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Señor Director
DIRECCIÓN DE NUEVAS CREACIONES
Superintendencia de Industria y Comercio
E. S. D.

Trámite : **011**
Evento : **378**
Actuación : **444**

Referencia	Expediente No. 08075699
Asunto	SOLICITUD DE PATENTE PARA: **UN MÉTODO PARA CONTROLAR MALEZAS ACUÁTICAS**
Solicitante	BASF SE
Fecha de solicitud	22 de julio de 2008

1. Yo, Luz Clemencia DE PÁEZ, en mi condición de apoderada de la sociedad solicitante de la patente de la referencia, me refiero al oficio No. **8427** notificado por fijación en lista del 25 de MAYO de 2012.

2. Mediante oficio No. **8427** el Examinador a cargo del estudio de patentabilidad de la presente solicitud, en virtud del artículo 46 de la Decisión 486, solicitó la presentación de los siguientes documentos:

2.1 DATABASE CAB [Online] CAB INTERNACIONAL, WALLINGORD, OXON, GB; A. ZOSCHEET AL. "CGA142'464 plus BAS-514, a new timing-flexible herbicide combination for broadspectrum weed control in rice (Oryza sativa L.) in South Korea" XP 002464635 retrieved from STN-INTERNATIONAL Database: accession no. 91-73631. CABA & PROCEEDINGS, 12TH ASIAN PACIFIC WEED SCIENCE SOCIETY CONFERENCE, no. 1, 1989, pages 245 – 253

2.2 DATABASE CAB [Online] CHEMICAL ABSTRACTS SERVICE, COLOMBUS, OHIO, US; XP002464636 retrieved from STN – INTERNATIONAL Database accession no. 141:84041 CA & CN 1 401 232 A (ZHONGKAI AGRIC CHEM CO LTD) 12 march 2003 (2003-03-12)

2.3 "The e-Pesticide Manual (Thirteen Edition) Version 3.0" 2003, BRITISH CROP PROTECTION COUNCIL, XP002464632 entry 712: "Quinclorac"

NIT. 860.041.367-3

2.4 "The e-Pesticide Manual (Thirteen Edition) Version 3.0" 2003, BRITISH CROP PROTECTION COUNCIL, XP002464633 entry 713: "Quinmerac"

2.5 KLINGMAN; ET AL: "AQUATIC-WEED CONTROL" WEED SCIENCE, WEED SCIENCE SOCIETY OF AMERICA, CHAMPAIGN, IL, US 1982, pages 383-402 XP 002962279 ISSN 0043-1745

2.6 "The e-Pesticide Manual (Thirteen Edition) Version 3.0" 2003, BRITISH CROP PROTECTION COUNCIL, XP002464634 entry 211: "2,4-D"

2.7 KAY S. H.; ET AL "RESPONSE OF TWO ALLIGATORWEED BIOTYPES TO QUINCLORAC" JOURNAL OF AQUATIC PLANT MANAGEMENT, WASHINGTON, DC US, vol. 30 1992 pages 35-40 XP 008086947 ISSN 0146-6623

3. Respuesta al requerimiento

Con el ánimo de dar respuesta al requerimiento formulado por el Examinador, se presenta junto con el presente memorial, copia de los siete documentos arriba mencionados.

4. Puesto que se han atendido a cabalidad las observaciones hechas por su Despacho sobre la presente solicitud de patente, atentamente solicito que se continúe su tramitación.

5. Anexos

5.1 DATABASE CAB [Online] CAB INTERNACIONAL, WALLINGORD, OXON, GB; A. ZOSCHEET AL. "CGA142'464 plus BAS-514, a new timing-flexible herbicide combination for broadspectrum weed control in rice (Oryza sativa L.) in South Korea" XP 002464635 retrieved from STN-INTERNATIONAL Database: accession no. 91-73631. CABA & PROCEEDINGS, 12TH ASIAN PACIFIC WEED SCIENCE SOCIETY CONFERENCE, no. 1, 1989, pages 245 – 253

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TWELFTH CONFERENCE, 1989 245

CGA142'464 Plus BAS-514, A New Timing-Flexible Herbicide Combination for Broadspectrum Weed Control in Rice (*Oryza sative* L.) *in* South Korea

A. Zoschke[1], S. K. Yun[2], and U. Kiessling[3]

> Abstract <

CGA142'464 and BAS-514 are herbicides detected by CIBA-GEIGY Ltd. (Switzerland) and BASF AG (West Germany), respectively. A mixture of the two compounds was of interest, since the individually established biological profiles proved to be complementary and appeared to have the potential to provide broadspectrum weed control in rice.

During 1986 and 1988, a total of 20 trials was carried out to test this combination in transplanted rice (*Oryza sativa* L.) in south Korea. The objectives of these studies were to investigate. firstly, whether the CGA142'464/BAS-514-combination fits into the south Korean rice production system ; secondly, what the weed spectrum of this combination would be ; and thirdly, how it should be applied under south Korean conditions to provide an optimal biological performance.

The results showed that in south Korea a granular CGA142'464/BAS-514-combination was most effective when applied early post to post emergence to the weeds (10-15 days after transplanting) at a rate of 24 + 300 g a.i./ha. Such an application was safe to the rice crop and provided control of all the most important weed species in south Korean rice fields including grasses such as *Echinochloa crus-galli*, sedges such as *Eleocharis kuroguwai* and *Scirpus juncoides*, annual broadleaved weeds such as *Monochoria vaginalis*, and perennial broadleaved weeds such as *Potamogeton distinctus* and *Sagittaria* spp. Yield data confirmed the excellent performance of this rice herbicide combination.

From the field data, which proved its broad weed control spectrum as well as its application timing flexibility, it is concluded that with the CGA142'464/BAS-514-combination an interesting herbicide is offered to the south Korean rice farmer to stop weeds from competing with his rice crop.

