rainfall shortly after the application of CL 11.344 does not diminish the herbicidal effect however, but rather assists the process.

Though herbicidal activity is found within a range of carbonothioic-acid alkylesters of 3-phenyl-6-chloro-4-hydroxy-pyridazine, this depends also on the length of the thioalkylgroup. Weed control potency is increased by shortening the alkyl chain, as shown by the results from greenhouse screening. On the other hand, the degree of weed control given by various analogues proves to be equal if the dose rates are calculated in terms of the free hydroxy compound yielded by hydrolysis of the esters. So there is a strong indication that the 3-phenyl-6-chloro-4-hydroxy-pyridazine constitutes the active principle while the ester component seems to serve as an agent for better penetration into the plant tissue.

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WL 43425 - A CHIRAL FORM OF FLAMPROP-ISOPROPYL

R. M. Scott, A. J. Sampson and D. Jordan

Shell Biosciences Laboratory, Shell Research Limited, Sittingbourne, Kent, ME9 8AG.

Summary WL 43425, a chiral form of flamprop-isopropyl has been obtained in sufficient quantity for field testing. Results in barley over three seasons show that its activity on wild-oat (*Avena* spp.) is at least double that of the racemate, and in poor growing conditions has been much higher. Selectivity is good. WL 43425 has also performed well in winter wheat although it is a little less active than racemic flamprop-methyl.

Résumé Un isomère chiral du flamprop-isopropyl, le WL 43425, a été fabriqué dans les quantités suffisantes pour le mise en place des essais de plein champs. Les résultats obtenus sur l'orge pendant trois saisons ont montré une efficacité contre la folle avoine (*Avena* spp.) au moins deux fois plus grande que celle due flamprop-isopropyl. Dans des mauvaises conditions de croissance, son activité est encore mieux. Sa selectivite est bonne. Des bons resultats ont été également obtenus sur blé d'hiver, bien que sur cette culture son efficacité soit légèrement moins bonne que celle d'un mélange racémique du flamprop-methyl.

INTRODUCTION

Wild-oat control by members of the amino-propionates has been well documented over the past decade and the story has been one of continual development and change to meet the increasing threat of wild-oats. Benzoylprop-ethyl, as SUFFIX*, was introduced in 1969 by Chapman *et al* to control wild-oats in wheat and is now well established. The chloro-fluoro amino-propionates were then discovered, and this led to the use of flamprop-isopropyl as BARNON* for wild-oat control in barley (Haddock *et al* 1975; Warley *et al* 1974) and the development of the more active methyl ester, WL 29761 for use in wheat (Haddock *et al* 1974).

WL 43425 represents a further possible exploitation of amino-propionate activity.

CHEMISTRY

In common with many chemicals, the amino-propionates are mixtures of two stereo isomers due to the presence of an asymmetric carbon atom. This is shown below. It has been known for a long time that resolution of racemates into their stereo isomers is possible. However, in most cases these separations are tedious and expensive even on a bench scale. Furthermore, where one isomer proves to be inactive, it is normally

*Shell Registered trade names

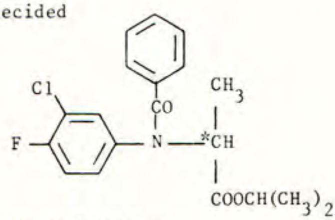
not possible to convert it to the active isomer, so the process is merely an expensive (and in some ways pointless) purification of the active material. This is not so with WL 43425 which is obtained from flamprop-isopropyl via a resolution procedure. Hydrolysis of flamprop-isopropyl to the acid, resolution with an optically active amine followed by the liberation of the laevorotatory acid and its esterification yields WL 43425. Racemisation of the unwanted dextrorotatory material, and recovery of the amine, permit recycling so that conversion of racemic to laevorotatory herbicide is achievable on a pilot plant scale with good efficiency.

Chemical and physical properties

Chemical name: (-)-isopropyl N-benzoyl-N-(3-chloro-4-fluorophenyl)-2-aminopropionate

Common name: Not yet decided

Chemical structure:



* asymmetric carbon atom

Appearance: White-tan crystalline solid

Odour: Mild chemical

Rotation: $[\alpha]_D^{25} = -38.6^o$ (c2, ethanol)

Melting point: 72.5 - 74.5°C

Vapour pressure: Not yet determined

Flash point: Non-flammable

Solubility: Low solubility in aliphatic hydrocarbons. Moderate solubility in aromatic hydrocarbons, chlorinated hydrocarbons, alcohols and ketones. Solubility in ortho-xylene 200-240 g/l at -5°C.

Formulation: 20% emulsifiable concentration

Toxicology: WL 43425 and its e.c. formulation are of a low order of acute toxicity.

Species	Material	Vehicle	Test	LD_{50}
Rat	Technical	50% in DMSO	Oral	>4000 mg/kg
Rat	Formulated	200 g/l e.c.	Oral	>3.7 ml/kg
Rat	Formulated	200 g/l e.c.	Percutaneous	>4.0 ml/kg

MATERIALS AND METHODS

Glasshouse tests with cultivated oats

In glasshouse tests, 7 cm pots containing oats or barley were sprayed when the plants had reached the 1-2 leaf stage. WL 43425 was compared with racemic flamprop-isopropyl and the dextrorotatory isomer, each applied at five doses to each species. Growth assessments were made before the untreated plants had become pot-bound. The dose in kg/ha, of each compound required to give 50% or 90% depression in growth was then calculated (GID_{50} or GID_{90}). Results from one of these tests are given in Table 1.

Table 1

Activity and selectivity of the chiral isomers of flamprop-isopropyl

	GID_{50} Barley (kg a.i./ha)	GID_{90} Oat (kg a.i./ha)	Selectivity GID_{50}/GID_{90}
WL 43425 (Laevorotatory isomer)	2.94	0.44	6.7
Racemate	3.63	0.84	4.3
Dextrorotatory isomer	4.17	10.23	0.4

Field trial details

Most trials were laid down on commercial crops of spring sown barley. In addition a few were on winter barley, and in 1976 on wheat. Field plots ranged from 20 m^2 to 45 m^2 and were usually sprayed across the rows to minimise variability caused by drilling or fertiliser applications. Four replicates per treatment were randomised in blocks with at least one untreated control plot per block.

Applications were made using a hand precision sprayer giving spray volumes 250-500 l/ha at pressures of 2-4 kg/cm^2.

Assessments - barley trials

Wild-oat counts. Wild-oats were assessed in all the trials by means of panicle counts in four 0.5 m x 0.5 m quadrats located in the central two-thirds of each plot.

In most of the trials a more detailed assessment of wild-oats was made by classifying the panicles, as suggested by Holroyd (1972), into one of three size categories:-

i. small panicles with less than 11 spikelets,
ii. medium panicles with 11-30 spikelets, and
iii. large panicles with more than 30 spikelets.

Crop health. Observations on crop health were made one month after treatment and again just before harvest.

Yield. Yield data were obtained where facilities for harvesting were available. The area harvested varied between 12.5 m^2 and 40 m^2 per plot depending on the size of the treated plots and the type of equipment being used.

Product

Throughout these trials a 200 g/l e.c. was used. In 1974 doses of 0.45, 0.6, 0.9 and 1.2 kg a.i./ha were used and in 1975 a lower dose of 0.35 kg a.i./ha was added.

