POSTER SESSION 3D
WEED CONTROL IN CEREALS

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Poster Papers 3D-1 to 3D-7

A comparison of post emergence control of *Galium aparine* in winter cereals using florasulam, amidosulfuron and fluroxypyr methyl-heptyl ester

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ABSTRACT

Florasulam is a new acetolactate synthase inhibitor (ALS) with activity against *Galium aparine* and a number of other key dicotyledonous weeds in cereals. Through analysis of efficacy trials data over a 3 year period from sites in the United Kingdom, France, Germany and Belgium, it was shown that florasulam gave equal or superior control of *G. aparine* compared to amidosulfuron. When applied to larger plants later in the season the best treatment was fluroxypyr.

Analysis of dose response data and comparisons to commercially available treatments were carried out to define the correct dose rate for a commercial recommendation.

INTRODUCTION

Florasulam is a new herbicide from the triazolopyrimidine group of herbicides (Lepiece *et al* 1998). It is an inhibitor of acetolactate synthase (ALS) for use in cereals for the control of *Galium aparine* and a number of other key dicotyledonous weeds. During the development process data were generated to characterise the efficacy of this material and to compare it to currently available products that are recommended for the control of *G. aparine*.

Galium aparine is an annual dicotyledonous plant of the family Rubiaceae. It is an important weed in winter cereals throughout the main cereal growing regions of Western Europe. For example Chancellor and Froud-Williams (1984) reported that *G. aparine* was the most frequently occurring broad leaved weed in winter cereals in Southern England. If not effectively controlled it causes significant yield loss, for example Peters (1984) showed that a population of 25 *G. aparine* plants per m^2 caused 30% loss of yield in winter wheat. In addition to yield loss Elliot (1980) reported that failure to control *G. aparine* in winter wheat could cause a reduction in the ratio of grain to matter other than grain from 0.82 to 0.42 thus considerably increasing the cost of harvesting the grain.

This paper summarises data generated from field trials carried out in France, Germany, Belgium and the United Kingdom from 1994 to 1996 where the new broadleaf herbicide florasulam (as 'Boxer' / 'Primus') was compared in terms of post emergence control of *G. aparine* in winter cereals with its main competitors amidosulfuron (as 'Eagle' / 'Gratil / Hoestar') and fluroxypyr (as 'Starane 2 '/ 'Starane 180').

The studies were designed to produce a direct comparison of the efficacy of the substances at different weed sizes and also to determine the dose rate of florasulam capable of producing equivalent efficacy to the label dose rate of amidosulfuron.

MATERIALS AND METHODS

Two trial designs were used, the multi-timing trials were split plot experiments with the main plot designated as the timing and the sub plots dose rates of the test compounds, dose response trials were randomised complete blocks. All trials had 3 replicates. Assessments included weed size at application measured as the length of the main stem, weed and crop growth stage at application using the BBCH scale, weed density at application using random quadrat counts and % control of *G. aparine* estimated visually compared with the untreated. The following tables summarise the site details and application data for all the trials included in this study.

1994 Trials

Trials Number	No. of Applications	Application Timings (Date)	Frequency of application (Days)	Size of *G. aparine* (mm)	Plants/M²	BBCH Crop
UK1	5	21/2-15/5	21	3-42	83	21-32
UK2	5	21/2-15/5	20-21	14-50	39	30-39
UK3	5	20/2-15/5	20-22	5-50	105-140*	23-32
UK4	5	23/2-18/5	18-23	3-35	262	23-37
UK5	5	21/2-5/5	11-23	3-38	18	22-36
FR1	5	23/2-21/4	14-15	9-25	23	22-32
FR2	5	22/2-30/3	13-22	7-50	23	24-32
FR3	5	7/2-28/4	15-25	6-60	48-53	23-33
FR4	5	14/2-28/4	3-22	8-70	118	22-32
GE1	4	22/3-3/5	11-14	4-22	143	25-32
GE2	3	6/4-19/5	15	8-45	35	25-39
GE3	4	3/4-4/4	9-12	5-27	72-75	29-31
GE4	4	24/3-4/5	13-15	5-22	23	22-31

*a range in plant population assessment indicates that *G. aparine* emerged after application.

1995 trials

Trials Number	No. of Applications	Application Timings (Date)	Frequency of application (Days)	Size of *G. aparine* (mm)	Plants/M²	BBCH Crop
BE1	5	1/3-1/5	10-21	5-27	49-68	23-32
BE2	5	10/3-25/5	10-12	3-17	34-59	24-31
UK15	1	2/3		5	10	23
UK16	1	21/3		8	12-18	25
UK17	1	13/4		20	12	33
FR11	1	13/4		5	8-56	25
FR12	1	9/3		15	48	30
FR13	1	11/4		27	10-58	34

1996 trials

Trials Number	No. of Applications	Application Timings (Date)	Frequency of application (Days)	Size of *G. aparine* (mm)	Plants/M²	BBCH Crop
UK6	5	27/2-30/5	17-34	10-55	34-66	21-39
UK7	5	27/2-14/5	13-22	8-45	172-177	23-32
UK8	5	26/2-14/5	14-22	2-20	34-39	22-31
UK9	5	13/2-13/5	17-22	3-25	29-46	23-31
UK10	5	27/2-13/5	13-21	1-8	10-28	12-32
GE5	3	9/4-7/5	14	5-20	44-45	23-31
GE6	3	9/4-7/5	14	7-27	17-18	23-31
GE7	3	16/4-21/5	14-21	5-15	50	29-32

ANALYSIS

In all cases, the final level of control achieved was used in the analysis. For the comparison of efficacy at various weed sizes descriptive analysis were carried out with mean % control and standard deviation reported. For comparison of dose responses data were subjected to a dose response analysis (Log-probit model), this allowed a calculation of the dose rate required for each compound to give a specific level of weed control. When the data showed no dose response or where the range of % control achieved did not give a good fit to the model (as measured by residuals R2) the value was estimated from the raw data.

Analysis was carried out using STATGRAPHICS PLUS version 6.

RESULTS

Results are presented from 116 applications on 29 sites.

Table 1 Efficacy as mean % control related to size of *G. aparine* at application

		Weed Size (StDev)					
Treatment	Dose Rate Gai/ha	<5cm n*=23	5-10cm n=29	10-20cm n=25	-30cm n=1	30-40cm n=9	-70cm n=1
Florasulam	5.0	97(4)	96(6)	96(6)	91(12)	85(15)	80(18)
Florasulam	7.5	98(3)	97(5)	97(5)	93(10)	93(9)	86(16)
Amidosulfuron	30	96(6)	93(10)	96(7)	94(7)	93(7)	84(17)
Fluroxypyr	200	91(15)	92(14)	99(2)	99(1)	98(5)	98(5)

*n=number of sites providing data for this weed size.

Table 2 Calculated dose rates of florasulam to give equivalent control to 30 and 15gai/ha of amidosulfuron (full and half label dose rate) calculated from dose response studies 1994-1996

	Size of *G.aparine* at application <20cm (n=16)	>20cm (n-14)
Rate of florasulam = to 30 gai/ha amidosulfuron	5gai/ha	6.6gai/ha
Rate of florasulam = to 15 gai/ha amidosulfuron	3gai/ha	4.3gai/ha

CONCLUSIONS

Results show that high levels of control can be achieved by florasulam. Applications made to *G. aparine* plants less than 20cm tall tend to be more effective than those made after. This also relates to an application timing in the early part of the spring. In the vast majority of cases the activity of florasulam is always equal to or better than the comparison treatment amidosulfuron. Levels of control recorded from applications made in the early spring were sometimes reduced by plants that germinated after application. Although levels of control made later in the season to larger plants were slightly less effective, they were still equal to the equivalent standard treatment of amidosulfuron. Under later season conditions and on larger *G.aparine* the most effective treatment was fluroxypyr.

Comparisons of the dose rate of florasulam required to give similar activity to the currently marketed standard amidosulfuron, show that when applied to *G. aparine* less than 20cm tall 5gai/ha was required, on larger plants 6.6gai/ha was required. These results will be reflected in the recommendations made for the commercial product.

This study shows how large amounts of data were utilised to produce a robust comparison with standard treatments and to define the dose rate for commercial use of a new active ingredient.

REFERENCES

Chancellor R J; Froud; Williams R J (1984) A second survey of cereal weeds in central Southern England. Weed Research, UK, (1984) Vol. 24, No. 1, pp. 29-36

Peters N.C.B (1984) Competition between *Galium aparine* and Cereals. Abstracts of AAB meeting 1994 page 3-4

Elliot J.G (1980) The economic significance of weeds in the harvesting of grain. Procedings Brighton Crop Protection conference – Weeds 1980 pp 787 - 797

Lepiece D; Thompson A; McReath A (1998) Florasulam (Primus) a new selective triazolopyrimidine sulfonanilide to control broad-leaved weeds in cereals. Belgian results from 1994-1997. *Proceedings of the 50th International Symposium on Crop Protection, Gent*, 735-749

Field evaluation of MKH-6561 for *Phalaris minor* control in durum wheat

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ABSTRACT

Six field experiments have been conducted on durum wheat from 1996 through 1999 in the Imperial Valley of southeastern California, USA to evaluate *Phalaris minor* control with MKH-6561, a new herbicide being developed by Bayer Co. *Phalaris minor* is an important weedy annual grass in warm temperate and subtropical cereal growing regions, such as the southwestern USA, northern Mexico, the Mediterranean, and south Asia. This grass is not adequately controlled by currently available herbicides. In addition, durum wheat is usually more easily injured by grass control herbicides that are safe to other types of wheat, which further reduces the herbicide options for *Phalaris minor* control. In these experiments, comparisons of MKH-6561 were made to five herbicides; diclofop-methyl, tralkoxydim, clodinafop, fenoxaprop, and flucarbazone-sodium. Over the six trials, MKH-6561 has provided the most consistent control of *Phalaris minor* among the herbicides tested. Crop injury has been observed in some cases, but appears to be related to stage of growth of the crop and herbicide dosage at time of application. Yield data from these trials indicates that MKH-6561, at most of the tested rates and timing of application, is safe to the crop.

INTRODUCTION

Phalaris minor is an annual grass infesting wheat grown in warm temperate areas of the world, including the southwestern USA, northern Mexico, the Mediterranean, and south Asia (Bell, 1992; Bhatia, *et al*, 1981; Damanakis, 1983; Esqueda, 1978, Tickes and Heathman, 1991). This weed has been shown to reduce wheat yield from 36 to 60%, depending upon density (Afentouli and Eleftherohorinos, 1996; Afentouli and Eleftherohorinos, 1999; Cudney and Hill, 1979). Control of *Phalaris minor* with herbicides currently available for use in wheat has been unsatisfactory (Bell, 1992; Tickes and Heathman, 1991). An additional problem in the southwestern US is that the type of wheat grown on the majority of farms is durum (*Triticum durum*), which is more prone to injury by some of the grass control herbicides.

The objective of these experiments was to evaluate the ability of a new herbicide being developed by Bayer Co., MKH-6561, to control *Phalaris minor*. Other grass control herbicides included for comparison were diclofop-methyl, clodinafop, tralkoxydim, fenoxaprop, and flucarbazone-sodium.

MATERIALS AND METHODS

Six field experiments were conducted starting in the fall of 1995 and completed in the summer of 1999, the first on the University of California Desert Research and Extension Center near Holtville, California and the others on cooperative farmer's fields in the Imperial Valley of southeastern California. In all cases, farming was managed by the farmer and the experiments imposed on a small section of the field. Crop seeding rate was in the typical range of 110 to 170 kg/ha. Fertilizer amounts varied by farmer practice, but about 200 kg/ha of N is commonly used. Other fertilizers are used only when indicated by soil test. Wheat is sown on level soil between raised borders and irrigated for germination and throughout the season because rainfall in the area is normally less than 75 mm per year. Table 1 below shows relevant information on each experimental site. All trials utilized a randomized complete block design with four replications. Herbicide application was made with a CO_2 pressured sprayer using flat fan nozzles and operated in the range of 140 to 200 kPa pressure to deliver from 200 to 280 l/ha diluent volume. All MKH-6561 applications included nonionic surfactant at 0.25% V in the spray mix. Other herbicides utilized surfactants as recommended on product literature or by manufacturer representatives. Stage of growth of the crop at time of application was recorded according to the Haun Scale (Haun, 1973). *Phalaris minor* stage of growth at the first (or only) application was at one to two leaves. Later applications were made after the weed had begun tillering. In two of the experiments, *Phalaris minor* was not present (Vail 507 in 1997 and Spruce 24 in 1998), herbicide applications were made at similar crop stage of growth as in the other experiment conducted in the same year. These two experiments were included to evaluate crop injury potential of MKH-6561 and the other herbicides.