INTRODUCTION

Rice cultivation in south Korea in 1985 was 1.2 mio. ha, of which 34% were transplanted by machine ; 72% and 28% of the varieties planted were of the japonica-type and indica x japonica-type, respectively (Kim et al., 1987). The introduction of machinery for rice transplanting has increased weed occurrence by 11-14% (Kim et al., 1986), and, additionally, the degree of weed suppression by the rice plants themselves is gone down probably due to the lower competitiveness of the less developed rice seedlings used in machine-transplanting (Kim et al., 1984). As a result, the proportion of perennial weeds and sedges increased (Guh & Lee, 1982 ; Huh & Guh, 1985 ; both cit. Huh *et al.*, 1987).

In south Korea, *Monochoria vaginalis*, *Sagittaria pygmaea*, *Cyperus serotinus*, *Potamogeton distinctus*, *Sagittaria trifolia*, *Rotala indica*, and *Eleocharis kuroguwai* have been identified as the dominant weed

[1] CIBA-GEIGY Ltd., AG 2.62, Postfach, CH-4002 Basel (Switzerland).
[2] YONGMA International Inc., C.P.O. Box 6132, Seoul (South Korea).
[3] BASF AG, Postfach 220, D-6703 Limburgerhof (West Germany).

species, but also *Echinochloa crus-galli*, *Eleocharis acicularis*, and *Ludwigia spp.* are important (Kim, S. C., 1983 ; cit. Kim et *al.*, 1986).

In general, yield losses due to weeds are higher in machine-transplanted rice compared with hand-transplanting (Kim *et al.*, 1984). Grasses such as *Echinochloa crus-galli* cause yield reductions of 5-89% (Noda *et al.*, 1968 ; MatsunaKA, 1976 ; both cit. Smith, 1983). Losses due to perennial weeds are 15-60% depending upon species under temperate climate conditions (Kim, 1983). Eguchi *et al.* (1987) reported that *Sagittaria pygmaea* decreased rice grain yield 20-30%. *Eleocharis kuroguwai* and *Cyperus serotinus* reduced yield by 59% in south Korea (De Datta, 1977 ; cit. Smith, 1983). The long period over which perennials emerge may account for the difficulty to control them (Kim, 1983).

Ryang (1986) has published a list of herbicides used in south Korea during 1978-1986.

BAS-514 provides consistent control of *Echinochloa spp.* and *Monochoria vaginalis* can be suppressed (Menck *et al.*, 1985). CGA142'464 has an excellent broad-spectrum activity controlling well paddy weeds such as *Scirpoideae* (sedges) and broadleaved weeds in annual as well as perennial forms ; under certain conditions, a reasonable degree of suppression of *Echinochloa spp.* can be achieved (Quadranti *et al.*, 1987). Some first information on the performance of both CGA142'464 and BAS-514 in south Korea has been reported by Kim *et al*, (1987).

The above mentioned biological profiles of the two compounds seemed interesting to develop a broad-spectrum herbicide combination for south Korean rice market. Therefore, our studies were aimed at the question whether the CGA142'464/BAS-514-combination fits into the South Korean rice production system, what the weed spectrum of this combination is under south Korean conditions, and how this mixture should be applied to provide an optimal biological performance.

MATERIALS AND METHODS

The CGA142'464/BAS-5140 combination has been field tested in south Korea since 1986. The respective trials were carried out at several locations throughout south Korea and were run either in collaboration with KYUNG NONG CORP., Seoul, or carried out through the technical department of BASF AG, Seoul.

Test compounds

The compounds used were CGA142'464 and BAS-514. CGA142'464 has been detected and developed by CIBA-GEIGY Ltd., Basel (Switzerland) ; the chemical as well as toxicological properties of the active ingredient have been described by Quadranti *et al.* (1987). BAS-514 has been detected and developed by BASF AG, Ludwigshafen (West Germany) ; the chemical and toxicological properties of the active ingredient have been described by Menck *et al.* (1985) and Wuerzer & Berghaus (1985).

Application timing of the combination of CGA142'464/BAS-514 was 10 or 15 DAT (Days After Transplanting). CGA142'464 was tested at a rate of 21-30 g a.i./ha (when applied at 10 DAT) or 24-45 g a.i./ha (when applied at 15 DAT), while BAS-514 was always used at 300 g a.i./ha.

Compounds were formulated as extruded granules and applied in a bag-mix in 1986, while in later trials ready-made-granules were used. Products were broadcast at 3 g/sqm.

Trial details

Between 1986 and 1988 a total of 20 trials (10, 6, and 4 trials in 1986, 1987, and 1988, respectively) was carried out. Plot size was 12-20 sqm. Treatments were replicated three or four times.

Soil types at the locations mentioned above included 'clay loam', 'loam', and 'sandy loam'. Field and crop management (including plant protection measures and fertilization) as well as water management were carried out according to local practices.

Different varieties of rice (*Oryza sativa* L.) were used. They included varieties of the japonica-type (cvs. Akibarea, Daechung, Dongjin, Nakdong, Palgong, and Umbong) as well as hybrid-varieties of the indica x japonica-type (cvs. Baekyang, Jungweon and Samkang).

Age of seedlings was ranged from 26 to 40 days. Except for 4 hand-transplanted trials, rice seedlings were machine-transplanted. Transplanting date varied from May 15 to June 16 in relation to location and year.

Evaluations

Evaluations regarding efficacy ('crop tolerance' and 'herbicidal activity') were done using a percentage scale by estimating for each treatment the 'biomass reduction' of rice (relative to the handweeded check) or weeds (relative to the untreated check). Evaluation timings were 'early' at 30 DAT (ranging 25-45 DAT) and 'late' at 55 DAT (ranging 50-65 DAT). In most cases natural weed flora was existent ; in few trials, artificial seeding or transplanting of bulbs was done to ease evaluation of herbicidal activity.

Rice grain yields (unhulled at 14% moisture content) were taken from 13 trials at grain maturity. Standard products were tested in all trials for comparison reasons. All such products were applied at 5 DAT and included butachlor/bensulfuron at 750+51 g a.i./ha (in Fig. 4, 6), pretilachlor/bensulfuron at 300+51 g a.i./ha (in Fig. 3, 6), and pyrazolate/butachlor at 1800+1050 g a.i./ha (in Fig. 4, 6).