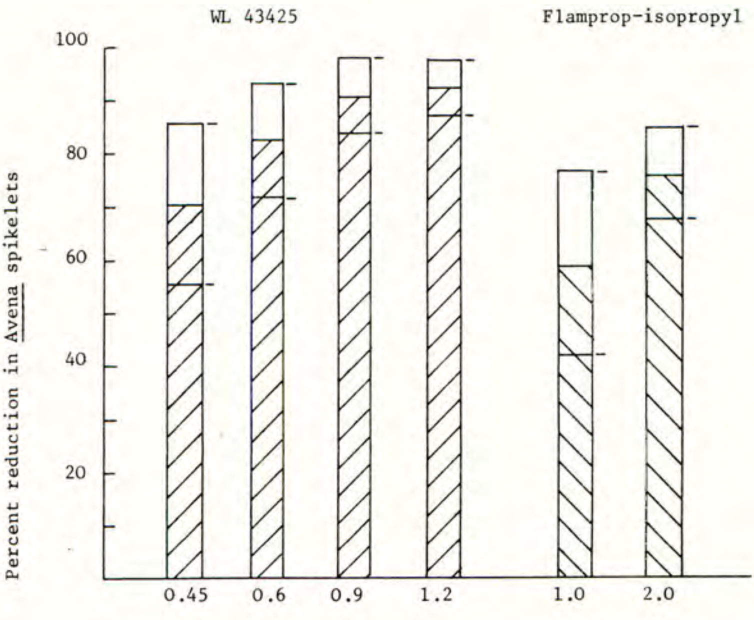
RESULTS

Wild-oat control

Mean results of wild-oat assessments from a total of nine trials carried out in 1974 are shown in Fig. 1.

Figure 1

Wild-oat control with WL 43425 in spring barley under 1974 growing conditions (mean of 9 sites)



Dose in kg a.i./ha

95% confidence limits are indicated

Poor growing conditions were experienced during the season largely due to lack of rain in the late spring and early summer in the S.E. of England and parts of N. France. Crops treated ranged from poor open crops, yielding 2.25 t/ha, to others yielding over 4.0 t/ha. One trial was carried out on the French cultivar Betina which proved to be susceptible to both products. However, in spite of poor competition from the crop the wild-oat control with WL 43425 was good (see Table 2).

Table 2

Wild-oat control achieved with WL 43425 and flamprop-isopropyl in the absence of effective crop competition, 1974

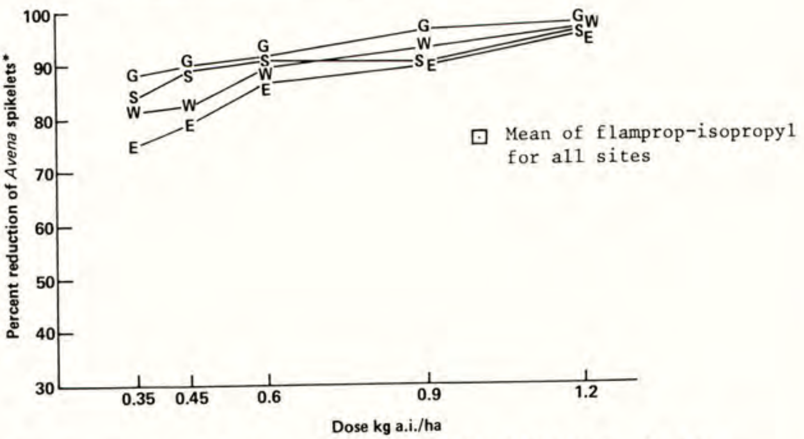
Compound	Dose kg a.i./ha	Detransformed mean values of Avena fatua spikelets expressed as percentage of untreated controls
WL 43425	0.45	2.3
	0.60	1.0
	0.90	0.3
Flamprop-isopropyl	0.8	14.5
	1.0	12.6
	1.6	8.2
Control value per m^2		2705
LSR between means		2.35

In the 1975 season, a more widespread series of trials was completed. Mean results from trials where a full range of five doses of WL 43425 were applied are shown in Fig. 2. The mean control obtained with 1.0 kg a.i./ha of flamprop-isopropyl is also shown.

The data show that good control was achieved in 4 countries with doses of 0.45 kg a.i./ha to 0.6 kg a.i./ha and above. Two trials have been omitted where unacceptable interactions occurred with hormone herbicides applied within 3 and 5 days of the wild-oat herbicides.

Figure 2

Wild-oat control in barley with WL 43425 in 1975

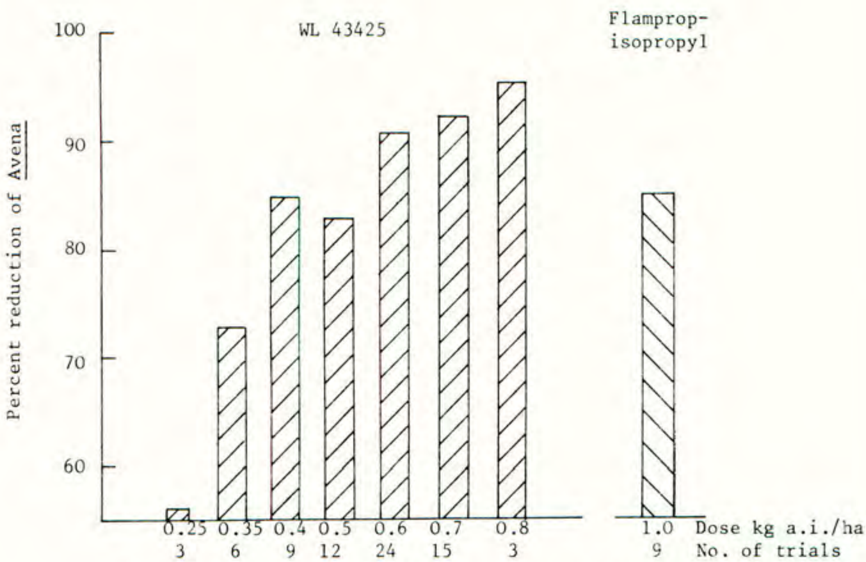


WL 43425 in spring barley: G Germany, 8 sites* (panicles);S=Spain, 3 sites E=England, 6 sites.
WL 43425 in winter barley: W=England and France, 4 sites.

Trials were carried out in more countries in 1976. The wild-oat control obtained in countries from which data is available at the time of writing is shown in Fig. 3. This again demonstrates the good control obtained in the 0.4 kg a.i./ha to 0.8 kg a.i./ha range.

Figure 3

Wild-oat control in barley in 1976



Mean values for data from France, Germany, Greece and Spain

Selectivity

With the exception of cv. Betina, no adverse crop effects were noted in 54 trials with treatments applied to barley crops at various stages between late tillering and the first node stage, i.e. the recommended stage for flamprop-isopropyl. The following varieties have shown tolerance to WL 43425:- Ager; Beka; Ceres; Delisa; Edda; Firlbeck; Gerkra; Golden Promise; Hassan; Hornisse; Hatif de Grignon; Julia; Karina; Maris Otter; Maris Mink; Mazurka; Nordal; Proctor; Pane 2; Pallas; Pomo; Tellus; Union; Villa; Vada; Wisa; Zephyr. When later applications were made, effects on the crops were sometimes observed. The data in Table 3 is from applications made at the second node stage to cv. Proctor which is given as an example to illustrate this trend.