Visual evaluations of weed control and phytotoxicity were made on a 0 to 10 scale and converted by arcsin transformation to percentage for presentation in Tables. Crop yield was estimated from a one square meter section hand harvested from each plot. Analysis of variance was used to compare yield data from treatments and means were separated using Fisher's Protected LSD (0.05).

Table 1. Field trial locations and agronomic information.

Field[a]	Soil type	Durum Wheat Variety	Planting date	Treatment dates	Harvest date
UC-DREC	Silty clay loam	Yavaros	7 Dec. 1995	11 Jan. 1996	5 June 1996
Woodbine 26	Silty clay loam	Kofa	12 Dec. 1996	9 Jan. 1997	13 May 1997
Vail 507	Silty clay	Kronos	14 Feb. 1997	7 Mar. 1997	23 May 1997
Woodbine 54	Silty clay	Kronos	15 Dec. 1997	21 Jan. 1998 13 Feb. 1998	6 June 1998
Spruce 24	Silty clay	Kronos	7 Feb. 1998	2 Mar. 1998 23 Mar. 1998	11 June 1998
L24	Silty clay loam	Kronos	25 Nov., 1998	29 Jan. 1999 23 Feb. 1999	28 May 1999

[a]Field is an irrigation canal designation, except UC-DREC is the University of California Desert Research and Extension Center.

RESULTS AND DISCUSSION

The first experiment, in 1996 (Table 2), demonstrated that MKH-6561 would control *Phalaris minor*. Trials in subsequent years have generally borne out that observation, but there has been some variation (Tables 3-5). In 1997 and 1998 control was nearly complete at all rates of application. By contrast, weed control by MKH-6561 in 1999 was marginal, ranging from 24% to 79% at the last evaluation. Applications of MKH-6561 at 30 g/ha were sufficient in 1997 and 1998, but not as successful in 1996 or in 1999. The higher rate of 45 g/ha controlled *Phalaris minor* better than the 30 g/ha rate in 1996, but this was not the case in 1999. The variability and lower levels of weed control in 1999 compared to other trials may have been caused by high soil salinity in the field (measured at an electrical conductivity level of 14 mmhos/cm; 3 mmhos/cm or below is considered desirable for wheat). MKH-6561 efficacy is apparently affected by soil salinity (Hans Santel, Bayer Corporation, personal communication).

Table 2. Weed control, crop injury, and wheat yield in 1996 at UC-DREC

Treatments (g/ha)[1]	% *Phalaris minor* control		% Phytotoxicity	Yield t/ha
	5 Feb.	17 Apr.	5 Feb.	5 June
MKH-6561 30	66	66	<1	5.4
MKH-6561 45	83	93	2	6.1
Flucarbazone 30	89	42	2	5.3
Flucarbazone 45	55	42	1	5.3
Diclofop 1260	70	85	<1	5.7
Untreated control	0	0	0	5.6

[1] Wheat stage of growth at time of treatment was Haun 2, *Phalaris minor* was 1 to 2 leaf.

Yield effects of MKH-6561 on wheat have been good. In two of the experiments, three of the MKH-6561 treatments in 1999 and the 45 g/ha dosage at the early timing on Woodbine 54 in 1998, there was a significant increase ($P = 0.05$) in yield compared to the untreated control. Yield reductions significantly different ($P = 0.05$) compared to the untreated control occurred in the 1998 Spruce 24 experiment with the higher rate of MKH-6561.

Crop injury was evident from MKH-6561 treatments in most cases. Phytotoxic symptoms are stunting and a general chlorosis. The crop generally seems to recover by the end of the season. Herbicide application at higher dosages and at later stages of growth tended to cause more crop injury, although these results are not entirely consistent across all experiments. High soil salinity may have been a factor in the crop phytotoxicity observed in the field experiments at Vail 507 in 1997 and Spruce 24 in 1998, fields in this area of the Imperial Valley are known to have elevated salinity, but soil analysis was not conducted to verify this possibility.

The other herbicides tested did not do as well as MKH-6561 for control of *Phalaris minor* with some exceptions, such as diclofop-methyl in 1996, flucarbazone in 1997, and tralkoxydim and fenoxaprop in 1999 at the later application timing. Overall, MKH-6561 shows promise for control of *Phalaris minor*, an important weed of wheat grown in warm temperate areas of the world.

Table 3. Weed control, crop injury, and wheat yield in 1997 field experiments in the Imperial Valley, California, USA

Treatments (g/ha)[1]	% *Phalaris minor* control		% Phytotoxicity		Yield t/ha
Woodbine 36	23 Jan.	8 May	23 Jan.	3 Mar.	13 May
MKH-6561 30	96	99	2	4	5.9
MKH-6561 45	95	100	10	8	6.4
MKH-6561 60	96	99	12	10	6.1
Flucarbazone 30	96	38	15	4	6.2
Flucarbazone 45	98	92	21	10	6.0
Flucarbazone 60	92	61	17	10	6.4
MKH-6561 30 + Flucarbazone 30	96	99	12	10	6.1
Untreated control	0	0	0	0	5.7
Vail 507			26 Mar.	8 May	23 May
MKH-6561 30			2	1	5.8
MKH-6561 45			5	21	5.8
MKH-6561 60			24	21	4.6
Flucarbazone 30			38	27	5.4
Flucarbazone 45			42	38	4.4
Flucarbazone 60			58	50	4.0
Clodinafop 70			<1	2	6.2
Tralkoxydim 200			<1	<1	6.0
Untreated control			0	0	5.4
					LSD (0.05) 1.0

[1] Wheat stage of growth at time of treatment at Woodbine 26 was Haun 3, *Phalaris minor* was 1 to 2 leaf. At Vail 507, wheat was in the Haun 4 stage at time of treatment.

Table 4. Weed control, crop injury, and wheat yield in 1998 field experiments in the Imperial Valley, California, USA

Treatments (g/ha)	Application[1] Timing	% *Phalaris minor* control		% Phytotoxicity			Yield t/ha
Woodbine 54		13 Apr.	27 Apr.	2 Feb.	13 Apr.	27 Apr.	6 June
MKH-6561 30	1	99	98	10	<1	1	5.5
MKH-6561 45	1	100	99	12	5	1	7.3
Fenoxaprop 75	1	4	0	0	0	0	4.8
MKH-6561 30	2	88	95	0	1	1	7.2
MKH-6561 45	2	100	99	0	4	2	5.9
Fenoxaprop 75	2	17	0	0	1	0	6.0
Untreated control		0	0	0	0	0	5.3
						LSD (0.05)	1.9
Spruce 24						27 Apr.	11 June
MKH-6561 30	1					2	5.5
MKH-6561 45	1					8	4.2
Fenoxaprop 75	1					<1	5.5
MKH-6561 30	2					2	4.9
MKH-6561 45	2					4	4.7
Fenoxaprop 75	2					5	5.3
Untreated control						0	5.9
						LSD (0.05)	1.0

[1] Wheat stage of growth at application timing 1, Woodbine 54 was Haun 4, *Phalaris minor* was 1 to 2 leaf. At timing 2, the crop was Haun 4.5 and the weed was 4 leaf to early tillering. At Spruce 24, crop stage of growth at timing 1 was Haun 3, and at Haun 5 at timing 2.

Table 5. Weed control, crop injury, and wheat yield in 1999 field experiment in the Imperial Valley, California, USA

Treatments (g/ha)	Application[1] Timing	%*Phalaris minor* control			% Phytotoxicity			Yield t/ha
		23 Feb.	5 Mar.	26 Mar.	23 Feb.	5 Mar.	26 Mar.	28 May
Tralkoxydim 200	1	46	24	10	0	0	0	4.7
Tralkoxydim 280	1	38	27	27	0	0	0	5.8
Fenoxaprop 67	1	27	15	10	0	0	0	4.9
Fenoxaprop 135	1	58	73	31	0	0	1	6.0
MKH-6561 30	1	35	58	66	0	0	1	7.3
MKH-6561 45	1	58	35	24	0	0	0	5.1
Tralkoxydim 200	2	0	73	66	0	0	0	6.1
Tralkoxydim 280	2	0	76	54	0	0	0	5.4
Fenoxaprop 67	2	0	58	61	0	0	4	6.9
Fenoxaprop 135	2	0	54	79	0	0	10	6.6
MKH-6561 30	2	0	61	76	0	0	10	6.3
MKH-6561 45	2	0	50	79	0	17	24	5.8
Untreated control		0	0	0	0	0	0	3.3
								LSD (0.05) 1.9

[1] Wheat stage of growth at timing 1 was Haun 3, *Phalaris minor* was 1 to 2 leaf. At application timing 2, the crop was Haun 5 and the weed had 6 leaves.

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REFERENCES

Afentouli, G C and I G Eleftherohorinos (1996). Littleseed canarygrass (*Phalaris minor*) and short-spiked canarygrass (*Phalaris brachystachys*) interference in wheat and barley. Weed Sci. **44,** 560-565.

Afentouli, G C and I G Eleftherohorinos (1999). Competition between wheat and canarygrass biotypes and their response to herbicides. Weed Sci. **47,** 55-61.

Bell, C E (1992). Littleseed canarygrass control in cereal grains. Research Progress Report, pp 232-233, Western Society of Weed Science, Salt Lake City, UT.

Bhatia, A K, N L Das, S S Solanki, and J P Tiwari (1981). Chemical control of *Phalaris minor* in irrigated wheat. Indian J. Weed Sci. **13**, 95-102.

Cudney, D W and J E Hill (1979). The response of wheat grown with three population levels of canarygrass to various herbicide treatments. Western Soc. Of Weed Sci. Proceedings **32**, 55-56.

Damanakis, M E (1983). Weed species in wheat fields of Greece – 1982, 1983 survey. Zizaniology **1**, 85-90.

Esqueda, M M C (ed.) (1978). El cultivo del trigo en el valle de Mexicali. Circular CIANO no. 104, Mexicali, BC. Mexico.

Garcia-Baudin, J M (1983). Importancia del genero *Phalaris* como adventicia en los cereales del invierno espanoles. Agricultura **52**, 526-528.

Haun, J R (1973). Visual quantification of wheat development. Agron. J. **65**, 116-119.

Tickes, B R and E S Heathman (1991). Littleseed canarygrass (*Phalaris minor*) has become an increasingly widespread weed in wheat grown in central and southwestern Arizona. Research Progress Report, pp 238-239, Western Society of Weed Science, Seattle, WA.

Population density and sequential distribution of dinitrogen fixing cyanobacteria in rice fields with application of herbicides

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ABSTRACT

Dinitrogen-fixing cyanobacteria were studied both in lab culture, to assess the effect of herbicides on propagation, and also in-field during the rice growing season, to assess the effect of nitrogen fertilizer and chemical weed control on population density and sequential distribution. Results revealed great complexity concerning effect of the herbicides on growth of the cyanobacteria in gnotobiotic cultures and their population densities and sequential distribution in rice fields. Enhancement of rice growth and performance were found positively correlated to population densities of cyanobacteria especially throughout the N–hunger period of rice growth extended between the maximum tillering and the early panicle initiation stages.