Additional information to Figures 1 to 6

Abbreviations used in Figures 4 and 5

CYPSE-*Cyperus serotinus*, ECHCG-*Echinochloa crus-galli*, ELOKU-*Eleocharis kuroguwai*, MOOVA-*Monochoria vaginalis*, PTMDI-*Potamogeton distinctus*, SAGPY-*Sagittaria pygmaea*, SAGTR-*Sagittaria trifolia*.

Compound rates used in Figures 1 to 6

Rate of BAS-514 was always 300 g a.i./ha. If none is indicated, rate of CGA142'464 was 21-30g a.i./ha (when applied 10 DAT) and 24-30 g a.i./ha (when applied 15 DAT).

RESULTS AND DISCUSSION

The field trials with the CGA142'464/BAS-514-combination were carried out for checking those parameters most important in a herbicide context : crop tolerance, weed spectrum, and rice grain yield.

Crop tolerance

The crop tolerance of a herbicide is known to depend on several factors. Since they were expected to have the biggest influence on the tolerance of rice, special emphasis was put on the parameters "climatic conditions (years)", "application timing", and "rice variety".

Climatic conditions, such as temperature, have shown an effect upon the crop tolerance of the CGA142'464/BAS-514-combination ; however, in no case the highest phytotoxicity values ever exceeded the 10%-level, which means that the treatments were always acceptable in terms of crop tolerance. Nevertheless, some interesting tendencies were noticed ; Fig. 1 shows that the CGA142'464/BAS-514-combination in absolute terms was most phytotoxic in 1988, while 1987 was the safest year. Since this observation held true irrespective of location (e.g. soil type), one has to assume that temperature played an important role. In fact, from temperature data collected at the different locations 1987 can be characterized by relatively warm weather in the first 2-3 weeks following the treatments (mid May to early June) ; in contrast, in 1988 a period of comparatively low temperature was followed by a fairly warm month of June. In both cases, the mean daily temperature was increased by about 2-3 degrees Celsius in 1988 compared to 1987. 1986 was the coolest of all three trial years.

From these temperature differences it appears likely that in the cooler weather during the period following the herbicide application (1986), the rice crop recovered slowly from the treatment only, while the opposite happened in 1987.

Another important factor for crop tolerance was rice variety, since both japonica- and indica x japonica-type-varieties were grown in south Korea. As pointed out already, hardly any phytotoxicity was observed in 1987 ; therefore, such data were excluded for the comparison of rice types. When splitting crop tolerance data into the two rice types (compare Fig. 2), there was a tendency for japonica-varieties to be more susceptible to this treatment. Such effect is probably due to the sulfonylurea herbicides (Ryang *et al.*, 1986 ; Pyon *et al.*, 1987). However, the highest level of phytotoxicity observed with the CGA142'464/BAS-514-combination was always within the acceptable level of 10%.

Since results showed that japonica-type-varieties were more susceptible than indica x japonica-type-varieties, for the compilation of data on application timing flexibility (see Fig. 3), only trials including japonica-varieties have been used. When application timing was delayed (15 DAT), the CGA142'464/BAS-514-combination never showed any significant sign of phytotoxicity. If the standard treatments were slightly more phytotoxic than our combination, then this may be due mainly to the fact that all the standards were herbicides recommended for early application (at 5 DAT) at which the phytotoxicity risk tends to be higher.

In summary, it can be stated that the CGA142'464/BAS-514-combination will be safe to south Korean rice, when this herbicide was applied between 10-15 DAT.

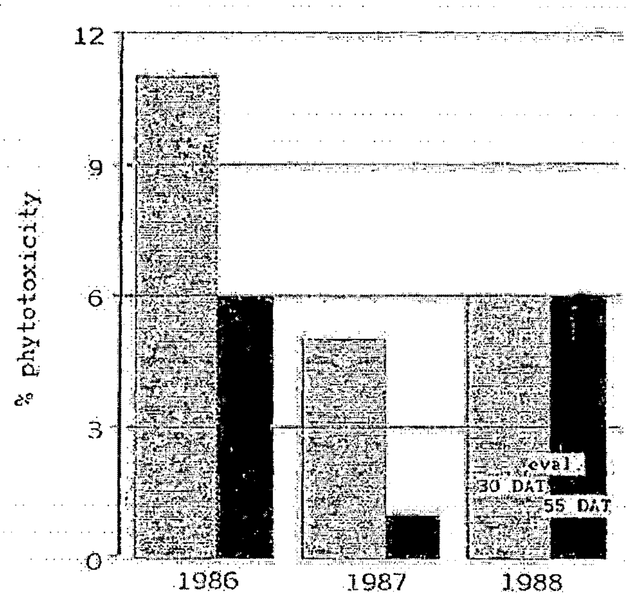

Fig. 1. Rice crop tolerance of the CGA142'464/BAS-514-combination in relation to trial year (mean over all varieties, appl. 10 DAT)

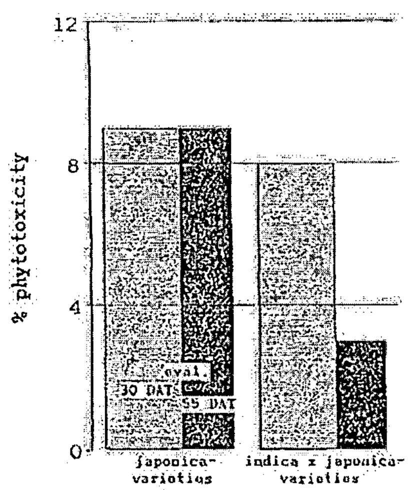

Fig. 2. Rice crop tolerance of the CGA142'464/BAS-514-combination to japonica- and indica × japonica-type-varieties (mean 1986/1988, appl. 10 DAT)