Yield

Mean values for eight trials carried out in the UK during 1975 are given in Table 4. Yield responses have been good, WL 43425 giving yields as good as those from flamprop-isopropyl. The increase in yields varied from zero to 40% over untreated depending on the level of wild-oat infestation and the yield potential of the crop. The infestation varied from 11 to 345 panicles/m^2.

Table 3

Wild-oat control, visible crop effects and yield after application of WL 43425 to barley, cv. Proctor, at the two node stage

Compound	Dose kg a.i./ha	Detransformed mean values as % of untreated wild-oat Spikelets	Crop* score	Yield as % of untreated
WL 43425	0.35	17.2	1.3	127
	0.45	9.3	1.5	138
	0.60	6.7	2.0	126
	0.90	4.2	3.3	131
	1.20	1.8	4.3	138
Flamprop-isopropyl	1.00	9.2	2.8	138
Control value		$4746/m^2$	1.0	3.45 t/ha
LSR (P=0.05)		2.5	-	-
LSD (P=0.05)		-	0.9	19.7

*1 = No effect, 9 = complete kill, 4 = just 'commercially acceptable'

Table 4

Improved yields obtained by treatment of wild-oat infested barley with WL 43425 and flamprop-isopropyl in 1975 (8 trials)

	WL 43425					Flamprop-isopropyl	
Dose kg a.i./ha	0.35	0.45	0.6	0.9	1.2	1.0	LSD (P = 0.05)
Yield as % of untreated	111	115	111	114	111	111	7.3

Mean control value 3.22 t/ha. Mean control infestation 2858 spikelets

Assessments - Wheat trials

It has been shown by Warley and Masheder (1976) that flamprop-methyl is consistently good and compared favourably with benzoylprop-ethyl. In the field programme for 1976, a direct comparison was made between WL 43425 and flamprop-methyl so that the relative merits of these two products in wheat could be determined. Results from these trials are summarised in Table 5.

Table 5

Wild-oat control in wheat with WL 43425 and flamprop-methyl in 1976

Compound	Dose kg a.i./ha	% Reduction in wild-oat Spikelets			Yield as % of untreated crop	
		Spain	France	U.K.	France	U.K.
Flamprop-methyl	0.45	87	86	93	108	110
	0.6	90	89	96	105	109
	0.9	96	97	97	104	106
WL 43425	0.45	75	78	92	108	110
	0.6	92	89	95	105	111
	0.9	94	93	97	107	108
Number of trials		2	4	4	4	4

DISCUSSION

A laboratory scale method for resolution of the chiral form of flamprop-isopropyl has produced sufficient compound to enable field trials to be conducted over 3 years. These have confirmed the early glasshouse indications of high wild-oat activity with adequate selectivity in barley and wheat. In barley trials, wild-oat control with WL 43425 was often more than twice the activity of commercial racemate. The general standard of activity together with good performance under poor conditions relative to the commercial racemate suggest that the dextrorotatory isomer may reduce the activity of the laevorotatory isomer in the mixture. WL 43425 does not differ from flamprop-isopropyl in its interaction with hormone weedkillers. Preliminary trials indicate that activity on wild-oat in wheat crops is good, although not as high as flamprop-methyl. More work is necessary in this crop before it's potential can be assessed. Selectivity in barley, which is generally good for flamprop-isopropyl, is even better for WL 43425 although the French cv. Betina has agained proved to be sensitive.

Acknowledgements

The authors acknowledge the work of Mr. P. A. Harthoorn and their colleagues at Sittingbourne and in the countries mentioned in the text.

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PROPERTIES OF SOME IMIDAZOLIDINONES AND TRIALS WITH BUTHIDAZOLE AND ITS DERIVATIVES

W. Furness and M.H. Halawi
Velsicol Chemical Corporation, Box 110922, Beirut, Lebanon

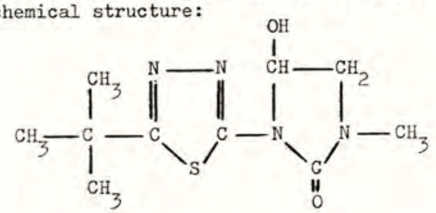
J.N. Barlow
Velsicol Chemical Limited, 66 Tilehurst Road, Reading, Berkshire

Summary Buthidazole is intensely active upon the foliage of many plants and has residual activity in the soil. The primary application of buthidazole is for total weed control on industrial sites. Because of its relatively high aqueous solubility the period of effective residual activity shortens with increasing rainfall, and this may be compensated by increasing the dose. The initial dose varies from about 7 to 13 kg a.i./ha as annual rainfall varies from 50 to 100 cm. One year later a smaller maintenance dose is needed.

In orchards and vineyards possibilities for selective use of buthidazole depend on directed spraying. Orange is tolerant to 1.5 kg a.i./ha, and pome fruits, stone fruits and vines to 1.0 kg a.i./ha. When used in association with the triazines, buthidazole greatly improves the control of Gramineae. Subject to the outcome of current research, other potential selective applications include weed control in dormant perennial field crops and in a small number of annual crops including maize, and possibly sorghum, potato, sunflower and *Vicia faba*.

INTRODUCTION

The new compound has two heterocyclic five-membered rings and may be regarded as a substituted thiadiazole or substituted imidazolidinone; it is identified as 1-(5-tertiary butyl-1,3,4-thiadiazol-2-yl)-3-methyl-5-hydroxy-2-imidazolidinone and is represented by the chemical structure:



Under the protection of USP 3,904,640 the compound was available from Velsicol Chemical Corporation for laboratory and field research in the U.S. as from 1972. Known at first by the code VEL-5026, very small samples were available in Europe and in Cyprus during 1974; afterwards it became more generally available to our collaborators for the 1975 season in Europe and in some eastern Mediterranean countries. ANSI has proposed the common name buthidazole, and Velsicol has registered the trade mark RAVAGE.

Buthidazole is colourless and crystalline, melting at $133^{o} - 134^{o}C$. Its solubility in water is 0.61g/100 ml; it is slightly soluble in aromatic hydrocarbons, more soluble in acetone (13% w/w) and in dimethylformamide (17% w/w). Formulations now available include 50% w.p., 75% w.p., 5% granules, and 10% extruded pellets. For almost all the field trials mentioned in this report buthidazole was formulated as 75% w.p.

Tests of acute toxicity, conducted with buthidazole 80% w.p., have given for acute oral LD 50 in the albino rat 3008 mg/kg for males and 2279 mg/kg for females. Tests of acute dermal and acute inhalation toxicity, eye irritation, skin irritation and corrosive hazard showed negative or only slight effects. Many other aspects of toxicological research are in progress.

Early screening trials were reported by Anderson (1974), Diskus and Auer (1975), Formigoni (1975), van Hoogstraten and Davies (1975), Linden (1975) and by Furness et al. (1974b). Field trials to investigate selective action against a wide range of weeds have been conducted by Formigoni (1975) in apple orchards, maize, onion, peas and vines, and by Linden (1975) in beans (Vicia faba), maize and potato. With reference to total or industrial weed control, field trials were described by Cognet (1975) and by Poulos (1975). The observations already published confirm the two modes of herbicidal activity: direct effects on foliage and residual activity in the soil.