INTRODUCTION

Biological nitrogen (N)–fixation in submerged rice fields is mainly a process performed by a diversity of cyanobacteria capable of contributing up to 30 kg fixed–N/ha (Yanni, 1992; Goyal, 1993). The beneficial effects of cyanobacterization of rice fields can not be attributed solely to contribution of biologically fixed-N, but other physiological, agronomical and physiochemical operations are involved. Yanni *et al.* (1988, 1996) and Yanni, (1998) reported that they comprise production of growth promoting and regulating substances, antagonism against some aquatic macrophytes, aid of soil particles aggregation, decrease of sulphide injury through improvement of redox status of the ecosystem, increase of phosphorus availability and optimize of N-status in the ecosystem and rice plant which lead to a decrease in the susceptibility of rice to various fungal and bacterial pests and infestation by insect pests. The high population and wide diversity of weeds in rice fields of the Nile delta necessitate application of various herbicides which may disturb population densities and bioactivities of both the indigenous or inoculated cyanobacteria. The effect of herbicides on cyanobacteria growing in laboratory growth cultures and their contribution to field grown rice crop produced contradictory results. This contradiction was explained mainly on the basis of different actions of the chemicals on cyanobacteria grown in gnotobiotic lab cultures, or their decomposition byproducts in the presence of a wide range of agro-physicochemicals factors and biodiversity of soil microorganisms in the open field conditions (Bollag & Liu, 1990; Yanni, 1998). The results lie in the "black box category of research", in which effects of a given herbicide on efficiency of cyanobacteria are derived from indirect evidence comprising only alterations in rice growth and yield parameters.

The estimation of population densities and sequential distribution of cyanobacterial genera in fields during the rice growth season can, in case of chemical control of weeds, improve the understanding of their role in to contributing rice performance. The design of integrated pest management programs for rice production in the tropics and subtropics when inoculation with cyanobacteria is to be included in fertilization schedules may also be better understood.

MATERIALS AND METHODS

Some hundred soil samples were collected from rice fields of the Nile delta for isolation and identification of the dominant cyanobacteria using standard bacteriological, physiological and microscopical methods (El-Haddad, 1969; Stainer *et al.* 1971; Reddy & Roger, 1988). Three out of sixty isolates were purified as bacterial free unialgal cultures and identified as strains belonging to the active dinitrogen-fixers: *Anabaena cylindrica, Aulosira fertilissima* and *Nostoc muscorum*. Their growth responses were tested in lab cultures in presence of concentrations simulated to be just as the field recommended doses of the herbicides: Bensulfuron methyl (T.N.: Londax, used at 72g/ha), Allyl-bensulfuron/metsulfurn (T.N Sindax, used at 192g/ha) or the combination: Benfulfuron methyl at 72 g/ha + Molinate (T.N. Ordram, used at 24 L/ha). The herbicidal treatments are referred to in the context as H_1, H_2 and H_3, respectively. The interacting effects of inoculation of rice fields by a balanced mixture of colony-forming units (CFU) of the three cyanobacteria, doses of fertilizer-N and the recommended amounts of the herbicides were tested in field plot experiment in the Nile delta where one month old seedlings of the rice cultivar Giza-175 were transplanted. In addition to several rice growth, yield and N-content parameters, densities of CFU of cyanobacteria were followed throughout the rice growth season. Ten representative composite samples were used to assess the initial population density of the indigenous cyanobacteria. Core samples were collected at 13, 27, 49 and 105 days post transplantation (dpt) of the rice seedlings to the permanent field. These dates were respectively, one week before and one week after the first application of combined N, at the mid -tillering stage and just before harvest. The samples were used to asses population densities of CFU of cyanobacteria. Microscopical examination was used to record the relative abundance of each of the inoculated cyanobacterial genera.

However, additional details are presented in the self-explanatory tables encountered in the cotext.

RESULTS AND DISCUSSION

Effect of herbicides in growth culture

The growth response of the cyanobacteria in lab culture in presence of the H_1, H_2 or H_3 (Table 1) showed that the presence of the herbicides enhanced production of new cells. No significant first order interaction between strains of cyanobacteria and the tested herbicidal treatments was detected. This indicated that the presence of the herbicides at concentrations which simulated field recommended doses did not cause adverse effects. However, in this case, there were no other micro-organisms present and, consequently, no herbicides degradation by-products capable of affecting growth of the cyanobacteria.

The questions is whether or not the growth of cyanobacteria and biochemical activities and contribution to rice performance will show the same tendency under the open field conditions.

Table 1. Effect of herbicides application on growth (mg/L) of 3 cyanobacterial strain after 10 days incubation period.

Cyanobacterial strain	Herbicides				Average for a strain
	Control (handweeded)	Londax	Sindax	Londax + Ordram	
Anabaena cylindrica	590	729	510	638	617
Aulosira fertilissima	966	969	1058	1030	1006
Nostoc muscorum	988	1362	1184	1350	1221
Average for herbicide	848	1020	917	1006	
LSD		0.05	0.01		
Cyanobacterial strains		137	200		
Herbicides		n.s.*	n.s.		
Cyanobacteria X herbicides		n.s.	n.s.		

*n.s.: statistically not-significant

Population density of cyanobacteria at different stages of rice growth

MPN of CFU of cyanobacteria in the experimental field before submergence revealed presence of 4.41 ($\pm$ 0.31) x 10^4 CFU/g of dried soil. Table (2) shows the figures at 13 dpt, when only the cyanobacterization and herbicidal treatments had been applied.

Table 2. Population density and sequential distribution of cyanobacteria in rice field as affected with combined N, cyanobacterization and herbicides.

		Isolation/identification cycles dpt)											
Fertilization	Herbicides	13			27			49			105		
		TC	*A*	*N*	TC	*A*	*N*	TC	*A*	*N*	TC	*A*	*N*
72 N		11	40	60	49	50	50	11	45	55	3	75	25
72 + cyan.		79	64	36	230	62	38	110	74	26	8	45	55
144 N	HW	120	43	57	70	28	72	11	53	47	2	43	57
144 N + cyan.		69	41	59	230	81	19	22	67	33	9	35	65
72 N		7	63	37	14	44	56	11	67	33	5	44	56
72 + cyan.		33	56	44	23	16	84	70	45	55	8	36	64
144 N	H_1	13	34	66	14	35	65	110	41	59	2	53	47
144 N + cyan.		15	76	24	15	58	42	13	80	20	7	67	33
72 N		5	36	64	33	60	40	12	69	31	5	61	39
72 + cyan.		28	49	51	70	66	34	33	47	53	11	61	39
144 N	H_2	17	39	61	49	42	58	540	46	54	1	27	73
144 N + cyan.		49	11	89	79	33	67	3	78	22	6	45	55
72 N		1	42	58	70	62	38	28	67	33	2	23	77
72 + cyan.		130	43	57	310	51	49	220	76	24	8	28	72
144 N	H_3	7	34	66	52	65	35	5	55	45	3	35	65
144 N + cyan.		49	78	22	117	72	28	7	81	19	8	55	45

N : kg N (urea 46 N%) applied in two equal doses: 20 dpt and at the mid-tillering stage.

Cyano : inoculation with a soil-based inoculum of a balanced colony forming units of the cyanobacteria: *Anabaena cylindrica* (*A*), *Aulosira fertilissima* and *Nostoc muscorum* (*N*) in the rate of 10 kg/ha at 5 dpt.

A,N : percentage abundance of cyanobacteria belonging to the genera *Anabaena* and *Nostoc* , respectively.

TC : Total colony forming units of cyanobacteria (x 10^4)/g

Rice growth and performance

Cyanobacterization and/or the N-fertilizer increased tillers bearing panicles over the corresponding counterparts (Table 3). Application of the herbicides seemed more effective than handweeding in enhancing production of panicles. Cyanobacterization increased grain yield even with increases in the amount of fertilizer-N. This enhancement effect was greater with application of the tested herbicidal treatments. A maximum grain yield of 13.2 tons/ha was obtained with 144 kg N/ha and application of the H_3. Statistical analysis revealed that effect of each of the tested factors in enhancing grain production is mostly controlled by each or both of the two

Table 3. Growth, yield, N-contents and the agronomic N-use efficiency of the rice var. Giza 175 as affect by inoculation with cyanobacteria, N-fertilization and application of herbicides.

Fertilization	Productive tillers/m^2				Grain yield (ton/ha)				Harvest index*				Grain N (kg N/ha)				Straw N(kg N/ha)				N-use efficiency			
	HW	H_1	H_2	H_3	HW	H_1	H_2	H_3	HW	H_1	H_2	H_3	HW	H_1	H_2	H_3	HW	H_1	H_2	H_3	HW	H_1	H_2	H_3
72 N	485	513	577	515	8.38	9.50	11.55	11.10	39.1	40.3	36.1	36.5	66.0	77.1	94.1	91.2	43.2	49.3	73.4	64.3	116	132	161	154
72 N + cyan.	440	597	600	568	8.55	9.8	10.86	10.63	32.3	32.0	31.3	36.6	70.0	87.6	96.2	94.7	62.8	79.6	90.1	72.1	119	139	151	148
144 N	542	545	548	557	8.33	11.60	11.81	10.46	34.1	34.8	34.3	36.0	66.3	95.7	97.9	87.1	55.4	79.0	82.8	69.1	58	81	82	73
144 N + cyan.	422	618	612	608	9.48	11.32	11.91	13.18	31.0	31.6	35.9	39.9	76.6	97.4	103.2	115.0	76.0	88.4	78.8	75.6	66	79	83	91
LSD (0.05)																								
Cyanobacteria (cyan.)	24				n.s.				n.s.				n.s.				5.7				n.s.			
N-fertilizer (N)	n.s.				0.22				n.s.				1.7				3.0				3			
Herbicides (H)	29				0.42				0.9				3.6				2.8				4			
Cyan. x N	n.s.				0.31				1.2				2.3				4.3				4			
Cyan. x H	4.1				0.60				1.3				5.1				3.9				5			
N x H	n.s.				0.60				1.3				5.1				3.9				5			
Cyan x N X H	n.s.				0.85				n.s.				7.2				5.5				7			

N : kg N (urea 46 N%) applied in two equal doses: 20 dpt and at the mid-tillering stage.

Cyan. : inoculation with a soil-based inoculum of a balanced colony forming units of the cyanobacteria: *Anabaena cylindrica*, *Aulosira fertilissima* and *Nostoc muscorum* in the rate of 10 kg/ha at 5 dpt.

HW, H_1, H_2, H_3 : handweeded control, 72 g/ha Benfuluron methyl, 192g/ha Allyl bensulfuron/metsulfuron and H_1 + 24 kg/ha Molinate, respectively.

Harvest index : percentage of grain yield/grain + straw

N-use efficiency : kg grain yield/kg fertilizer-N

LSD (0.05) : least significant differences at the 95% confidence level n.s. : statistically not significant

There were increases as a result of inoculation, especially in the absence of the herbicides. At 27 dpt, one week after application of the first dose of combined nitrogen, the CFU in the inoculated subplots which received 36 kg N/ha and H_1, H_2, H_3 or the handweeded control were higher by 64, 112, 343 and 369% over the non-inoculated counterparts, respectively. The corresponding figures with application of 72 kg N/ha as a first dose of combined-N were only 6, 61, 125 and 229%. However, this interval registered the highest record of field colonization with cyanobacteria throughout the rice growth seasons. The CFU at 49 dpt, one week after application of the second N-dose, showed clear declines proportional to the population densities observed at 27 dpt. This can be related to sharp decrease in incident sunlight on the rice flood water with the increased canopy of growing plants. Population densities at 105 dpt indicated limited variation as the recorded figures ranged from 2.3 to 7.9 x 10^4 CFU/g over the experimental plots. The figures for the inoculated plots were 2 to 3 times that of their non-inoculated counterparts. This, however, confirm records on positive residual effects of cyanobacterization of rice fields extended to crops subsequent to rice (Ghosh & Saha, 1993).

Sequential distribution of cyanobacterial genera during the rice growth season

Although a balanced mixture of CFU of *Anabaena cylindrica, Aulosira fertilissima* and *Nostoc muscorum* was inoculated in the rice field, cyanobacteria belonging only to the first and the third genera were detectable throughout the rice growth season. It seems that the *Aulosira fertilissima* failed to propagate, probably due to adaptation problems encountered. However, this strain was originally isolated from saline soil in the northern part of the Nile delta and used here under different physico-chemical conditions. Data of Table (2) show that at 13 and 27 dpt, the proportional existence (%) of the *Anabaena* and *Nostoc* fluctuated according to application of the different amounts of fertilizer-N, handweeding or the herbicidal treatments. No definite trend could be related particularly to any of the two factors.