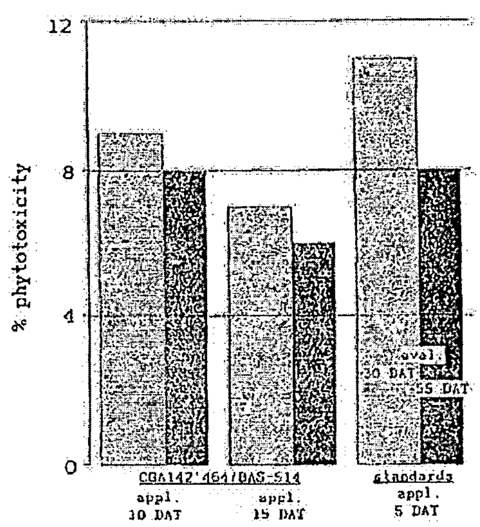

Fig. 3. Rice crop tolerance of the CGA142'464/BAS-514-combination to japonica-type-varieties in relation to application timing (mean 1986/1988)

Weed spectrum

Basically, our studies were aimed at investigating the dose of CGA142'464, performance of the CGA142'464/BAS-514-combination relative to application timing, and establishment of a list of susceptible weeds.

Fig. 4 shows the level of control of the CGA142'464/BAS-514-combination at two selected doses of CGA142'464, 24 and 30 g a.i./ha. Not all weed species have been included, because they were fully controlled (see later). It can be seen that the dose response generally is small. However, all in all 24 g a.i./ha of CGA142'464 are being considered optimal in order to achieve a constantly good level of weed control.

Compared with the standard herbicide used, the performance of the CGA142'464/BAS-514-combination was superior against a number of weed species, but most pronounced against *Eleocharis kuroguwai* and *Sagittaria trifolia*. The differences with the other weeds are probably not significant, even though the activity against *Cyperus serotinus* seems slightly inferior. However, a control level of 70-75% will be high enough to clearly reduce the competition from this weed.

Fig. 5 summarizes data of trials in which the CGA142'464/BAS-514-combination was tested for its application timing flexibility. From the first view it becomes clear that there is no major difference in performance between application timings. However, the speed of activity obviously is not quite the same ; when applied at 15 DAT, the peak of activity is often reached at the second evaluation timing (55 DAT) only, but at early evaluation (30 DAT) already in the case of an application at 10 DAT. This observation, however, has no consequence in terms of level of weed control or duration of activity, since the differences observed vary within relatively small limits at a already high level of activity.

In *summary*, based on our 3-year field experience in south Korea, the following weeds were found to be susceptible to the CGA142'464/BAS-514-combination :

Echinochloa crus-galli	Gramineae	*Ancilema japonicum*	Commelinaceae
		Lindernia procumbens	Scrophulariaceae
Cyperus difformis	Cyperaceae	*Ludwigia prostata*	Oenotheraceae
*Cyperus serotinus**		*Monochoria vaginalis*	Pontederiaceae
Eleocharis kuroguwai		*Potamogeton distinctus*	Potamogetonaceae
Fimbristylis miliacea		*Rotala indica*	Lythraceae
Scirpus juncoides		*Sagittaria pygmaea*	Alismataceae
		Sagittaria trifolia	Alismataceae

* weed species is not entirely controlled but heavily suppressed from the herbicide treatment)

When compared to the weeds identified by Kim, S. C. (1983 ; cit. Kim *et al.*, 1986), it can be seen that the weed spectrum controlled by the CGA142'464/BAS-514-combination include all the species dominant in south Korean paddy fields. In addition, CGA142'464 is known to control other weeds that may occur in South Korean rice fields as well, such as *Eleocharis acicularis* (Quadranti *et. al.*, 1987). Unfortunately, however, the infestation of this weed was never high enough to allow a reasonable judgement.

Data published by Kim *et al.* (1987) confirm the good performance of the CGA142'464/BAS-514-combination against *Echinochloa crus-galli*, but also against *Eleocharis kuroguwai*. If *Eleocharis kuroguwai* is well controlled, this may be linked with its late germination and slow development in temperate climate (Kim 1983 ; Kwon & Seong, 1983) ; while annual weeds need 5-7 days after puddling for emergence only, the propagule of *Eleocharis kuroguwai* can require up to 20 days. Since the sulfonylurea is translocated to the actively growing meristems, one can assume that the herbicide will act best when applied during the early stages of *Eleocharis kuroguwai* development ; and this will be

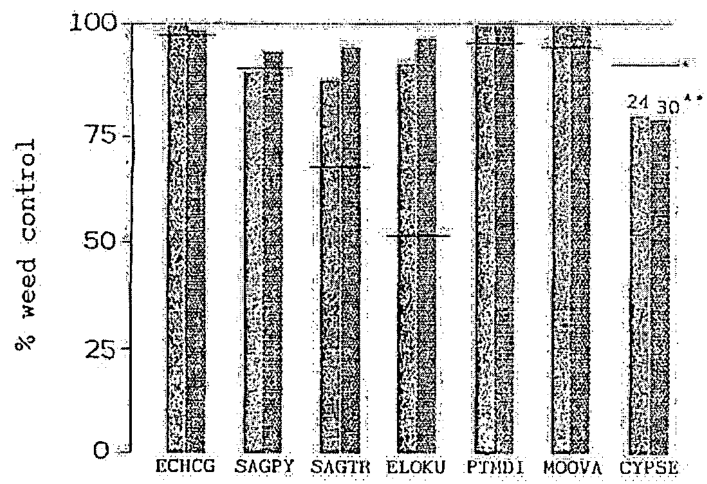

Fig. 4. Weed control of the CGA142'464/BAS-514-combination relative to the rate of CGA142' 464 and in comparison with the standard (1987, appl. 10 DAT, eval. 30 DAT)