The aqueous solution of buthidazole is basic: when its solution or suspension is applied to a moist soil having appreciable clay or organic content, buthidazole is adsorbed on the uppermost layer. Laboratory experiments indicate that the tenacity of this adsorption is lower than for atrazine (Peeper, 1976), and much lower than has been determined for methazole (Brockman, 1975). Undoubtedly this weaker adsorption is due partly to the aqueous solubility of buthidazole. We have, therefore, become interested in derivatives of lower solubility which still possess the basic structure of buthidazole. Accordingly, we have begun field trials with the esters of buthidazole including the acetate and the octanoic esters, with solubilities in water of respectively 0.28% and 0.004% at $25^{o}C$, and with the benzoate ester. The acetate and benzoate can each be formulated as 50% w.p., whilst the octanoic ester has much greater solubility in hydrocarbons and can be formulated as e.c.

The purpose of this report is to discuss the properties of buthidazole in particular and the prospects for the imidazolidinones in general as herbicides for total and selective weed control. We must do this mainly on the basis of 1974/75 trials by our collaborators.

TOTAL WEED CONTROL ON INDUSTRIAL SITES

Over a period of 3 years Poulos (1975) accumulated data for buthidazole from more than fifty tests at nine non-cropland sites in the U.S. in order to evaluate long-term performance by reference to dose and to annual rainfall. As an initial treatment on industrial sites and public utilities it is generally desirable to apply residual herbicides just after the end of winter dormancy when broadleaf and grass weeds are beginning to emerge, though in practice it often happens that many weeds are 30 cm tall at the first treatment. It is expected that a single treatment should suffice for 12-15 months after which a maintenance dose, smaller than the initial dose, may be required. Under such practical conditions and during three consecutive seasons, Poulos observed the continuous performance of buthidazole at doses in the range 4.5 - 13.5 kg a.i./ha in comparison with bromacil at 6.7 kg a.i./ha. At some sites he was able to determine the effects of buthidazole when applied as a maintenance dose one year after a preliminary bromacil treatment, and so to identify certain weeds which, though resistant to bromacil, were later susceptible to buthidazole.

Table 1

Species of broadleaf weeds and Gramineae susceptible to buthidazole at 6.7 kg a.i./ha where annual rainfall exceeds 50 cm and at 4.5 kg a.i./ha where annual rainfall is less than 50 cm

Susceptible broadleaf species

Abutilon theophrasti	Lapsana communis
*Achillea millefolium	Lathyrus aphaca
Allium vineale	Lepidium spp.
Amaranthus spp.	*Linaria vulgaris
Ambrosia artemisiifolia	Lotus sp.
Ambrosia trifida	Matricaria matricarioides
Anoda cristata	Medicago lupulina
Anthemis cotula	Mirabilis nyctaginea
Apocynum cannabinum	Oxalis europaea
*Artemisia spp.	Physalis heterophylla
Barbarea vulgaris	Plantago lanceolata
Cassia tora	Plantago major
*Centaurea jacea	Polygonum spp.
Cerastium vulgatum	Potentilla spp.
Chenopodium album	Ranunculus philonotis
Chrysanthemum leucanthemum	Raphanus raphanistrum
*Cirsium arvense	*Rubus fruticosus
*Cirsium vulgare	Rumex acetosella
*Convolvulus arvensis	Sesbania exaltata
Cruciferae	Solanum carolinense
Daubentonia texana	Solidago spp.
Datura stramonium	Tanacetum vulgare
Daucus carota	*Taraxacum officinale
Echium vulgare	Tragopogon porrifolius
Euphorbia serrata	Trifolium spp.
Geranium sp.	Verbena hastata
Ipomoea spp.	*Veronica persica
Lactuca serriola	Xanthium spp.

Susceptible Gramineae

Agropyron repens	Echinochloa crus-galli
Agrostis stolonifera	Eleusine indica
Alopecurus myosuroides	Panicum capillare
Arrhenatherum elatius	Panicum texanum
Andropogon virginicus	Paspalum dilatatum
Avena fatua	Phleum pratense
Bromus tectorum	Poa pratensis
*Cynodon dactylon	Poa trivialis
Dactylis glomerata	Setaria spp.
Digitaria sanguinalis	Sorghum halepense
Echinochloa colonum	Spartina pectinata

*For persistent control throughout a 12-month period slightly greater doses than those given at the head of this Table may be required.

In France total weed control trials were started by Cognet (1975) in February and April by application of buthidazole at 2 - 8 kg a.i./ha and by reference to adjacent treatments with bromacil at 4.8 kg a.i./ha. His observations at intervals up to 204 days enable the effects on individual broadleaf weeds and grasses to be separately evaluated.

The reports of Cognet (1975) and of Poulos (1975) are complementary although their working plans were not directly comparable. Both confirm that a single, well-timed application of buthidazole can be effective against broadleaf and grass weeds first by contact activity upon their foliage and later by residual activity in the soil. Poulos presents data which distinguish these two effects; for single doses of buthidazole selected from the range 4.5 - 9.0 kg a.i./ha he scores contact activity according to "top kill" observed during the first 2 months, then he evaluates residual activity according to weed eradication during the next 8 months. On broadleaf and grass weeds already 30 cm tall a dose of 4.5 kg a.i./ha was not generally sufficient, though Poulos concluded that short-term commercial requirements could be satisfied by 6.7 kg a.i./ha; Cognet found that a single dose of buthidazole at 4 or 8 kg a.i./ha was comparable or superior to bromacil at 4.8 kg a.i./ha.

Both Cognet and Poulos observed the effects of later rainfall in the continuing residual ability of buthidazole to control the renewed germination of broadleaf and grass weeds. In approaching his conclusions Poulos was assisted by a classification according to annual rainfall, and so recommended treatments with buthidazole by reference to the scale:

rainfall $<$ 50 cm	4.5 - 9.0 kg a.i./ha
rainfall 50-100 cm	6.7 - 13.5 kg a.i./ha
rainfall $>$ 100 cm	13.5 - 22.0 kg a.i./ha

These doses were recommended for application at the time of emergence of new foliage of the perennial weeds. For the second year of weed control much smaller doses provide adequate maintenance, but precise recommendations must depend on still more detailed experience. Meanwhile Cognet noted that, for long-term control of certain perennial broadleaf weeds, e.g. *Achillea millefolium*, *Centaurea jacea*, *Cirsium arvense*, *Linaria vulgaris*, *Rubus fruticosus* and *Taraxacum officinale*, buthidazole should be applied in the first instance at 10 kg a.i./ha, although the residual activity of much smaller doses in the range 2 - 4 kg a.i./ha consistently provided a high degree of control over the Gramineae.

By combining the conclusions expressed by Cognet (1975) and by Poulos (1975) with observations of some other field trials, those species of broadleaf weeds and grasses that should be susceptible to buthidazole in industrial weed control are tentatively listed in Table 1.