It seems that during this active propagation stage the cyanobacteria can withstand wide range of agrochemical conditions. However, they can survive and grow successfully regardless of their contribution to the rice crop and ecosystem with fixed-N. One week after the application of the second fertilizer dose (49 dpt) there was a clear tendency of increase in population density of the *Anabaena* over the *Nostoc* specially in the subplots which received 144 rather than 72 kg N/ha. During this period the effect of the different herbicidal treatments seemed limited, particularly as this estimation was made more than 40 days after application of the herbicides. The period is also characterized by a start in the decline in the population density of the two genera, which may be related to the effect of: a) rice canopy and reduction of incident sunlight on the rice flood water, b) similar rate of production of new cells and autolysis of old ones, and c) cessation of field irrigation 15-20 days before harvest. Eventually, the rice ecosystem seemed to have the potential to maintain existence and balanced growth and proliferation for the two tested cyanobacterial genera.

other factors. Inoculation, in most cases, decreased the harvest index (% grain yield/grain + straw yields), indicating more vegetative rather than reproductive rice growth. This is quite expected as the maximum active stage of cyanobacteria contribution to rice is that related to the availability of sunlight needed for photosynthesis (Table 2), which is coincidentally the same active tillering stage of rice growth. Statistically significant first and second order interactions between each two or the three tested factors were apparent, indicating that effect of each factor was not independent from action of the other two factors. Cyanobacterization, increasing N and application of each of the tested herbicidal treatments increased N-content of both grain and straw. The most relevant observation is that the increases were greater in straw than in grain. This is expected since most of the vegetative growth period of rice (tillering and booting stages) is coincidental with the period of active propagation of cyanobacteria (Table 3). Development towards grain production is usually linked not only with fixation of a limited amounts of atmospheric N in cyanobacterial cells, but also with autolysis of the old trichomes and liberation of N plus other cellular components to the rice ecosystem. Efficiency of cyanobacteria in contributing to N content of grain and straw was higher with fertilization by 144 rather than 72 kg N/ha, probably due to greater activation of plant growth in the early crop season with addition of the first dose of 72 rather than 36 kg N/ha. It is well known that during the early tillering stage of rice growth, a high amount of nitrogen is simultaneously required while field colonization with the inoculated cyanobacteria is still insufficient. This finding is in accordance with the data of total colony-forming units of the cyanobacteria presented in Table (2). However, 23.3 and 31.0 kg N/crop/ha were calculated to have originated from cyanobacterization along with application of 72 or 144 kg N/ha with only handweeding, respectively. The data in case of the application of the herbicides followed similar pattern. Increases of 40.8, 18.7 and 11.7 kg N/crop/ha were obtained with application of the H_1, H_2 or the H_3 plus cyanobacterization and 72 kg N/ha, respectively, with corresponding figures of 11.0, 1.3 and 34.3 kg N/crop/ha with application of 144 kg N/ha. The maximum gain in N-content amounting to 40.8 kg N/crop/ha was obtained in case of cyanobacterization, H_1 and 72 kg N/ha while the minimum amount of 1.3 kg N/crop/ha was derived from cyanobacterization, H_2 plus 144 kg N/ha.

Data of the agronomic productivity of one unit of combined-N (Table 3) indicate that increases due to cyanobacterization is correspondent to the amount of applied N, as the productivity of N-unit (one kg N) decreased by about 50% with doubling the N-dose. Application of the herbicides, in general, significantly enhanced fertilizer productivity while the handweeding seemed less effective. This is quite expected because growth of weeds for at least one month during the early rice growth season, before they were able to be hand-weeded, normally, leads to consumption of high amounts of nitrogen completely lost from the rice ecosystem by handweeding. It is expected here that prevention of growth of aquatic weeds in the rice field by application of the herbicides eliminate their competition with rice and cyanobacteria on space, sunlight and nutrients. This, eventually, enhances the contribution of the cyanobacteria to rice growth and performance. Results of this experiment revealed that when the application of herbicides is necessary for better rice crop performance, only field testing can verify whether or not a package of input recommendations including such chemicals will interfere with propagation, bioactivities and sequential distribution of different cyanobacterial genera and their overall contribution to crop performance.

It is then necessary to select effective pesticide treatments which have minimal effects on the population densities of cyanobacteria and, consequently, maximum contribution to the rice crop and subsequent crops.

REFERENCES

Bollag J M; Liu S Y (1990). Biological transformation of pesticides. In: *Pesticides in the Soil Environment: Processes, Impact, and Modelling,* ed. H H Cheng, pp. 169-209. soil Science Society of America, Inc. Madison.

El-Haddad M E M (1969). Studies on Some Local Strains of the Algae Chloroellae. M.Sc. Thesis, Faculty of Agriculture, Ain-Shams University, Egypt.

Ghosh T K; Saha K C (1993). Effects of inoculation with N_2-fixing cyanobacteria on the nitrogenase activity in soil and rhizosphere of wetland rice (*Oryza sativa* L.). *Biology and Fertility of Soils* **16**, 116-20.

Goyal S K (1993). Algal biofertilizer for vital soil and free nitrogen. Proceedings of the Indian National Academy of Science-Part B: *Biological Sciences* **59**, 295-302.

Reddy P M; Roger P A (1988). Dynamics of algal populations and acetylene-reducings activity in five rice soils inoculated with blue-green algae. *Biology and Fertility of Soils* **6**, 14-21.

Stanier R Y; Kunisawa R; Mandel M; Cohen-Bazire G (1971). Purification and properties of unicellular blue-green algae (order chroococales). *Bacteriological Review* **3**, 171-205.

Yanni Y G (1992). The effect of cyanobacteria and azolla on the performance of rice under different levels of fertilizer nitrogen. *World Journal of Microbiology and Biotechnology* **8**, 132-136.

Yanni Y G (1998). Efficiency of biofertilization management of rice and soybean in the Nile delta with application of pesticides. The Brighton Conference-Pests & Diseases **7B-7**, 643-648.

Yanni Y G; Salem K Gh; Shalan S N (1988). Response of transplanted rice to algalization under different treatments of herbicides. *Proceedings of the Second Conference of the Agricultural Development Research, Ain-Shams University* pp. 216-226, Cairo.

Yanni Y G; Sehly M R; Abdallah F E (1996). Enhancement of rice performance and incidence of natural fungal and insect damage with cyanobacterization, microelements, combined nitrogen and certain pesticides. In: Nitrogen *Fixation with Non-Legumes*, eds, K A Malik, M S Mirza & J K Ladha, pp. 159-164. Kluwer Academic Publishers: Doredrect/Boston/London.

Integrated weed management systems for maize using mesotrione, nicosulfuron and acetochlor

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ABSTRACT

ZA1296 (2-[4-methylsulfonyl-2-nitrobenzoyl]-1,3-cyclohexanedione), proposed common name mesotrione, provides control the major broadleaf weeds and selected annual grasses in maize (*Zea mays L.*) when applied either to the soil surface or to weed foliage. It can be used in integrated weed management programmes depending on the grower's preferred weed control strategy. Two partners of choice are acetochlor and nicosulfuron. Acetochlor provides control of germinating annual grasses and small seeded broadleaf weeds, and nicosulfuron provides post-emergence control of grass and broadleaf weeds. Flexibility of mesotrione in combination with acetochlor and/or nicosulfuron provides growers with different modes of action and timing and gives them the tools needed to design integrated weed management systems for many crop/soil/weed complexes.

At post-emergence rates of 150g ai/ha or less and pre-emergence rates of up to 200g ai/ha mesotrione provides naturally selective control of *Chenopodium album*, *Amaranthus, species*, *Solanum nigrum*, *Polygonum persicaria*, *Stellaria media*, *Sinapis arvensis*, *Digitaria sanguinalis* and *Echinochloa crus-galli*. Mesotrione applied post-emergence will also provide residual control of new germinating weeds. *Setaria* species can be controlled by using mesotrione in combination with nicosulfuron applied post-emergence or soil applied acetochlor . Weed control programmes including mesotrione applied pre-em or post-em either alone or in combination with acetochlor or nicosulfuron are safe to maize.

INTRODUCTION

The maize growing areas in Europe and the USA are fertile, rain-fed and warm so in these conditions, weed growth is luxuriant and quickly produces large numbers of seed, and a large weed seed bank has built up over recent years of agriculture. As a consequence anything from 50-500 weed seedlings/m^2 emerge to compete with the young crop. Against such a population of aggressive weeds the field manager must employ an effective weed control strategy. Maize is sown at a low seed rate (approx. 8-10 plants/m^2) and especially the young maize plants (0-6 leaves) are intolerant of weed competition. The best crops and yields are produced where weed competition is removed in this early phase of the crops growth.

Hand weeding and hoeing is the traditional method but above all it is time-consuming and very hard work, and in modernised farming is the first operation to be dropped. Mechanical inter-row hoeing is also an option whilst the crop is small, but it will damage the roots near the surface, and still does not remove weeds from within the row.

Integrated weed management 'however defined' will require that the farm or field manager has a number of options and alternative strategies to hand so that they can then choose an appropriate weed management strategy for their site, conditions and criteria. Approaches to consider are:

Crop Rotation - spring and winter crops
Crop Competitiveness - varieties, spacing
Cultivation - stale seed beds, no-till, inter-row
Costs, Timing and Benefit (crop value)
Weed population, Biology and Ecology
Herbicide choice (spectrum, mode of action and timing)

Table 1. Major weeds in maize - USA and France/Italy/Germany

USA	France/Italy/Germany
Setaria spp	*Chenopodium spp*
Xanthium strumarium	*Polygonum spp*
Abutilon theophrasti	*Echinochloa crus-galli*
Amaranthus retroflexus	*Digitaria sanguinalis*
Chenopodium spp	*Setaria spp*
Ambrosia artemissifolia	*Solanum nigrum*
Helianthus annuus	*Amaranthus retroflexus*
Sorghum halapense	*Stellaria media*
Amaranthus tamariscinus	*Matricharia spp*
Digitaria sanguinalis	*Mercurialis annua*
Ambrosia trifida	*Abutilon tleophrasti*
Ipomoea hederacea	*Galinsoga spp*
Agropyron repens	*Agropyron repens*
Polygonum pensylvanicum	*Datura stramonium*
Cirsium arvense	
Kochia scoparia	
Panicum dichotomiflorum	
Sorghum vulgare	
Echinochloa crus-galli	

Source: Zeneca market research, Doane 1998, Agricultural Information Services Ltd 1997.

THE MAJOR WEEDS IN MAIZE

Maize crops in the USA and Europe are infested with a wide range of summer annual weeds. Table 1 shows the ranking of major weeds with an infested and treatable area greater than 1 million hectares. Given this species diversity it is essential that an integrated weed management programme can control weeds across the whole spectrum. Mesotrione offers a wide weed spectrum, particularly of important weeds such as *Digitaria, Echinochloa, Abutilon, Amaranthus, Ambrosia, Chenopodium, Polygonum, Solanum* - see Table 2, ref Beraud & Bernard (1988), Beraud & Le Siourd (1998), Kimura *et al* (1998) and Zeneca trials data across the USA and Europe. However for a complete spectrum of control, or to tailor weed management to specific situations programmes of mesotrione plus nicosulfuron post-em or acetochlor pre-em help to improve control and to simplify management. This is shown in Table 2, given the complementary and additive nature of these mixtures in the field.

RESULTS

Post-emergence broad-leaved weed control

Table 3 shows typical results from maize herbicides trials in France and Italy for the 1997 and 1998 seasons. The results show that the following species were well controlled by 75g/ha of mesotrione with built in adjuvant at the growth stages tested: CHEAL, POLPE, SOLNI, POLAV, and XANST . An increased rate of 100-150g/ha was required for control of AMARE (GS 12-19) and MERAN. Nicosulfuron alone gave good control of most species, but not CHEAL, POLAV and POLPE. The mesotrione plus nicosulfuron mixture gave good control across all the species tested. This will make such a tank-mix very attractive to the field manager.