* standard

** rate of CGA142'464 (g a.i./ha)

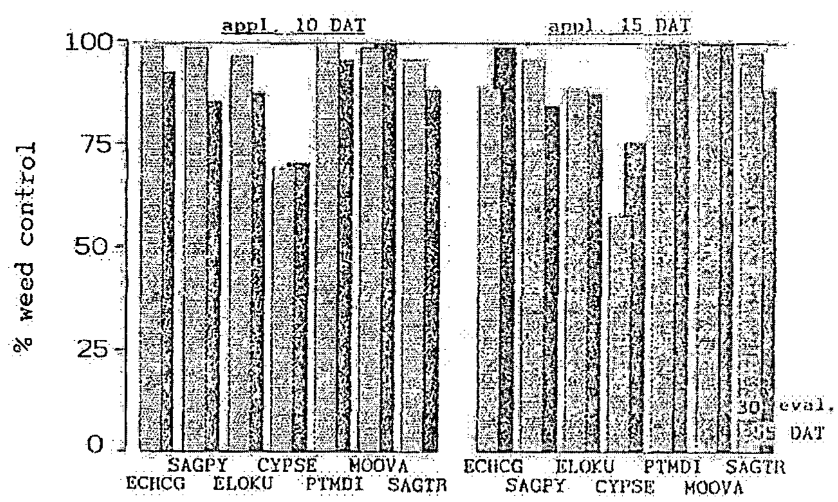

Fig. 5. Weed control of the CGA142'464/BAS-514-combination as influenced by application timing (mean 1987/1988)

the case with the CGA142'464/BAS-514-combination at its recommended application timing of 10-15 DAT.

Rice grain yield

In average, rice in the untreated check yielded 5.10 t/ha (=100%). All the herbicide treatments tested for their effectiveness in enhancing rice grain yield resulted in an increase of 20-25% (compare Fig. 6); there were no significant yield differences between the CGA142'464/BAS-514-combinations

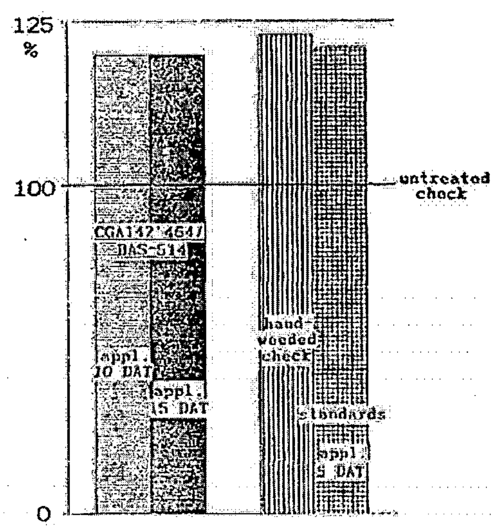

Fig. 6. Rice grain yield of the CGA142'464/BAS-514-combination as compared with checks and standard treatments (100% = 5.10 t/ha)

when applied at 10 or 15 DAT. All the herbicide treatments yielded about the same compared with the check that was handweeded according to local practise.

CONCLUSIONS

Our field trials have clearly shown the excellent performance of the CGA142'464/BAS-514-combinations in south Korean rice fields. When applied at 10-15 DAT (days after transplanting) at a dose of 24+300 g a.i./ha, this herbicide will be safe to the rice crop (both japonica- and indica x japonica-type-varieties) and will control a wide range of weeds; according to available information, the weed spectrum of CGA142'464/BAS-514 covers today's most widely spread weeds in South Korean rice firlds including difficult-to-control perennial weeds. The excellent performance profile of this herbicide combination is supported by yield data reaching a level similar to that of the handweeded check. The good application timing flexibility and its low dose are additional positive features of the CGA142'464/BAS-514-combination.

From the field data it can be concluded that the CGA142'464/BAS-514-combination offers an excellent solution to the South Korean farmer to stop the most important weeds from competing with his rice crop.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to all the gentlemen responsible for the excellent establishment and evaluations of our trials with the CGA142'464/BAS-514-combination, especially the technical department of KYUNG NONG Crop., Seoul, and BASF AG, Seoul.

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CLASS

PATENT NO.	CLASS	PATENT FAMILY CLASSIFICATION CODES
CN 1401232	ICM	A01N043-76
	IPCI	A01N0043-76 [ICM,7]; A01N0043-72 [ICM,7,C*]
	IPCR	A01N0043-72 [I,C*]; A01N0043-76 [I,A]

AB - The herbicidal compn. is composed of fenoxaprop-o-Et and other compd. (such as quinclorac, bensulfuron Me, and/or pyrazosulfuron ethyl). The herbicidal compn. may be used to prep. suspension, wettable powder, emulsion, granule, etc for removing Panicum crus-galli, Leptochloa chinensis, Monochoria vaginalis, etc.
ST - synergistic herbicide fenoxaprop ethyl quinclorac bensulfuron pyrazosulfuron
IT - Echinochloa crus-galli
Leptochloa chinensis
Monochoria vaginalis
Pesticide formulations
Potamogeton distinctus
Sagittaria pygmaea
(fenoxaprop-p-Et-contg. synergistic herbicidal compn., its prepn. and application)
IT - Herbicides
(synergistic; fenoxaprop-p-Et-contg. synergistic herbicidal compn., its prepn. and application)
IT - 502161-83-3, Fenoxaprop-p-ethyl-bensulfuron methyl mixt. 713502-63-7 713502-65-9
RL: AGR (Agricultural use); BIOL (Biological study); USES (Uses)
(fenoxaprop-p-Et-contg. synergistic herbicidal compn., its prepn. and application)

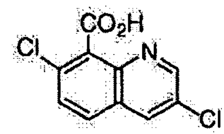
The e-Pesticide Manual (Thirteenth Edition) Version 3.0
BCPC (British Crop Protection Council)

quinclorac (712)

Herbicide

HRAC O, also L **WSSA** 4; quinolinecarboxylic acid

XP-002464632



NOMENCLATURE

Common name quinclorac (BSI, draft E-ISO, (*m*) draft F-ISO)
IUPAC name 3,7-dichloroquinoline-8-carboxylic acid
Chemical Abstracts name 3,7-dichloro-8-quinolinecarboxylic acid
CAS RN *[84087-01-4]* **EEC no.** 402-780-1 **Development codes** BAS 514 H (BASF)