The efficacy of buthidazole is greater wherever the total annual rainfall is rather small and is distributed more uniformly throughout the growing season. Where rainfall is irregular the herbicidal activity of buthidazole may diminish noticeably towards the end of a long dry spell, then during later downpours some appreciable part of the applied buthidazole is desorbed leaving a smaller concentration near the surface and diffuse gradients of concentration in deeper layers. These circumstances may weaken the control of all weeds and especially of deep rooted perennial weeds to which the footnote and many of the asterisks in Table 1 refer. This tendency, which can be traced back to the relatively high aqueous solubility of buthidazole, is partly offset by those less soluble esters of buthidazole which are now becoming available for research.

DIRECTED SPRAYING IN ORCHARDS AND VINEYARDS

Accidental contact of the imidazolidinones with the foliage of citrus, pome fruits, stone fruits or vines causes symptoms of phytotoxicity which may spread to other foliage of the same tree and which may even develop into leaf necrosis. Because accidental contact can be prevented in citrus groves and in orchards of pome fruits and stone fruits, even though the corresponding precautions might not always be practicable in vineyards, this property should not in our opinion obstruct trials of buthidazole and its less soluble derivatives in these tree crops. But it is crucial to find out whether buthidazole directed at an effective herbicidal dose over the soil and weed flora can be adsorbed in the surface layers with a tenacity sufficient to prevent absorption by the roots of the trees or vines; and this test will be the more critical in an irrigated orchard of young trees on light soil.

Because of the high value of established orchards our first tests were conducted on young trees of grapefruit, olive and pecan planted in pots (Furness *et al.*, 1974b). Buthidazole or the corresponding trifluoromethyl analogue (VEL-5028) were applied to the surface of the soil in these pots. Final study of these trials suggested that there need be little risk in conducting tests on mature trees in the consolidated soil of established orchards providing that irrigation is not excessive. Another precaution which is being adopted is to introduce buthidazole as a minor component in a mixture with other residual herbicides of proven safety, then year by year to increase the proportion of buthidazole as experience suggests. These trials with buthidazole are being planned along lines similar to those we have developed in an earlier paper concerning methazole (Furness *et al.*, 1974a).

Field applications have been investigated by our collaborators only since the beginning of the 1975 season; and, as detailed reports from many 1976 trials are not available to us at the time of writing, the following remarks also must be tentative.

Orange

In trials conducted by A.I. Kovàcs (private communication) in the south of Italy buthidazole at 0.5 and 1.5 kg a.i./ha was applied on previously cultivated groves of Washington Navel and Tarocco. Assessments at 2 and 3 months showed the inadequacy of the lower rate. The higher rate in one trial completely suppressed: *Amaranthus retroflexus*, *Lamium* spp., *Polygonum aviculare*, *Portulaca oleracea*, *Solanum nigrum*, *Tribulus terrestris*, *Urtica urens* and Gramineae (mostly *Setaria* spp.) though in the other trial *P.oleracea* and *S.nigrum* were not fully controlled. No symptom of phytotoxicity to orange was detected.

Apple, pear, peach, vines

In screening trials by Formigoni (1975) on previously rotovated sandy loam soil supporting four varieties of 5-year old apple trees and four varieties of 5-year old vines, buthidazole alone at 1.0 kg a.i./ha had been shown inadequate, and it was thought that a somewhat higher rate of buthidazole or a combination of buthidazole with another herbicide would be needed to satisfactorily suppress *Artemisia vulgaris*, *Convolvulus arvensis*, *Cynodon dactylon* and *Sorghum halepense*.

In trials on apple, pear, peach and vines, A.I. Kovàcs (private communication) has tested buthidazole at 1.0 kg a.i./ha in association with atrazine and simazine in a manner corresponding to his earlier association of methazole with atrazine and simazine (Kovàcs *et al.*, 1975). The activity of the mixture of buthidazole with the triazines was slightly weak against the perennials *Cirsium arvense* and *Convolvulus arvensis*, but was excellent against annual broadleaf weeds and grasses.

In the foregoing Italian trials no symptom of phytotoxicity to apple, pear, peach or vines was noted, but Z. Arenstein (private communication) reported chlorosis which he could ascribe only to buthidazole in one trial on apple under irrigation.

PERENNIAL FIELD CROPS

The roots of these crops are relatively shallow compared with those of the trees considered above, so that risks of buthidazole leaching to the root zone under the influence of rainfall or irrigation will be correspondingly greater.

It is reported that sugar cane, pineapple and dormant established lucerne have been successfully treated with buthidazole at rates up to 2 kg a.i./ha. Our tests show that freshly sown lucerne is highly susceptible to pre-emergence applications of buthidazole at rates up to 0.1 kg a.i./ha. On lucerne, artichoke, bush fruits, flower bulbs, hops and rhubarb, during winter dormancy, we propose to test the selectivity of buthidazole at rates close to 1 kg a.i./ha and to extend these trials with equivalent rates of the less soluble esters of buthidazole.

ANNUAL FIELD AND ROW CROPS

When directed spraying is impracticable, post-emergence applications of buthidazole over annual field and row crops are generally exceedingly phytotoxic. The only exceptions so far known may be onion and leek, and then only after the film of natural wax has protected the foliage. Accordingly, trials are to be undertaken in onion in which buthidazole will be applied after the two-leaf stage.

The annual crops which have shown greatest resistance to post-planting pre-emergence application of the imidazolidinones include beans (Vicia faba), maize, potato, sorghum and sunflower. Of these maize showed the greatest resistance. For these crops the problem of working selectively with buthidazole is delicately balanced upon:

(a) properties of the soil, for example, organic and clay content which are essential to the tenacious adsorption of buthidazole in the uppermost layers,

(b) moisture content of the soil which, up to a point, beneficially influences both uniformity of adsorption and gradual desorption of buthidazole for effective weed control, but which when present in excess can leach dangerous quantities of the herbicide towards the shallow root zone of these crops.

For soils of low organic or clay content, for crops that need irrigation, or in countries where rainfall is heavy, its free solubility of 0.61% may be too great to permit reliable practical use of buthidazole as a selective herbicide in many annual field and row crops. For this reason the less soluble esters of buthidazole are becoming available for trials of selectivity.

Trials in 1975 had shown that application post-planting pre-emergence of maize could afford one of the best opportunities for selective use of buthidazole in annual field crops. The 1975 data had permitted no clear conclusion as to the maximum tolerable dose on maize, partly because of variations of soil type, moisture content and rainfall among the numerous trials. Since these variations are unavoidable in practice, the only certain conclusion was that if it should be used at all buthidazole would become one component in a mixture with other less soluble residual herbicides, e.g. atrazine or simazine. The objectives in developing such a mixture would be two-fold: first to improve the selective control of grasses in maize, secondly to permit some diminution of residues of persistent triazines in the soil.

Many of the 1976 trials in maize were in soils drier than usual and the conclusions must again be tentative. The maximum tolerable pre-emergence dose of buthidazole on irrigated maize in medium loam soils seems to be close to 0.35 kg a.i./ha, and this may be used safely in association with atrazine at 1.0 kg a.i./ha.