Post-emergence grass weed control

In trials for the post-emergence control of summer annual grasses such as ECHCG, DIGSA and PANDI, the data indicates that for good control applications of mesotrione at 150g/ha are needed, but this rate does not control SETVI. Again, the mixture of mesotrione with nicosulfuron at the relatively low rates of 75g/ha + 40g/ha gives excellent control over the full range of grass weeds.

Crop tolerance

Mesotrione works on weeds with a mode of action targeting the HPPD enzyme and maize is naturally tolerant to triketone herbicides of this type. However in some stress situations, usually cold, wet conditions crop chlorosis of the 'target leaf' can be seen where mesotrione has been applied at double the registered rate. This contact damage is not translocated and does not affect subsequent crop growth - such that in weed-free situations final yields are not affected (Table 4) and the normal yield enhancement is seen in weedy sites.

Table 2. List of weeds controlled

	PRE-EM ACETO- -CHLOR	PRE-EM MESO- -TRIONE	POST-EM MESO- -TRIONE	POST-EM NICO- SULFURON	
GRASSES					
Agropyron repens				++++	AGGRE
Avena spp	++			++++	AVESS
Digitaria sanguinalis	+++	+++	++++	+++	DIGSA
Echinochloa crus-galli	++++	+++	+++	++++	CHECG
Panicum dichotomiflorum	++		++	++++	PANDI
Poa annua	++++		++	++++	POANN
Setaria spp	++++		+	++++	SETSS
Sorghum halapense				++++	SORHA
Sorghum vulgare				++++	SORVU
BROAD-LEAVED WEEDS					
Abutilon theophrasti		++++	++++	++	ABUTH
Amaranthus retroflexus	++++	++++	++++	++++	AMARE
Amaranthus tamariscinus	+++	++++	++++	R	AMATA
Ambrosia artemissifolia	++++	+++	+++	++++	AMBEL
Ambrosia trifida	+	++	++++		AMBTR
Chenopodium spp	+++	++++	++++	+++	CHESS
Cirsium arvense			++		CIRAR
Datura stramonium	+++	++++	++++	+++	DATST
Galinsoga spp	++++		++++	++++	GASSS
Helianthus annuus		++++	++++		HELAN
Ipomoea hederacea			++	++	IPOHE
Kochia scoparia		++++	++++	R	KCHSC
Matricharia spp	++++	++++	+++	++++	MATSS
Mercurialis annua	R	++	++	+++	MERAN
Polygonum avculare	+	++	++	+	POLAV
Polygonum convolvulus	++	++	++	++	POLCO
Polygonum lapathifoloium	+++	++++	++++	+++	POLLA
Polygonum pensylvanicum		++++	++++		POLPY
Polygonum persicaria	+++	++++	++++	+++	POLPE
Solanum nigrum	++++	++++	++++	+++	SOLAN
Stellaria media	+++	+++	++++	+++	STEMA
Xanthium strumarium		++++	++++	+++	XANST

Key (at label rates and growth stages):
++++ excellent >90%
+++ good >80%
++ moderate >60%
+ poor
R = Resistant

Table 3. Post-emergence broad-leaved weed control France/Italy 1997 and 1998.

Weed (No. Trials)	CHEAL (11)	AMARE (10)	POLPE (4)	SOLNI (4)	MERAN (2)	POLAV (1)	XANST (3)
Atrazine (500g)	41	42	47	100	-	-	-
Pyridate (900g)	95	91	68	98	-	17	-
Mesotrione (50-75g)	99	67	95	99	72	95	97
Mesotrione (100-150g)	99	97	98	99	99	100	99
Nicosulfuron (60g)	69	94	74	80	-	68	30
Mesotrione + Nicosulfuron (50-75g + 30-40g)	100	98	99	97	96	96	-
Growth Stage (BBCH)	12-18	12-19	12-19	12	12-14	13-14	12-14

Table 4. Crop tolerance, France, 1998. Yields in weed-free situations

Trial	Yield relative to untreated = 100*	
	150g/ha	300g/ha
H117	95.4	96.2
H808	95.2	100.0
H809	106.3	106.3
H974	93.6	98.9
MEAN	97.6	98.9

* No treatments significantly different to untreated.

DISCUSSION

These results briefly show how these three herbicides offer potential for programmes with one or two sprays with either pre-em, early post or late post timings to cope with the full range of weeds, soil types and climatic conditions. These management tools can also be combined with other techniques and products. Choice of variety, row spacing, seed rate and nitrogen levels can help to reduce weed biomass - though in general the maize crop does **not** tolerate weed competition, particularly from emergence to the six leaf stage. Herbicide rotation has become a desirable aspect of weed management as it will help in the delay of weed resistance problems. Factors that **increase** likelihood of resistance in maize are:

- Continuous maize
- Continuous non-ploughing
- Reliance on herbicides only
- Reliance on herbicides with the same mode of action
- Reliance on herbicides where resistance is known
- High weed pressure
- Weeds with high seed production and low dormancy.

Consequently any sustainable weed management system in maize needs to incorporate at least three, and preferably more modes of action for the control of key weeds. Mesotrione and other HPPD inhibitors introduce a new mode of action to the crop - the other key modes of action are given in Table 8.

Table 8. Modes of action for use in maize

Group	Mode of Action	Active on		Example
		Grasses	BLWs	
F_2	HPPD	✓	✓	Mesotrione
K_3	Cell Division	✓	✓	Acetochlor
B	ALS	✓	✓ R	Nicosulfuron
O	Auxins		✓	Dicamba
C_3	PSII		✓	Bromoxynil
C_1	PSII	✓	✓ R	Atrazine R
N	Lipid Synthesis	✓	✓	EPTC

Key: R indicates Resistance in the market.
Source: HRAC - Classification of Herbicides according to Mode of Action

REFERENCES

Beraud J-M, Bernard J-L (1998). *ANPP Dix-Septieme Conference du Columa.* SA1433: the formulation microencapsulee originale combinant l'acetochlor et le dichormid (phytoprotecteur) et destinae an desherbage du mais

Beraud J-M, Le Siourd J (1998). *ANPP Dix-Septieme Conference du Columa.* ZA1296, the nouvelle tricetone destinee au desherbage du mais pour lutter en post emergence centre des dicotyledones et les graminees adventices

Kimura F, Haga T, Sakashita N, Murai S, Fujikawa K (1989). *BCPC-Weeds: SL-950.* A novel sulfonylurea herbicide for corn. 1 29-34.

The biology of autumn and spring emerging cleavers (*Galium aparine*) individuals

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ABSTRACT

Field studies into the emergence patterns of cleavers (*Galium aparine*) populations and the biology of individuals emerging on different dates were undertaken in autumn sown winter wheat crops. The emergence pattern study showed that 7% of the total population emerged in the spring. The emergence pattern of cleavers populations was variable both within and between populations at the different sites. The vigour of cleavers individuals emerging later was significantly reduced when compared to those emerging with the crop in the autumn. However, later emerging individuals (after March 1st) were less sensitive to competition from the established crop than those of black-grass (*Alopecurus myosuroides*). Autumn emerging cleavers caused a 23% reduction in yields, whilst the same density emerging in spring had no detectable effect. Although spring emerging cleavers did not impact significantly on the growth of the crop they produced up to 150 seeds/m^2 (at an average of 5.34 seeds/plant).

INTRODUCTION

Cleavers (*Galium aparine*) is one of the most significant arable weed species of the UK and in Europe. Whitehead & Wright (1989) found that 58% of cereal fields were infested with this weed, and current perceptions are that it is still just as common and may be increasing. A 2% reduction in yield can result from only 1.6 cleavers plants/m^2 (Wilson & Wright, 1990; Cussans, Lutman, Blair, *et al*, 1996), and hence even high levels of control can leave damaging levels of survivors.

Previous work (Figure 1) has indicated that a proportion of a cleavers population emerges in the spring, and that because of this the population can be divided in two cohorts; an early ('autumn') cohort, and a late ('spring') cohort of individuals emerging after March 1st. The exact size and variability of this cohort, and its significance to the biology of the species is not well understood (van der Weide, 1993).

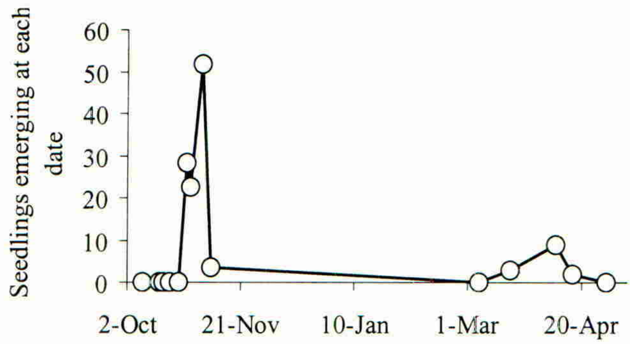

Figure 1. The emergence pattern of a cleavers population at IACR Rothamsted in 1996/97.

METHODS AND MATERIALS

Emergence patterns of cleavers populations

The emergence pattern of cleavers populations was studied in winter wheat crops at eight sites across the UK, and at one site in winter linseed (Table 1). At six of these sites the same cleavers population was sown into field plots on the same day as the crop was drilled, whilst at three sites the naturally emerging cleavers population was observed. The seed for the sown cleavers population ('RES97') had been harvested at IACR Rothamsted in the previous season (August 1997).

All the emerged cleavers were counted and tagged within replicated $0.5m^2$ quadrats using coloured wire, except at the Novartis site where the number of other broad-leaved weeds made this impractical. At this site cleavers were counted and carefully removed by cutting at ground level. These assessments began from the time of sowing at the six sites where the 'RES97' cleavers population had been sown, and on March 4^{th} for the naturally emerging populations, and were continued until no more cleavers plants emerged.

Table 1. Site details for the study of cleavers emergence patterns.

Site	Population	Sowing Date	Soil type
IACR Rothamsted	RES97	6-October 1997	Clay loam with flints
Whittlesford (Novartis)	RES97	8-October 1997	Sandy loam
ADAS Drayton	RES97	22-October 1997	Brown clay
ADAS Bridgets	RES97	24-October 1997	Heavy chalk loam
ADAS High Mowthorpe	RES97	13-October 1997	Silty clay over chalk
ADAS Boxworth #1	RES97	3-October 1997	Clay
ADAS Boxworth #2	Natural	2-October 1997	Clay
ADAS Boxworth -linseed	Natural	23-September 1997	Clay loam
ADAS Rosemaund	Natural	14-October 1997	Silty clay loam

Assessing vigour of cohorts

At the IACR Rothamsted site in the 1997/98 season the individual cleavers plants were also tagged with markers that identified their date of emergence, more precisely. These plants were harvested at two times (half of the total number of quadrats at each date) during the season to obtain plant biomass data for each emergence cohort. Only the data for the last harvest, taken on 30th May 1998 are shown here. A comparison with a contrasting weed species, black-grass (*Alopecurus myosuroides*), was carried out at the same site. The performance of cohorts emerging at different dates is expressed as dry weight per plant on the basis of the accumulated Degree Days (base 0°C) from emergence in order to account for changing ambient temperature.

Relative competitivity and seed production of autumn and spring emerging individuals

At IACR Rothamsted's Woburn experimental farm in the 1998/99 season a cleavers population sown into a winter wheat crop was tagged and hand weeded as necessary to create six emergence date and plant density treatments (see Table 2). The actual densities obtained for the treatments differed from the treatment 'target density' because of mortality and variability in establishment across the trial site. For this experiment the cut off point between early ('autumn') and late ('spring') emerging cleavers was taken to be 1st March 1999. Three replicates of each treatment were sampled. The treatments were imposed on a 1m^2 area and samples were taken from the central 0.5m^2. At the time of crop harvest (August 1999) the crop and cleavers within the sampling area were removed and the crop yield, cleavers biomass and cleavers seed production were assessed.