PHYSICAL CHEMISTRY

Mol. wt. 242.1 **M.f.** $C_{10}H_5Cl_2NO_2$ **Form** Colourless crystals. **M.p.** 274 ºC **V.p.** <0.01 mPa (20 ºC) **Kow** logP = -1.15 (pH 7) **Henry** 4.4×10^{-10} Pa m^3 mol^{-1} (calc.) **S.g./density** 1.75 **Solubility** In water 0.065 mg/kg (pH 7, 20 ºC). In ethanol, acetone 2 g/kg (20 ºC). Practically insoluble in other organic solvents. **Stability** Stable to heat and light and between pH 3 to 9. **pKa** 4.34 (20 ºC)

COMMERCIALISATION

History Herbicide reported by E. Haden *et al.* (*Proc. Br. Crop Prot. Conf. - Weeds*, 1985, **1**, 77). Introduced in Spain and Korea (1989) by BASF AG. **Patents** EP 60429; US 4497651; US 4632696; DE 3108873 **Manufacturers** BASF; Sundat

APPLICATIONS

Biochemistry Synthetic auxin (acting like indolylacetic acid); also inhibitor of cell wall (cellulose) biosynthesis. **Mode of action** Rapidly absorbed through the foliage. Weak auxin activity as determined in wheat coleoptile elongation test, cucumber root elongation test, cucumber curvature test and ethylene biosynthesis test in soya beans. No influence on Hill reaction. Plant response is similar to IAA or auxin-type herbicides of the class of benzoic acids and pyridine compounds. **Uses** Pre- and post-emergence control of grass weeds (*Echinochloa* spp., *Aeschynomene* spp., *Sesbania* spp.) and other weeds in direct-seeded and transplanted rice, at 0.25-0.75 kg/ha. **Phytotoxicity** Non-phytotoxic to transplanted and direct-seeded rice. Under continuous irrigation conditions, injury may occur in adjacent umbelliferous crops if connected to the same waterway. **Formulation types** GR; SC; WP. **Compatibility** Good combination partner for all rice herbicides which are insufficiently effective against *Echinochloa*. **Selected products:** 'Facet' (BASF); 'Queen' (Sanonda)

OTHER PRODUCTS

'Accord' (BASF); 'Drive' (BASF); 'Paramount' (BASF); 'Fas-Nox' (Crystal) **mixtures:** 'Cao Neng' (+ bensulfuron-methyl) (Anhui); 'Propacet' (+ propanil) (Crystal)

ANALYSIS

Product analysis by rplc with u.v. detection (*CIPAC Handbook*, 1998, **H**, 244). **Residues** in plant and animal matrices by glc, in soil by hplc.

MAMMALIAN TOXICOLOGY

Oral Acute oral LD_{50} for rats 2680, mice >5000 mg/kg. **Skin and eye** Acute percutaneous LD_{50} for rats >2000 mg/kg. Non-irritating to eyes and skin (rabbits). **Inhalation** LC_{50} (4 h) for rats >5.2 mg/l. **NOEL** (2 y) for rats 533 mg/kg b.w. **Other** Not carcinogenic. **Toxicity class** WHO (a.i.) U; EPA (formulation) III **EC classification** Xi; R43

ECOTOXICOLOGY

Birds Acute oral LD_{50} for mallard ducks and quail >2000 mg/kg. Dietary LD_{50} (8 d) for mallard ducks >5000 mg/kg. **Fish** LC_{50} (96 h) for rainbow trout, bluegill sunfish, carp, and minnows >100 mg/l. **Daphnia** LC_{50} (48 h) 113 mg/l. **Other aquatic spp.** LC_{50} (96 h) for mysid shrimp (*Mysidopsis bahia*) 67, blue crab >100 mg/l. LC_{50} (48 h) for Quahog clam >100 mg/l. **Bees** Non-toxic by contact or ingestion.

ENVIRONMENTAL FATE

Animals More than 90% of radiolabelled quinclorac administered orally to rats is excreted in the urine within 5 days. **Plants** In plants, systemically translocated to the roots and to the leaves. **Soil/Environment** Only slightly adsorbed by the soil. Depending on soil type and organic matter content, the chemical is relatively mobile, this mobility increasing with higher percolation rates in fields. Quinclorac is degraded by micro-organisms, 3-chloro-8-quinolinecarboxylic acid being a major metabolite. Water regimes causing changes in moisture content in rice soils enhance the microbial degradation. Photolytic decomposition in active paddy water occurs in the presence of sunlight and dissolved humic acids.

quinmerac (713)

Herbicide

HRAC O **WSSA** 4; quinolinecarboxylic acid

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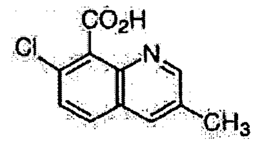

NOMENCLATURE
Common name quinmerac (BSI, draft E-ISO)
IUPAC name 7-chloro-3-methylquinoline-8-carboxylic acid
Chemical Abstracts name 7-chloro-3-methyl-8-quinolinecarboxylic acid
CAS RN *[90717-03-6]* **Development codes** BAS 518H (BASF)

PHYSICAL CHEMISTRY
Mol. wt. 221.6 **M.f.** $C_{11}H_8ClNO_2$ **Form** Colourless, odourless solid. **M.p.** 239 ºC **V.p.** <0.01 mPa (20 ºC) **Kow logP** = -1.11 (pH 7) **Henry** $<9.9 \times 10^{-6}$ Pa m^3 mol^{-1} **S.g./density** 1.49 **Solubility** In water (deionised) 223 mg/l, (pH 9) 240 g/l (both 20 ºC). In acetone, dichloromethane 2, ethanol 1, *n*-hexane, toluene, ethyl acetate <1 (all in g/kg, 20 ºC). **Stability** Stable to heat and light, and at pH 3-9. **pKa** 4.32 (20 ºC)

COMMERCIALISATION
History Herbicide reported by B. Wuerzer *et al.* (*Proc. Br. Crop Prot. Conf. - Weeds*, 1985, **1**, 63) and W. Nuyken *et al.* (*ibid.*, p. 71). Introduced by BASF AG and marketed since 1993. **Patents** DE 3233089 **Manufacturers** BASF