CONCLUSIONS

For the purpose of total weed control, research with buthidazole has progressed almost to the point which would permit recommendations for large-scale demonstration trials. In different environments such recommendations would be far from uniform; they would vary according to the indigenous weed flora, the expected annual rainfall, and the desired period of weed control. For example, where expected annual rainfall is between 50 and 100 cm and where total control is desired for one year, the initial dose of buthidazole would be within the range 7 - 13 kg a.i./ha. The lower dose should be adequate where annual grasses (not taller than 30 cm) predominate; if there is a high proportion of perennial broadleaf weeds, the higher dose will be advisable. These rates may perhaps be a little greater than are necessary for commercially acceptable programs of total weed control, and further research is desirable to arrive at recommendations more specific and precise, as well as to gain experience of the secondary maintenance dose one year later.

In aquatic weed control the relatively high solubility of buthidazole is a convenience, and experiments are progressing favourably at concentrations in the range 0.1 - 1 ppm.

In orchards and vineyards trials are being conducted cautiously to minimize the apparent risk of phytotoxicity which might prove to be inseparable from the physical properties of so soluble a herbicide. Accordingly we foresee that buthidazole may not prove acceptable for use alone; it might preferably become one component of a proprietary mixture with well-known residual herbicides of lower aqueous solubility where there is need to improve their performance against grass weeds. Current research along these lines is promising, but opportunity to substitute for buthidazole one of its less soluble esters is presently leading to still more interesting experiments in selectivity.

For the present there is less progress in tests of efficacy and selectivity among the perennial and annual field crops except for maize, which shows a reasonable degree of tolerance towards buthidazole and its esters, and which provides incentives to minimise residues of other well-known herbicides that are very persistent in the soil.

Acknowledgements

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BUTAM, N-BENZYL-N-ISOPROPYLTRIMETHYLACETAMIDE, FOR PRE-EMERGENCE WEED CONTROL

R. A. Schwartzbeck

Gulf Oil Chemicals Company, P.O. Box 2900, Merriam, Kansas 66201 U.S.A.

Summary Butam (GCP-5544), N-benzyl-N-isopropyltrimethylacetamide, is a new pre-emergence herbicide discovered and developed by Gulf Oil Chemicals Company. Butam specifically controls the major annual grassy weeds that occur in the United States and in addition *Alopecurus myosuroides* which occurs in Europe. It has been found that the only broadleaved weeds susceptible are *Amaranthus retroflexus* and *Chenopodium album*. Rates necessary for good control in the field are 2.5-4.5 kg a.i./ha. The lower rate can be used on coarse-textured or low organic matter soils and the higher rates for fine-textured or high organic matter soils. Crops on which butam is safe are soybeans, edible types of beans, peanuts, cotton, rapeseed (either spring- or fall-seeded), flax, potatoes and cabbage. Mixtures with metribuzin, linuron or chlorbromuron gave complete weed control of all annual grasses and weeds in soybeans except *Ipomoea* spp. Butam has no post-emergence activity.

Résumé Le butam (GCP-5544), N-benzyl-N-isopropyltrimethylacetamide, est un nouvel herbicide de pré-émergence découvert et développé par Gulf Oil Chemicals Company. Butam contrôle spécifiquement la plupart des graminées annuelles que l'on trouve aux Etats-Unis et en plus l'*Alopecurus myosuroides* que l'on trouve en Europe. Il a été trouvé que seules les mauvaises herbes à larges feuilles sensibles sont *Amaranthus retroflexus* et *Chenopodium album*. Les doses nécessaires pour obtenir une bonne efficacité dans les champs sont de 2,5 à 4,5 kg de matière active à l'hectare. La dose la plus faible peut être utilisée dans les sols à texture grossiere ou dans les sols à teneur faible en matières organiques et la dose la plus forte dans les sols à texture fine ou dans les sols à teneur élevée en matières organiques. Le butam s'est montré sélectif dans les cultures suivantes: soja, les variétés comestibles de haricots, cacahuètes, coton, colza (de printemps ou d'hiver), lin, les pommes de terre et les cultures de choux. Les mélanges avec metribuzin, linuron ou chlorbromuron assurent un désherbage complet de toutes les graminées annuelles et des mauvaises herbes des cultures de soja, excepté *Ipomoea* spp. Le butam n'a pas montré une activité de post-émergence.

Zusammenfassung Butam (GCP-5544), N-benzyl-N-isopropyltrimethyl-acetamide, ist ein neues Unkrautvertilgungsmittel vor dem Aufkommen der Saat, das entdeckt und entwickelt wurde von Gulf Oil Chemicals Company. Butam hat besonders die hauptsächlichen einjährlichen grasartigen Unkräuter unter Kontrolle, die in den U.S. vorkommen und zusätzlich *Alopecurus myosuroides* das man in Europa vorfindet. Man erkannte, dass nur die breitblättrigen Unkräuter anfällig sind wie *Amaranthus retroflexus* und *Chenopodium album*. Die Dosierung, die erforderlich ist für eine gute Kontrolle auf den Feldern beträgt 2.5-4.5 a.i./ha. Die geringere Dosierung kann Anwendung finden für grob strukturierte oder mit wenig organischen Bestandteilen versehene Böden und höhere Dosierungen für feinere oder mit mehr organischen Bestandteilen angereicherten Böden. Gewächse, die durch Butam nicht angegriffen werden sind Sojabohnen, andere Sorten Bohnen für die menschliche Ernährung, Erdnüsse, Baumwolle, Raps (sowohl Sommer- als auch Winterraps) Flachs, Kartoffeln und Kohlsorten. Mischungen mit Metribuzin, Linuron oder Chlorbromuron ergeben eine völlstandige Unkrautkontrolle aller einjährlichen Gräser und Unkräuter, die bei Sojabohnen auftreten, ausgenommen *Ipomoea* spp. Butam entwickelt keine Aktivität nach dem Aufkommen der Saat.

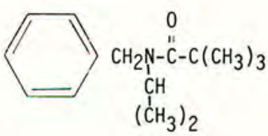
INTRODUCTION

Annual grasses continue to be a weed problem even though effective herbicides have been widely used for several years.

The herbicidal activity of butam was first discovered in 1969 during screening tests for new herbicides. In greenhouse tests at 4.5 kg/ha, most of the grass species and only *Chenopodium album*, *Amaranthus retroflexus* and *Polygonum* spp. of the broadleaves tested were susceptible to butam when applied either pre-emergence or preplant incorporated. The other dicots tested were resistant.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical structure



N-benzyl-N-isopropyltrimethyl-acetamide

Formulation

6 lb a.i./U.S. gal or 190 g a.i./litre emulsifiable concentrate

Solubility of technical material

Water - insoluble	Benzene - very soluble
Alcohol (25°C) - very soluble	Toluene - very soluble

Handling characteristics

There are no known handling difficulties.

Special precautions

Normal precautions for the handling of agricultural chemicals should be observed.

TOXICOLOGY

Active ingredient

Acute oral LD_{50} in albino rats - >6000 mg/kg
Acute oral LD_{50} in guinea pigs - 2025 mg/kg
Acute dermal LD_{50} in albino rabbits - >2000 mg/kg

GREENHOUSE TRIALS

Under greenhouse conditions, tests on a silt loam soil showed that butam controlled most annual grassy weeds at 2.3 kg/ha. At this same rate broadleaf crops were tolerant while the grassy crops were susceptible. Susceptible plants usually emerged but were malformed and died within a week.