Table 2. Treatment details of relative competitivity study (Woburn 1998/99)

Treatment	Treatment cleavers density (plants/m^2)	Actual cleavers density plants/m^2 *(Standard error)*
Control	0	0 *(-)*
20 Spring	20	17.3 *(1.8)*
20 Autumn	20	16.0 *(2.0)*
40 Spring	40	26.6 *(6.0)*
40 Autumn	40	28.6 *(4.6)*
20 Spring & 20 Autumn	Total 40	28.0 *(2.0)*
	Spring 20	10.0 *(1.2)*
	Autumn 20	18.0 *(2.0)*

RESULTS AND DISCUSSION

Emergence patterns of cleavers populations

Table 3 summarises the results obtained in this study. There were very large and significant differences between the relative size of autumn and spring cohorts emerging within the same ecotype ('RES97'), suggesting an important role for environmental factors. Other work at IACR Rothamsted work (not shown here) has also shown that there is considerable variability in emergence pattern for the same cleavers ecotype at the same site.

There appeared to be a larger proportion of spring emerging individuals in the experimentally established plots (where the cleavers population was sown). It is not possible to determine whether this was due to different environmental conditions, or was an inherent characteristic of this ecotype. Other workers have found polymorphism in emergence patterns for this species (*e.g.* Ferris-Khan & Froud-Williams, 1991). One possibility is that it was related to the experimental establishment of the cleavers populations. Further work at ADAS Boxworth is being carried out to identify the key environmental triggers for spring emergence of cleavers, and to quantify inherent ecotype differences.

Table 3. Total population size and the proportion of the population in the spring (after March 4th). Standard error values are given in parentheses.

Site	Total Population plants/m^2	Spring emerging individuals plants/m^2	Percentage emerging in Spring
IACR Rothamsted	24.0 (3.1)	4.3(0.8)	17.9(3.3)
Whittlesford (Novartis)	62.3 (16.1)	3.7(0.8)	5.9(1.3)
ADAS Drayton	43.0 (3.8)	5.7(1.4)	13.3(3.3)
ADAS Bridgets	36.3 (7.0)	0.7(0.4)	1.9(1.1)
ADAS High Mowthorpe	43.7 (10.8)	2.0(1.0)	4.6(2.3)
ADAS Boxworth #1	81.1 (14.6)	8.0(1.8)	9.9(2.2)
ADAS Boxworth #2	202.7 (80.5)	6.3(2.0)	3.1(1.0)
ADAS Boxworth -linseed	29.0 (4.3)	0.7(0.4)	2.4(1.4)
ADAS Rosemaund	32.3 (5.9)	1.7(0.8)	5.3(2.5)
Average Sown 'RES97'	**48.4** (6.4)	**4.1**(1.1)	**8.9**(2.3)
Average natural	**88.0** (32.1)	**2.9**(1.7)	**3.6**(1.9)
Overall Average	**64.7** (10.1)	**3.7**(0.9)	**7.1**(1.4)

Assessing vigour of cohorts

There was a large difference between the growth of individuals of both species influenced by the date on which they emerged (Figure 2). These data suggest that in addition to possessing a longer period of germination than black-grass, the vigour of cleavers individuals was slightly less sensitive to emergence date.

It is clear that cleavers individuals, in contrast to other weed species, exhibit a degree of tolerance of late emergence into an established crop and have the potential to establish a substantial spring emerging cohort of cleavers. This raises questions about the role of these individuals in the overall population biology of the species. In order to explore this issue a study of the relative competitiveness and fecundity of spring and autumn emerging cohorts was undertaken in the 1998/99 season.

Relative competitivity and seed production of autumn and spring emerging individuals

In this study it was apparent that whilst a population of approximately 30 autumn emerging cleavers plants/m^2 (see Table 3 for details) caused a significant ($p>0.05$) yield reduction of 1.4t/ha (23% yield loss), an equivalent density of spring emerging plants caused no significant yield loss (Figure 3). Despite emerging over 140 days after the crop, the late ('spring') individuals reached maturity and produced viable seed. The total number of seeds produced per spring emerging cleavers plant was greatly reduced compared to that from early emerging plants. Autumn emerging cleaver produced 138 seeds per plant, whereas spring emerging ones only 5.34 per plant. Despite this up to 151.5 seeds/m^2 were produced, at the highest density. In this study there was no effect of the density of cleavers plants on the number of seeds produced per plant ($P<0.05$).

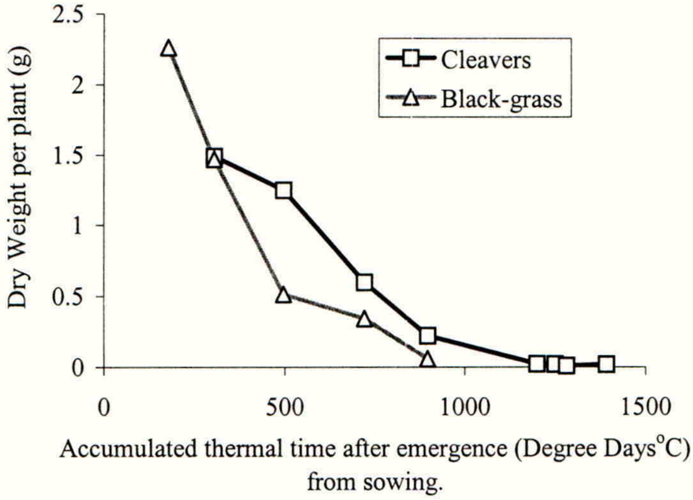

Figure 2. A comparison of the growth of cleavers and black-grass individuals, harvested on 30th May 1998, emerging at different dates within a winter wheat crop.

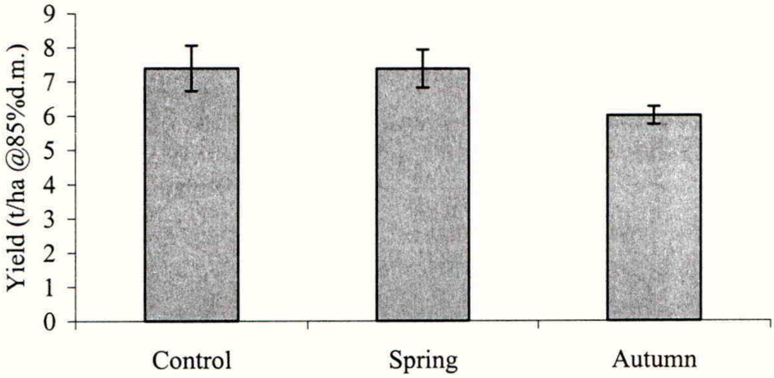

Figure 3. The effect of autumn (28.6 plants/m^2) and spring (26.6 plants/m^2) cleavers plants on crop yield, compared to a control (no weeds) treatment. Vertical bars represent the standard error of each mean.

These results confirm that a relatively large number of cleavers individuals emerge later in the life of an autumn sown crop. This second flush of emergence commences in March and ends in May (*e.g.* Figure 1). In comparison to a species where no spring emergence is observed (*e.g.* black-grass) cleavers individuals do seem to tolerate competition from the established crop relatively well. The ecological and agronomic significance of these late emerging individuals is not associated with their potential to compete with the crop and reduce crop yield - effective control of the bulk of a cleavers infestation using herbicides applied before April in most years will result in no appreciable yield loss from the remaining late emerging cleavers individuals. Rather, the significance of these individuals is their ability to produce weeds seeds and maintain a cleavers population in the face of high levels of herbicidal control.

ACKNOWLEDGEMENTS

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REFERENCES

Cussans J W; Lutman P J W; Storkey J; Blair A M; Corbett S J; Green M; Hill A L; McDonald H (1996). Inter-site variability in crop-weed interference in winter wheat. *Proceedings of Second International Weed Control Congress,* 203-208. Copenhagen, Denmark.

Ferris-Khan R; Froud-Williams R J (1991). Interspecific variation among populations of cleavers. *Proceeding Brighton Crop Protection Conference, (Weeds),* 1007-1014

van der Weide R Y (1993). *Population dynamics and population control of* Galium aparine *L.* Thesis, Wageningen University, The Netherlands.

Whitehead R; Wright H C (1989). The incidence of weeds in winter cereals in Great Britain. *Proceedings Brighton Crop Protection Conference, (Weeds),* 107-112.

Wilson B J; Wright K J (1990). Predicting the growth and competitive effects of annual weeds in wheat: *Weed Research*, **30**, 201-211.

N-acyl sarcosinate: a safe, effective and eco-friendly adjuvant for glyphosate

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ABSTRACT

N-acyl sarcosinates have a long history of safe use in personal care products such as shampoo and toothpaste. Glyphosate formulations containing sarcosinate as the sole adjuvant were shown to exhibit excellent efficacy at low surfactant concentration and to reduce the surface tension of the system to below 25 mN m^{-1}, at use concentration. Aquatic toxicity studies have shown that these systems are more than an order of magnitude less toxic to rainbow trout than conventional glyphosate systems. An in-vitro corneal toxicity study shows that the sarcosinate based glyphosate systems exhibit no toxicity to bullock corneal tissue while conventional formulations cause severe damage under the same conditions. The results of field studies, at elevated application rates, on glyphosate tolerant corn shows that conventional glyphosate formulations can cause severe stunting and deformation of the plants while the sarcosinate based formulations cause no significant damage.

INTRODUCTION

Adjuvants are conventionally added to pesticide formulations to aid in stabilization of the formulation and assist in delivery of the active to the site of action. Surfactants, which reduce surface tension, aid in atomization of the spray product, promote wetting of the plant surface and help in penetration of the herbicide into the target plant.

The surfactant of choice for conventional glyphosate formulations has been tallow amine ethoxylate. These formulations have some limitations:

- They are only moderately effective at reducing surface tension;
- Products containing tallow amine ethoxylate carry a hazard warning because of the potential of the surfactant to cause eye damage;
- The extremely high toxicity of these formulations to fish can be attributed to the surfactant;
- Crops that have been genetically engineered to be glyphosate tolerant have often shown a yield drag that may be attributable to herbicidal activity of the surfactant.

N-acyl sarcosinates, which are produced from the amino acid, sarcosine, N-methyl glycine, and coconut fatty acid, are potentially suitable candidate adjuvants for glyphosate because of their mildness, low order of toxicity, high surfactancy and compatibility with the herbicide.

EXPERIMENTAL

Glyphosate acid was neutralized with isopropylamine in water to produce a 60% active glyphosate isopropylamine salt solution. This solution was further diluted to 41% activity with isopropylamine or ammonium cocoyl sarcosinate and water.

A conventional commercial tallow amine ethoxylate, Roundup®[1]; and a 2nd generation glyphosate which is recommended for use with glyphosate tolerant crops, Roundup Ultra; both 41% active, along with 41% glyphosate isopropylamine salt without adjuvant were used as controls.

DETERMINATION OF OPTIMUM SURFACTANT CONCENTRATION

A study was carried out to assess optimum concentration of the isopropylamine salt of cocoyl sarcosinate, CIPA, required to act as an effective adjuvant in 41% active glyphosate IPA formulations. Concentrations of 2, 4, 8, and 16% CIPA were evaluated. Commercial glyphosate formulations that are believed to contain approximately 16% surfactant were run as controls. A field trial was carried out to determine the efficacy of each formulation, against a range of weed species, at an application rate of 0.2805 Kg ai/ha. The results are presented in Table 1.
The system containing 2 and 4% CIPA show the greatest activity on most target species and for the most part exhibit greater control than the commercial formulations.

Table 1. Efficacy of Glyphosate Formulations on Certain Weed Species at an Application Rate of 0.2805 Kg ai/ha

	Percent Control (13 Days After Treatment)			
Surfactant	Palmer Ameranth (Amerantus Palmeri)	Cheatgrass (Bromus Secalinus)	Henbit (Lamium Amplexicaule)	Velvetleaf (Abulilon Theophrasti)
CIPA 2%	98.7 a	95.7 a	86.0 a	95.7 ab
CIPA 4%	98.7 a	91.0 ab	89.3 a	93.3 ab
CIPA 8%	99.3 a	94.7 a	80.3 a	96.7 ab
CIPA 16%	96.7 ab	91.3 ab	78.3 a	90.7 b
Roundup	97.7 a	91.0 ab	83.7 a	99.3 a
Roundup Ultra	97.3 a	92.0 ab	84.0 a	95.3 ab
Glyphosate (no adjuvant)	94.0 b	88.3 b	73.0 a	89.3 b

SURFACE TENSION

The concentration dependence of surface tension of the system containing 4% sarcosinate was determined using a Kruss K12 Tensiometer, fitted with a Willhelmy plate. The two commercial glyphosate systems and 41% glyphosate IPA with no added surfactants, were run as controls. The results are presented in Figure 1.