APPLICATIONS
Biochemistry Synthetic auxin (acting like indolylacetic acid). Induces formation of 1-aminocyclopropane-1-carboxylic acid, leading to ethylene formation which induces the formation of abscisic acid (K. Grossmann & F. Scheltrup, *Proc. Br. Crop Prot. Conf. - Weeds*, 1995, **1**, 393). **Mode of action** Taken up primarily via the roots, in post-emergence applications; in part also by the leaves. Moist conditions promote the uptake of the a.i. as well as the rapid onset of activity. Ethylene and abscisic acid production lead to epinasty, altered uptake and water relations and other effects. **Uses** Control of *Galium aparine*, *Veronica* spp. and other broad-leaved weeds in cereals, oilseed rape and sugar beet, at 0.25-1.0 kg/ha. **Formulation types** SC; WP. **Selected products:** 'Gavelan' (BASF); **mixtures:** 'Butisan Star' (+ metazachlor) (oilseed rape) (BASF); 'Fiesta' (+ chloridazon) (sugar beet) (BASF); 'Rebell' (+ chloridazon) (BASF)

OTHER PRODUCTS
'Nimbus' (BASF) **mixtures:** 'BAS 526H' (+ metazachlor) (BASF); 'Butisan Top' (+ metazachlor) (BASF); 'Katamaran' (+ metazachlor) (BASF); 'Novall' (+ metazachlor) (BASF)

ANALYSIS
Product analysis by hplc. Details available from BASF.

MAMMALIAN TOXICOLOGY
Oral Acute oral LD_{50} for rats >5000 mg/kg. **Skin and eye** Acute percutaneous LD_{50} for rats >2000 mg/kg. Non-irritating to skin or eyes (rabbits). **Inhalation** LC_{50} (4 h) for rats >5.4 mg/l. **NOEL** In feeding trials, NOAEL (12 mo) for rats 404, dogs 8 mg/kg b.w.; (78 w) for mice 38 mg/kg b.w. **ADI** 0.08 mg/kg b.w. **Other** Non-mutagenic, non-teratogenic, non-carcinogenic. **Toxicity class** WHO (a.i.) U

ECOTOXICOLOGY

Birds Acute LD_{50} for bobwhite quail >2000 mg/kg. **Fish** LC_{50} (96 h) for trout 86.8, carp >100 mg/l. **Daphnia** LC_{50} (48 h) 148.7 mg/l. **Algae** EC_{50} (72 h) for green algae (*Chlorella fusca*) 48.5 mg/l. **Bees** Not hazardous to bees; LD_{50} (oral and contact) >200 µg/bee. **Worms** LC_{50} for *Eisenia foetida* >2000 mg/kg soil.

ENVIRONMENTAL FATE

Animals Only minor metabolites formed (rat). **Plants** For details of metabolism in rape, wheat and sugar beet, see E. Keller, *IUPAC 7th Int. Congr. Pestic. Chem.*, 1990, **2**, 154. **Soil/Environment** DT_{50} (lab.) 28-85 d (20 °C), (field) 3-33 d. K_{oc} 19-185.

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29 Aquatic-Weed Control

Aquatic plants, as the term is used here, include those plants that normally start in water and complete at least part of their life cycle in water.

Excessive growth of aquatic weeds causes many serious problems for people who use ponds, lakes, streams, and irrigation and drainage systems. Excess weeds (1) obstruct water flow and increase water losses; (2) interfere with navigation, fishing, and other recreational activities; (3) destroy wildlife habitats; (4) cause undesirable odors and flavors; (5) lower real-estate values; (6) create health hazards; and (7) speed up the rate of silting by increasing the accumulation of silt and debris.

On the plus side, aquatic weeds may reduce erosion along shorelines, and some plant species provide food and protection for aquatic invertebrates, fish, fowl, and game. Algae are the original source of food for nearly all fish and marine animals; and swamp smartweed, wildrice, wild millet, and bulrush provide food and protection for waterfowl, especially ducks.

Controlling aquatic weeds sometimes causes problems other than those of the chemical itself. For example, the rapid killing of dense, weedy growth may kill fish, which happens even though the chemical is nontoxic to the fish. During photosynthesis, living plants release oxygen, and fish depend on this oxygen for respiration. When plants are killed, they produce no more oxygen. Worse yet, dead plants are decomposed by microorganisms that require oxygen for respiration. These two actions may reduce oxygen content in the water, causing the fish to suffocate. The answer is to treat only a part of very heavily infested areas at one time; fish will move to the untreated part.

Suppose you owned a recreation area suitable for both swimming and fishing. The right fertilization favors microscopic plants, used as food by fish. This heavy growth of microscopic plants makes the water appear cloudy or dirty and may give it an undesirable odor; hence it is less desirable for swimming. Here you can choose swimming or fishing, but not both—at least not at their best.

METHODS OF CONTROLLING AQUATIC WEEDS

Methods of controlling aquatic weeds include the following:

1. Proper construction of pond.
2. Competition for light.
3. Pasturing.
4. Drying.
5. Mowing.
6. Hand cleaning.
7. Chaining.
8. Dredging.
9. Burning.
10. Biological control.
11. Chemical control.

Proper Construction of Pond

Proper pond construction is highly important in controlling pond weeds. Many rooted aquatic plants are not easily established in deep water. The pond should be built so that as much water as possible is at least 3 ft deep. You can have water 3 ft deep only 9 ft from shoreline if all the edges of the pond have a slope of 3 to 1. Such a slope greatly reduces the area where cattails, rushes, and sedges first start growing. However, steep banks are hazardous for swimming. Gentle slopes should be provided for swimming areas.

Competition for Light and Fertilization

Ponds adequately fertilized develop millions of tiny plants and animals that give the water a cloudy appearance (bloom). If the water has a bloom and is at least 3 ft deep, submerged aquatic weeds have almost no chance to grow because of inadequate light. The benefits of fertilization include the following:

1. Increased growth of beneficial microscopic life, including phytoplankton and zooplankton.
2. Increased food supply for fish from the food chain that develops from the above.
3. Effective weed control by shading. Plants that do reach the surface should be cut off; otherwise they will be stimulated by the fertilizer.