Table 1

Response of weed and crop species to pre-emergence application of butam in the greenhouse

Plant species		Response*	
Common name	Scientific name	4.5 kg/ha	2.3 kg/ha
Pigweed	*Amaranthus retroflexus*	9-10	3-6
Lambsquarter	*Chenopodium album*	9-10	3-6
Wild buckwheat	*Polygonum convolvulus*	9-10	1-2
Wild mustard	*Brassica kaber*	1-2	1-2
Cocklebur	*Xanthium pensylvanicum*	0	0
Morningglory	*Ipomoea purpurea*	0	0
Crabgrass	*Digitaria sanguinalis*	9-10	9-10
Downy brome	*Bromus tectorum*	9-10	9-10
Giant foxtail	*Setaria faberii*	9-10	9-10
Barnyardgrass	*Echinochloa crusgalli*	9-10	9-10
Blackgrass	*Alopecurus myosuroides*	9-10	9-10
Green foxtail	*Setaria viridis*	9-10	9-10
Shattercane	*Sorghum bicolor*	9-10	7-8
Wild oats	*Avena fatua*	9-10	9-10
Yellow nutsedge	*Cyperus esculentus*	1-2	0
Cotton	*Gossypium herbaceum*	0	0
Peanuts	*Arachis hypogaea*	0	0
Tomatoes	*Lycopersicum esculentus*	1-2	0
Sugar beets	*Beta vulgaris*	3-6	1-2
Soybeans	*Glycine max*	1-2	0
Alfalfa	*Medicago sativa*	1-2	1-2

*0 = no injury or control; 10 = complete control

Table 1 (Cont'd)

Response of weed and crop species to pre-emergence application of butam in the greenhouse

Plant species		Response*	
Common name	Scientific name	4.5 kg/ha	2.3 kg/ha
Corn	*Zea mays*	9-10	3-6
Sorghum	*Sorghum vulgare*	9-10	7-8
Wheat	*Triticum aestivum*	9-10	9-10
Rice	*Oryza sativa*	9-10	9-10
Rape	*Brassica napobrassica*	0	0

*0 = no injury or control; 10 = complete control

FIELD RESULTS

Butam by itself has given good control of grassy weeds, *Amaranthus retroflexus* and *Chenopodium album* in broadleaf crops such as soybeans, peanuts, cotton and rapeseed. Under the low rainfall conditions in Western Canada *Avena fatua* control was erratic. Mixtures of butam with metribuzin, linuron and chlorbromuron have broadened the spectra of weeds controlled in soybeans.

Table 2

Response of weed species to pre-emergence applications of 4 kg/ha in field trials in the United States and Europe

Susceptible	Tolerant
Avena fatua	*Agropyron repens*
Avena ludoviciana	*Cyperus esculentus*
Alopecurus myosuroides	*Fumaria officinalis*
Amaranthus retroflexus	*Galium aparine*
Chenopodium album	
	Matricaria chamomilla
Digitaria sanguinalis	*Mecurialis annua*
Echinochloa crusgalli	
Eleusine indica	*Polygonum persicaria*
	Polygonum convolvulus
Lolium multiflorum	
Oryza sativa	*Raphanus raphanistrum*
	Senecio vulgaris
Panicum texanum	*Sinapsis arvensis*
Poa annua	
	Veronica officinalis
Setaria faberii	*Viola arvensis*
Setaria viridis	
Setaria glauca	
Setaria italica	
Sorghum halepense	
Stellaria media	

In fine-textured, high organic soils, some grassy weeds may emerge and appear to grow normally; however, a closer observation will reveal that many of the roots are severely shortened and undeveloped. Susceptible broadleaf weeds such as *Amaranthus retroflexus* and *Chenopodium album* emerge and appear to be normal until the first true leaves develop. These are found to be abnormally long and narrow, and the affected plants become stunted and eventually die. Sugar beets are affected in a similar fashion.

In the United States, soybeans, most other types of edible beans, peanuts, cotton, potatoes, cabbage and flax were quite tolerant to butam. In Europe and Canada, rapeseed (either spring- or fall-seeded) was tolerant to butam.

A COMPARISON OF SOME CEREAL HERBICIDES APPLIED BY FAN JETS AND BY A CDA SYSTEM

S.A.Evans and R. Kitchen

ADAS, Lawnswood, Leeds

Summary Seven trials, two on wild oats and five on broad-leaved annual weeds, compared a controlled drop application (CDA) sprayer at 3 different volume rates with a conventional sprayer. The weed control with CDA was, in general, poorer than with the conventional sprayer, but with the exception of barban on wild oats at one site, the results were commercially acceptable. Volumes of 10, 20 and 40 l/ha made only little difference to the results except, again, with barban. The results are sufficient to encourage development of the CDA sprayer.

INTRODUCTION

Work at the Weed Research Organisation and the National Institute of Agricultural Engineering has shown that application of herbicides from a spinning disc, which produces spray drops of a fairly uniform size, was effective and had advantages.

In order to investigate the application system further some prototype spraying machines were made available to ADAS by courtesy of Horstine Farmery Ltd. Trials were carried out across the country and this report gives the results of the seven trials in the Yorkshire and Lancashire region.

METHOD AND MATERIALS

Two commercial herbicides were used on each site, each being applied with either a Cooper Pegler knapsack sprayer with "flat fan" nozzles at a single volume or the CDA sprayer at the same doses: but in three different volumes. The volumes compared were 225 l/ha in the conventional sprayer and 10, 20 and 40 l/ha in the CDA sprayer.

At two sites, wild oats were treated with difenzoquat ("Avenge") and barban ("Carbyne B 25"); and at five sites broad-leaved weeds were treated with a mixture of dicamba, mecoprop and MCPA ("Banlene Plus") and either mecoprop in the case of three winter wheat sites, or a mixture of bromoxynil, ioxynil and dichlorprop ("Oxytoril P") at the two spring barley sites. The doses used were those normally recommended in commerce.

Assessments included scores for the control of broad-leaved weeds or panicle counts of wild oats, post-harvest-weed assessments and crop yields.

Treatments were applied to plots, 30m x 2.13m, arranged in three randomised blocks.