The system containing cocoyl sarcosinate depresses the surface tension of water to less than 25 mN m^{-1} at less than 3g/L which is below the normal application concentration.

Neither of the commercial formulations depressed the surface tension below 33 mN m^{-1} at any concentration. Glyphosate without adjuvant had a surface tension of about 69 dynes/cm.

It has been suggested, (Holloway & Stock, 1990), that it is necessary for a pesticide solution to reach a surface tension below 30 mN m^{-1} in order to gain access to the plant through the stomata.

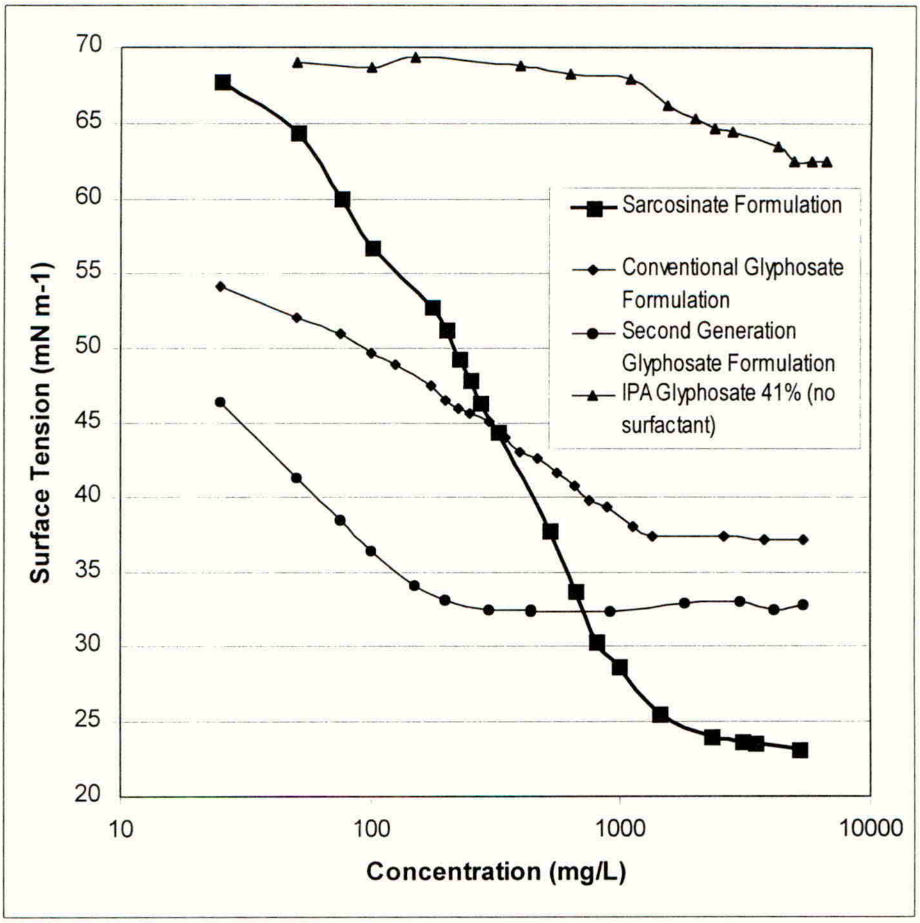

Figure 1. Surface Tension vs. Concentration of Glyphosate Formulation

EYE TISSUE TOXICITY

Conventional glyphosate formulations carry hazard cautions because of the potential that the formulation may cause substantial eye injury. The potential of the test formulation to cause injury to excised bullock cornea was assessed using an in vitro method. In this method a MTT assay is used to determine the viability of the bullock cornea cells which have been exposed to the test substance for a fixed period of time.

A sample of the tissue was immersed in a 25% solution of the pesticide for 30 minutes and subsequently assayed for viable mitochondria by an MTT assay. The MTT assay, (Carmichael et al, 1987) is a colorimetric method for determining cell viability based on the reduction of a tetrazolium salt (MTT) into a colored formazan dye, by mitochondrial enzymes of the electron transport chain. The extent which the number of viable mitochondria has been reduced, compared to that of the control, is taken as a measure of the toxicity of the test substances to the cells of the tissue. The two commercial formulations and glyphosate without surfactant were run as controls. The results are presented in Table 2.

The commercial formulations significantly reduce the viability of the tissue whereas the systems containing sarcosinate, and glyphosate alone, do not.

Table 2. Corneal Tissue Toxicity of Glyphosate Formulations

Sample	Percent Viability at 30 Minutes
CSIPA, 4%	105
Roundup	44
Roundup Ultra	31
Glyphosate IPA 41% (without adjuvant)	110
Positive Control	24
Negative Control, saline	100

Notes: All systems contained 41% glyphosate IPA and were diluted 4:1 before application to the tissue.

AQUATIC TOXICITY

Inevitably, quantities of formulated glyphosate will end up in watercourses from spray drift, run-off, rinsing of equipment and disposal of containers. Glyphosate formulations containing 4% isopropylammonium cocoyl sarcosinate and ammonium cocoyl sarcosinate were evaluated for their potential to cause toxicity to rainbow trout. Commercial, conventional and second-generation glyphosate products were run as controls. The results, expressed as 96 hour LC_{50}, the concentration required to kill half the test population in 96 hours, are presented in Table 3. The systems containing sarcosinates as adjuvants can be seen to be more than 20 times less toxic than the conventional glyphosate formulation and more than 40 times less toxic than the second-generation product.

Table 3. Aquatic Toxicity of Glyphosate Formulations

Formulation	Aquatic Toxicity (Rainbow Trout) LC_{50} (96 Hour) mg/L
Ammonium Cocoyl Sarcosinate 4%	> 400
IPA Cocoyl Sarcosinate 4%	> 400
Roundup	20
Roundup Ultra	7.5

All formulations contain 41% glyphosate IPA.

PHYTOTOXICITY TO GLYPHOSATE TOLERANT CORN

Glyphosate formulations containing IPA cocoyl sarcosinate and ammonium cocoyl sarcosinate were applied to corn, which had been genetically transformed to be resistant to glyphosate herbicide. The commercial products and IPA glyphosate without adjuvant were run as controls. All products were applied directly to the whorl of each plant at 4 and 8 times the recommended glyphosate use rate. The results are presented in Table 4. The commercial products caused greater than 50% injury to the plants at the higher concentration, whereas the sarcosinate-based formulations, which caused less than 4% injury, are virtually equivalent to glyphosate without adjuvant.

Table 4. Phytotoxicity of Glyphosate Formulations to Glyphosate Tolerant Corn

Formulation	**Rate Kg ai/ha**	**Corn % Injury**	**Corn Height**
Isopropylammmonium Cocoyl Sarcosinate 4%	4.488	3.30 d	29.70 ab
(41% Isopropylammonium Glyphosate)	8.975	5.00 cd	29.70 ab
Ammonium Cocoyl Sarcosinate 4%	4.488	3.30 d	28.70 ab
(41% Isopropylammonium Glyphosate)	8.975	3.30 d	29.00 ab
Ammonium/Sodium Cocoyl Sarcosinate 4%	4.488	3.30 d	30.30 a
(41% Isopropylammonium Glyphosate)	8.975	6.70 cd	29.30 ab
Roundup	4.488	16.70 b	27.00 b
	8.975	55.00 a	20.70 c
Roundup Ultra	4.488	13.30 bc	31.00 a
	8.975	61.70 a	17.70 d
Isopropylammmonium Glyphosate 41%	4.488	3.30 d	31.00 a
(no surfactant)	8.975	0.00 d	31.30 a
Water		0.0 d	31.30 a

Notes:

1) Plants were about 10" at time of application.
2) Treatments were diluted to an application volume of 197 L/ha and 3 mls were applied by syringe to the whorl of each plant.

Means followed by same letter do not significantly differ (P= 0.05 Duncan's New MRT)

CONCLUSIONS

Sarcosinates act as effective adjuvants in glyphosate at low concentration. At required use concentration, the sarcosinate formulation does not cause damage to corneal tissue.

The sarcosinate formulation is more than an order of magnitude less toxic to rainbow trout than commercially available glyphosate formulations.

The sarcosinate based adjuvant system is non toxic to glyphosate resistant corn whereas the adjuvant systems in commercial products can cause significant injury and deformation at elevated application rates. This surfactant phytotoxicity might cause yield drag at normal application rates.

The efficacy of sarcosinate may be linked to its potential to reduce surface tension of the spray solution to below 25 mN m^{-1}.

REFERENCES

Carmichael J; Degraff W G; Gazdar A F; Minna J D; Mitchell J B (1987). Evaluation of a Tetrazolium-Based Semiautomated Colorimetric Assay: Assessment of Chemosensitivity Testing. In: *Cancer Research*. **47**, 936-942

Holloway P J; Stock, S (1990). Factors Affecting the Activation and Uptake of Agrochemicals. In: *Industrial Applications of Surfactants II*, Karsa D R. (ed), R.S.C.

Chemical weed control in wet - seeded rice

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ABSTRACT

A study was conducted in Aus season (March to June), 1996 and repeated in Aman season (July to November), 1997 at BRRI farm, Gazipur to observe the efficiency of three herbicides in controlling weeds in wet-seeded rice. The treatments were (i) Cinosulfuron @ 20 g a.i./ha (ii) Oxadiazon @ 50 g a.i./ha (iii) Butachlor @ 1 kg a.i./ha (iv) Hand weeding (2 times), and (v) No weeding (control). Oxidizon and Cinosulfuron applications controlled weeds effectively in both Aus and Aman season. These herbicide results comparable grain yield to hand weeding and also incurred lower costs. So Oxadiazon @ 50 g a.i./ha and Cinosulfuron @ 20 g a.i./ha may therefore be recommended for effective and economical weed control under wet-seeded rice in Aus and Aman seasons.

INTRODUCTION

Direct seeding and transplanting can grow Rice. Broadcast Aus and Aman rice are direct seeded in dry soil and give lower yield than transplanted rice. Under favourable condition, transplanting during the Boro and T. Aman season may produce 5-7 tons/ha of rice. Rice grain yield does not vary between transplanting and direct seeding, in wet seeding method under good management. On the other hand direct seeding is less costly than transplanting due to a lower requirement of labour and water. Direct seeding is gaining popularity in much rice growing countries and also in Bangladesh.

The main disadvantage of direct seeding is high weed infestation. Effective and timely weed control is necessary in direct seeded rice. Hand weeding is costly now a day due to increase in labour cost. Chemical weed control may be a solution in this situation.

In many rice growing countries herbicides are extensively used in direct seeded and transplanted rice and provide effective and economical weed control (De Datta, 1972). So this experiment was undertaken to observe the performance of (i) Cinosulfuron; 3-(4,6-dimethoxy-1, 3, 5-triazin-2-yl)-[2-(2-methoxyethoxy)-phenylsulfonyl-urea, (ii) Oxadiazon; 3-[2. 4-dichloro-5- (methylethoxy) phenyle, and (iii) Butachlor; N- (Butoxymethyl)-2-Chloro-2', 6' diethylacetanilide] herbicides in controlling weeds in wet-seeded lowland rice.

MATERIALS AND METHODS

In the 1995 Aus season, three herbicides Cinosulfuron, Oxidizon and Butachlor were tested along with hand weeding (HW) at BRRI farm, Gazipur. The soil was heavy textured and slightly acidic (pH 6.8). The experiment was laid out in a randomized complete block design with four replications. The unit plot size was 5 m x 3 m. Brridhan 26, a modern variety was used as test crop in the experiment.

The land was prepared thoroughly by power tiller. Fertilizers N, P_2O_5, K_2O and S were applied @80-60-40-10 kg/ha, respectively. The pre-germinated seeds were broadcast on puddled soil at the rate of 50 kg/ha. Herbicides were applied at 6 days after seeding DAS). The treatments were (i)

Cinosulfuron @ 20 g a.i./ha, (ii) Oxadiazon @ 50 g a.i./ha, (iii) Butachlor @ 1 kg a.i./ha (iv) Hand weeding (2 times), and (v) No weeding (control).

The experiment was repeated in the Aman season, 1997 and the test variety was Brridhan 31. Data were collected on (i) Weed population and biomass weight, (ii) Weed control efficiency, (iii) Leaf area index (LAI), (iv) Plant height and tiller number of crop, (v) Yield component, and (iv) Grain and straw yield. The results thus obtained were statistically analysed using IRRISTAT software. The costs incurred in each weed control treatment were also determined.

RESULTS AND DISCUSSION

Weed growth

In the 1996 Aus season, Cinosulfuron and Oxadiazon 25 EC and the two hands weeded plot were similar in respect of weed population but were significantly lower than Butachlor treated and no weeded plot. Weed weight observed in the hand weeded plot was the lowest but comparable to Oxadiazon and Cinosulfuron treatment (Table 1). Butachlor treated plots produced higher weed weights than those of Cinosulfuron and Oxadiazon treatment.

In the 1997 Aman season, Cinosulfuron, Oxadiazon and the hand weeding treated plots resulted in similar weed populations. Butachlor resulted in a plot total weed population, which was higher than two hands weeded and other herbicide treated plots. A similar weed weight was found in the hand weeded, Oxadiazon and Cinosulfuron treated plots (Table 1). Oxadiazon, Cinosulfuron and hand weeding gave good control of grass and sedge and thereby reduced weed weight. The Butachlor treatment resulted in higher weed weights than Oxadiazon and Cinosulfuron treatments. Greatest weed weight was observed in the unweeded treatment due to higher weight of grass and sedges in both seasons. Weed control efficiency of Cinosulfuron and Oxadiazon treated plots were observed high and almost similar to the two times hand weeded plot.

Table 1. Effect of herbicides and hand weeding on weed weight at 40 DAS of wet-seeded rice.

Treatment	Grass (g/m^2)	Sedge (g/m^2)	Broadleaf (g/m^2)	Total	Weed control efficiency (%)
		Aus 1996			
Cinosulfuron @ 20 g a.i./ha	8.75 c	10.35 c	2.20 b	21.30 c	91.50
Oxadiazon @ 50 g a.i./ha	7.85 c	11.19 c	3.17 b	22.21 c	91.64
Butachlor 1 kg a.i./ha	40.35 b	48.25 b	8.25 b	96.85 b	46.41
Two hand weeding	6.65 c	11.25 c	2.16 b	20.96 c	91.20
No weeding	90.71 a	135.75 a	24.28 a	250.75 a	-
		Aman, 1997			
Cinosulfuron @ 20 g a.i./ha	8.72 c	16.45 b	1.53 a	16.70 cd	91.42
Oxadiazon @ 50 g a.i./ha	5.60 c	9.87 c	2.37 a	17.94 c	90.77
Butachlor 1 kg a.i./ha	22.95 b	44.65 a	7.12 a	74.72 b	61.58
Two hand weeding	4.35 c	6.84 c	2.96 a	14.15 d	92.72
No weeding	38.45 a	32.22 a	3.81 a	194.48 a	-

In a column in each season means followed by same letter(s) are not different significantly at 5% level by DMRT.

Table 2. Effect of herbicides and hand weeding on grain yields and yield component of wet-seeded rice.

Treatment	Panicles (no./m^2)	Filled grain (no./m^2)	1000 grain wt. (g)	Sterility (%)	Grain yield (t/ha)	Straw yield (t/ha)
			Aus, 1996			
Cinosulfuron @ 20 g a.i./ha	317.25 a	88.75 a	18.95 a	18.20 a	3.86 a	4.32 a
Oxadiazon @ 50 g a.i./ha	318.15 a	89.25 a	19.05 a	19.20 a	3.95 a	4.21 a
Butachlor 1 kg a.i./ha	280.55 b	81.55 b	18.88 c	19.75 c	2.95 b	4.28 a
Two hand weeding	325.16 a	91.35 a	18.75 a	18.95 a	4.05 a	4.25 a
No weeding	175.85 a	78.55 a	17.90 a	19.10 a	1.26 c	3.15 b
			Aman, 1997			
Cinosulfuron @ 20 g a.i./ha	357.0 a	98.65 a	21.25 a	12.14 a	3.02 a	4.10 a
Oxadiazon @ 50 g a.i./ha	369.9 a	105.25 a	22.05 a	13.65 a	3.76 a	4.20 a
Butachlor 1 kg a.i./ha	320.0 b	90.00 a	22.06 a	11.42 a	2.10 b	4.05 a
Two hand weeding	347.7 a	103.72 a	22.15 a	12.35 a	4.00 a	4.15 a
No weeding	185.7 c	82.16 b	22.12 a	10.68 a	1.71 c	2.36 b

In a column in each season means followed by same letter(s) are not different significantly at 5% level by DMRT.

Plant growth

In the 1996 Aus season, the LAI of the Cinosulfuron and Oxadiazon treated plots were similar to hand weeding (Fig. 1). Similar results were obtained in aman season, 1997. Butachlor treated plots resulted in lower LAI than the other herbicide treatments. The LAI was lowest in unweeded plots in both the seasons. Cinosulfuron and Oxadiazon treated plots gave comparable plant height tiller number to hand weeded plots. Butachlor treated plots gave lower plant height and tillers numbers than Oxadiazon and Cinosulfuron. Unweeded plots gave the lowest plant height and number of tillers.

Grain yields and yield component

In Aus season, 1996 Cinosulfuron and Oxadiazon treated plots produced comparable grain yield to hand weeding which produced the highest grain yield (Table 2). Butachlor treated plot gave the lowest grain yield. The high grain yield of the Cinosulfuron and Oxadiazon treated plots was contributed to by the higher number of panicles/m^2 and filled grains/ panicle. In Aman season, 1997 similar grain yield was obtained in Cinosulfuron, Oxadiazon and two hand weeding treatments but Butachlor gave a lower grain yield (Table 2). Unweeded plots produced the lowest grain yield in both the seasons.

COSTS OF WEED CONTROL

Cinosulfuron treatment incurred the lowest weed control costs (TK. 1250/- in Aus and Tk. 1280/- in Aman season) followed by Oxadiazon (Tk. 1400/- in Aus and Tk. 1450/- in Aman season; Tk 46=US$1) (Figure 2). Two hand weeded plots incurred the highest weed control costs in both Aus and Aman seasons. Butachlor treatment gave higher costs than the other two herbicides in both the seasons. Considering costs involved Cinosulfuron and Oxadiazon were more cost effective than Butachlor.

The experiment reveals that Cinosulfuron and Oxadiazon controlled grass and sedge weeds as effectively as hand weeding in both Aus and Aman seasons. No phytotoxicity effect of herbicides on rice plants was observed.

Cinosulfuron and Oxadiazon treatments resulted in a similar leaf area index to the hand weeding treatment, which indicated the normal growth of the plant. Cinosulfuron and Oxadiazon also gave comparable grain yield to hand weeding due to effective weed control as hand weeding in both Aus and Aman season. Butachlor was not comparable to hand weeding in controlling weed, moreover it showed adverse effect on plant growth. On the other hand Cinosulfuron and Oxadiazon application were cheaper than hand weeding and Butachlor. These two herbicides can reduce the weeding cost in wet-seeded rice. Chemical weed control was also reported by many researcher to be less expensive (Ali *et al.*, 1977, Dubey *et al.*, 1977 and Mukhapadhay, 1978).

Therefore, in terms of weed control efficiency, economy of weed control and grain yield, Oxadiazon @ 50 g a.i./ha and Cinosulfuron @ 20 g a.i./ha might be considered as effective means of weed management in wet-seeded rice.

REFERENCES

Ali, M., A.A. Raj and S. Sankaraman. 1977. Weed control in direct-seeded rice. *Weed Science Conference Workshop in India* (Abstract), Hyderabad (January 17-20). Page 2.

Biswas, J.C., S.A. Sattar and S.B. Siddique. 1991. Evaluation of herbicides in direct-seeded rice. *Bangladesh Rice Journal*. 2 (1 & 2): 40-43.

De Datta, S.K. 1972. Chemical weed control in tropical rice in Asia. *PANS* 18: 433-400.

Dubey, A.N., G.B. Mann and M.V. Rao. 1977. Studies on weed competition weed control and varieties interaction with proposal and parathion in direct-seeded rice. *Indian Journal of Weed Science*. (2): 75-80.

Mukhapaddayay, S.K. 1978. Weed control in different rice culture system. 1. Weed control in lowland rice under submergence. *In: Proceedings National Symposium on Increasing Rice Yield in Kharif.* Central Rice Res. Institute, Cuttack, Orissa. Feb. 8-11.

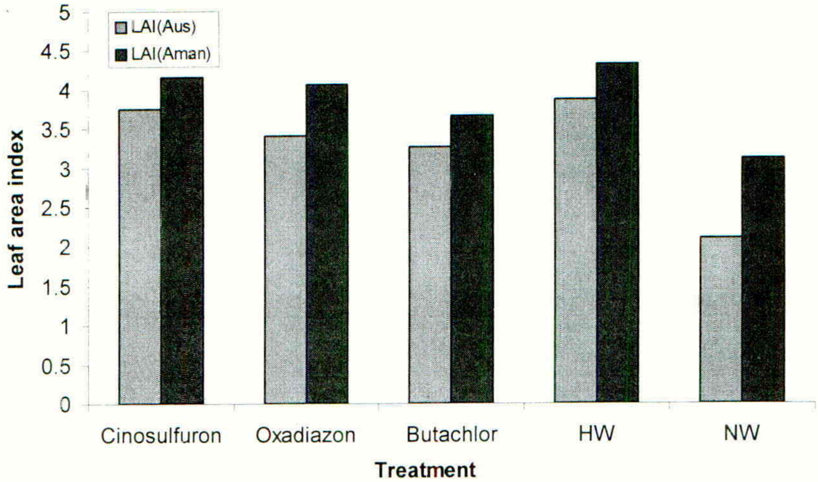

Fig.1. Leaf Area index (LAI) of direct seeded Aus and Aman rice as affected by Cinosulsuron,Oxadiazon and Butachlor application.

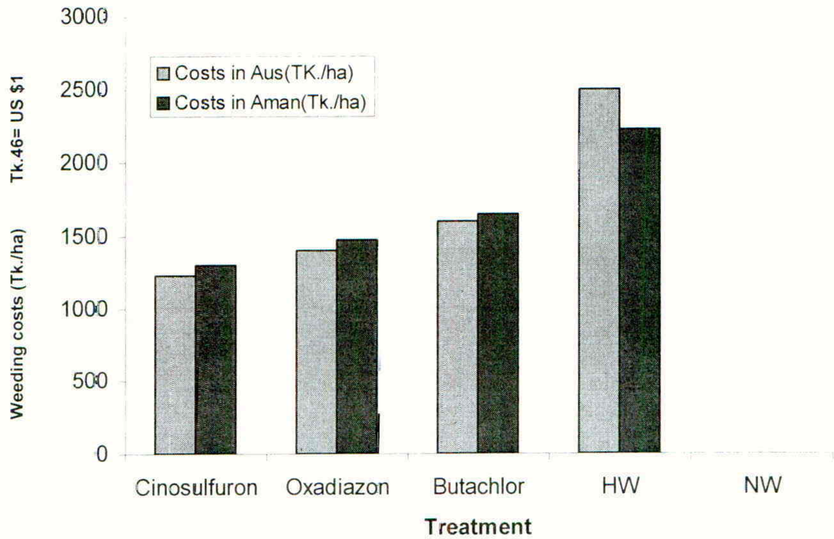

Fig.2. Cost (Tk./ha) of weed control with the application of the herbicides-Cinosulfuron,Oxadiazon and Butachlor in direct seeded Aus and Aman rice.