Table 1 shows the site details

TABLE 1

A Site details

	Crop	Variety	Stage of crop (leaves)	Ground cover %	Weeds	Weed density	Date of Spray	Conditions at spraying
1	S.Barley	M.Mink	4½	60	Br.leaved	med/heavy	14/5	V. good
2	"	Aramir	5½	90	"	light	18/5	Ideal
3	W.Wheat	M.Huntsman	5-6	35	"	med/heavy	30/4	Good
4	"	M.Templar	1st node	80	"	heavy	13/5	Fair
5	"	M.Huntsman	5-6	60	"	heavy	29/4	Good
6	S.Barley	M.Mink	5½	95	W.oats	heavy	17/5	V.poor
7	"	Julia	4	85	"	heavy	11/5	Good but poor after spraying

B Weed details

	Polygonum aviculare	Polygonum convolvulus	Stellaria media	Galium aperine	Veronica spp	Mayweed	Fumaria	Others
1	DOM up to 3in.	Sub - DOM 2L	Sub - DOM up to 4in.	OCC up to 3in.	OCC	OCC	-	-
2	Sub - DOM 6 - 8in.	Co - DOM 2-3L	Co - DOM up to 6in.	-	-	-	-	OCC
3	FR 1L	FR 1L	DOM up to 9in.	Sub - DOM up to 9in.	-	FR 2-4in.	-	FR
4	-	-	Co - DOM up to 9in.	OCC up to 9in.	Co - DOM up to 6in.	-	FR up to 9in.	FR
5	-	-	Co - DOM up to 9in.	CO - DOM up to 9in.	Co - DOM up to 6in.	-	FR up to 9in.	-
6	Wild oats on 3½ - 5½ leaf stage							
7	Wild oats on 3 - leaf stage							

TABLE 2

BROAD-LEAVED WEED CONTROL BASED ON A SCORE 0-9

(0 = NO CONTROL, 9 = COMPLETE CONTROL)

SPRING BARLEY

Product and dose	Spray vol (l/ha)	Site 1	Site 2	Mean
Banlene Plus 4.9 l/ha	225	8.9	9.0	9.0
" "	10	7.4	8.4	7.9
" "	20	7.7	8.6	8.2
" "	40	8.0	8.4	8.2
Oxytril P 1.0 l/ha	225	9.0	8.7	8.9
" "	10	7.6	8.0	7.8
" "	20	6.1	8.3	7.2
" "	40	6.3	8.4	7.4
Control (unsprayed)		0	0	0

WINTER WHEAT

Product and dose	Spray vol (l/ha)	Site 3	Site 4	Mean
Banlene Plus 4.9 l/ha	225	6.3	8.5	7.4
" "	10	2.4	5.4	3.9
" "	20	5.2	4.8	5.0
" "	40	5.2	4.2	4.7
Mecoprop (64%) 4.2 l/ha	225	6.0	7.8	6.9
" "	10	4.3	4.6	4.5
" "	20	4.9	5.8	5.4
" "	40	4.4	5.6	5.0
Control (unsprayed)		0	0	0

NB. Scores were not taken at Site 5 although visually results were similar to sites 3 and 4 in that CDA, at all levels on both herbicides, was slightly less effective than the conventional sprayer, although still commercially acceptable.

TABLE 3

WILD OAT CONTROL, PANICLES/m^2 (TRANSFORMED FIGURES)

Product and dose		Spray vol (l/ha)	Site 6	Site 7	Mean
Avenge 620(+Agral)	1.6kg/ha	225	1.8	2.1	2.0
" "	"	10	2.3	2.7	2.5
" "	"	20	2.5	2.0	2.3
" "	"	40	2.9	1.8	2.9
Carbyne B25	1.1 l/ha	225	3.8	2.3	3.1
"	"	10	3.0	5.2	4.1
"	"	20	5.0	4.3	4.7
"	"	40	4.6	3.2	3.9
Control (unsprayed)			5.4	9.6	7.5
				(± 0.54)	(± 0.89)

An assessment was made of seeds per panicle on those plots where wild oats remained and these show a trend for spray treatments to reduce the size of head compared with control with a slight trend for the conventional sprayer to reduce head size more than CDA treatments amongst which there were no differences between volume rates.

TABLE 4

BROAD-LEAVED WEEDS IN THE STUBBLE BASED ON A SCORE

0-9 (0 = NO CONTROL, 9 = COMPLETE CONTROL)

SPRING BARLEY

Product and dose	Spray vol (l/ha)	Site 1	Site 2	Mean
Banlene Plus 4.9 l/ha	225	9.0	9.0	9.0
" "	10	7.3	8.3	7.8
" "	20	7.8	8.7	8.3
" "	40	8.3	9.0	8.7
Oxytril P 1.0 l/ha	225	8.8	8.3	8.6
" "	10	5.5	8.7	7.1
" "	20	5.7	8.0	6.9
" "	40	7.3	8.7	8.0
Control (unsprayed)		0	0	0

WINTER WHEAT

Product and dose	Spray vol (l/ha)	Site 3	Site 4	Mean
Banlene Plus 4.9 l/ha	225	6.0	7.0	6.5
" "	10	4.3	5.3	4.8
" "	20	6.3	7.0	6.7
" "	40	6.3	6.0	6.2
Mecoprop (64%)4.2 l/ha	225	7.0	7.0	7.0
" "	10	5.7	6.0	5.9
" "	20	7.0	7.0	7.0
" "	40	8.0	7.0	7.5
Control (unsprayed)		0	0	0

TABLE 5

YIELD OF GRAIN (t/ha AT 85% DM)

SPRING BARLEY

Product and dose	Spray vol (l/ha)	Site 1	Site 2	Mean
Banlene Plus 4.9 l/ha	225	3.3	5.2	4.2
" "	10	3.4	5.2	4.3
" "	20	3.4	4.9	4.2
" "	40	3.3	5.1	4.2
Oxytril P 1.0 l/ha	225	3.4	4.9	4.2
" "	10	3.6	5.2	4.4
" "	20	3.6	4.8	4.2
" "	40	3.6	5.1	4.3
Control (unsprayed)		2.8	5.1	3.9
			(± 0.16)	(± 0.11)

WINTER WHEAT

Product and dose	Spray vol (l/ha)	Site 3	Site 4	Site 5	Mean
Banlene Plus 4.9 l/ha	225	3.7	5.9	6.0	5.2
" "	10	3.8	6.0	5.8	5.2
" "	20	3.8	5.9	5.9	5.2
" "	40	4.1	6.0	5.8	5.3
Mecoprop (64%)4.2 l/ha	225	4.1	6.1	6.0	5.4
" "	10	4.1	6.2	6.0	5.4
" "	20	3.9	6.0	6.0	5.3
" "	40	3.8	6.1	5.8	5.2
Control (unsprayed)		3.7	5.9	5.4	5.0
		(±0.30)	(±0.12)	(±0.12)	

RESULTS

The scores for the control of broad-leaved weeds were made some 5 to 6 weeks after spraying (Table 2.) and after harvest (Table 4.)

Wild oat panicles were counted in five quadrats (each 0.56 m^2) per plot.

Table 3 shows the results as wild oat panicles per m^2 after transformation $\sqrt{x+1}$)

Yields of crops are shown in Table 5.

DISCUSSION

The conventional spraying of broad-leaved weeds has generally produced a better weed control than the best CDA treatment particularly in winter wheat. Nevertheless the weed control achieved by CDA has, practically, been as commercially acceptable as conventional spraying and yields of crops have been comparable. Volume rate has had little effect.

The CDA application of wild oat herbicides again did not produce quite such good results as the conventional sprayer although the results with difenzoquat would generally have been commercially acceptable. The results with barban were poorer and there was a distinct trend for decreasing volume rate to give less control. Crop yields were not taken.

The results of these trials suggest that with at least some herbicides CDA spraying can produce acceptable weed control. The effect of different volume rates was only really apparent with barban which in any case did not seem nearly so good as through a conventional sprayer. The CDA applicator used was a proto-type and the experimental team had to gain experience in its use. It seems reasonable to suppose that development and experience can improve the effectiveness of CDA spraying. Even with the degree of weed control reported here, however, the sprayer appears acceptable and because of its potential advantages (speed, safety etc.) its development should be encouraged.

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