A 16-20-4 or similar fertilizer is suggested at about 50 lb/acre. The

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first application is put on in early spring and is repeated as needed to maintain the cloudy appearance. A light-colored object should not be visible 1.5 ft below the surface. Fertilization of ponds is practical only where there is little loss of water from the pond, because fertility is lost with the overflow.

Pasturing

Pasturing is economical and effective in controlling marginal aquatic grasses, weeds, and some woody species. A good legume-grass pasture mixture, if properly managed and grazed, will give the banks and dam a lawnlike appearance. A good sod also protects the banks against erosion and helps to control undesirable species.

Excessive trampling may destroy the banks and muddy the water. Also, leeches in the water may attack animals, and some diseases are spread in the water to livestock, especially to dairy animals.

Drying and/or Freezing

Drying is a simple way to control many submerged aquatics. If the water can be drawn from the pond or ditch, leaf and stem growth of submerged weeds may be killed after 7–10 days' exposure to sun and air. Drying usually must be repeated to control regrowth from roots or propagules in the bottom mud or sand. In ditches this operation may be repeated several times per season.

Especially in cold climates, if the water is drawn down in late fall and the lake not allowed to refill until early spring, many aquatic weeds will be killed. As the lake refills, reinfestation may occur from weed pieces from the deeper part of the lake.

Mowing

Mowing effectively controls some ditch-bank weeds. Power equipment can be most easily used where the banks are relatively smooth and not too steep. Also, underwater power-driven weed saws and weed cutters are available. The effects usually are short-lived. Mowing is usually required at rather frequent intervals, and disposal of mowed weeds is often difficult.

Hand Cleaning

In lightly infested areas, hand cleaning may be the most practical method of control. A few hours spent in pulling out an early infestation may prevent the weed from spreading. The method is particularly effective on new infestations of emergent weeds such as cattail, arrowhead, and willow.

Chaining

Chaining aquatic weeds resembles chaining woody plants (see Chapter 27). A heavy chain, attached between two tractors, is dragged in the ditch. The chain tears loose the rooted weeds from the bottom. The method is effective against both submerged and emergent aquatics.

Chaining should be started whenever new shoots of emersed weeds rise about 1 ft above the water or when submersed weeds reach to the water surface. It should be repeated at regular intervals. Dragging the chain both ways may be effective in tearing loose most of the weeds.

The method is limited primarily to ditches of uniform width, accessible from both sides with tractors, and free of trees and other obstructions. After chaining it is usually necessary to remove plant debris from the ditch to keep it from collecting and stopping the flow of water.

Dredging

Dredging is a common method of cleaning ditches that are accessible from at least one side. The dredge may be equipped with the usual bucket, or a special weed fork may be used. Dredging may solve two problems: removal of weeds and removal of silt and debris.

Dredging has been tried in ponds from specially built pontoons, but in general the pontoon dredge has not proven practical. Dredging is an expensive operation, because of high equipment costs and the large amount of labor involved.

Burning

Burning may control ditch-bank weeds such as cottonwoods, willows, perennial grasses, and many annual weeds. Green plants are usually given a preliminary searing. After 10–14 days, vegetation may be dry enough to burn from its own heat.

Large trucks have been used in irrigation districts in the West. Each truck is equipped with a 30–35-ft maneuverable boom with oil-spraying nozzles at the end; lighter-weight equipment is also available.

Burning can also be combined with chemical- or mechanical-control programs. Burning the previous year's debris allows better spray coverage of regrowth. It may be desirable to burn the dead debris after chemical treatment. Mowing followed by burning the dried weeds may increase the effectiveness of the mowing.

Biological Control

Aquatic weeds have been controlled by fish, snails, insects, microorganisms, and higher plants. Ducks often effectively control duckweed in small ponds. Biological control has appeal because of the continuing control potential and the nonuse of chemicals in the water. However, as with other biological-control methods, care must be taken not to introduce a biological-control organism that will have undesirable side effects; for example, a fish that reduces the population of game fish.

Some freshwater fish will eat aquatic vegetation. The white amur (Chinese grass carp), tilapia, and silver dollar fish are used to control aquatic weeds in certain areas of the world. The white amur has been used in the People's Republic of China, Czechoslovakia, Poland, and the Soviet Union. It is now being used in Arkansas. See Figure 2-5.

For alligatorweed control a fleabeetle (*Agasicles hygrophila*), and a moth (*Vogtia malloi*) are providing control in the southeastern United States.

Although biological control holds great potential, its actual use has been limited. The federal government now supports considerable research on this method. Hydrilla and eurasian watermilfoil are two aquatic weeds receiving considerable research effort from the federal research program.

Chemical Control

Chemicals effectively control many aquatic and ditch-bank weeds. To control these you need to know (1) the name or names of the weed species, (2) the appropriate chemical, recommended rate, and time of treatment, and (3) the amount of water or size of area to be treated.

Water surface areas are usually measured in acres, like field areas. One acre is 43,560 ft^2, or an area 208.7 ft square (on each side). One acre-ft of water means 1 acre of water, 1 ft deep—that is, 43,560 ft^3 of water; 325,828 gal, or 2,719,450 lb. Thus, to produce a chemical concentration of 1 ppm, one would add 2.7 lb of the chemical (active ingredient) per acre-ft of water; 5 ppm would require 13.5 lb, and 5 ppm to an average depth of 3 ft would require 40.5 lbs. A closely related technique involves treating the "bottom acre-foot". Two methods of application are used. Using formulations that are heavier than water, the chemical can be applied to the water surface as either a spray or granule. The chemical sinks to the bottom. The second method involves drop hoses or weighted hoses dragged behind a boat, releasing the chemical at the lake bottom. Rates of application are usually based on a bottom acre ~~(43,560 ft²), much the same as with field-crop application. For conver-~~ sion factors to other measurements see page 429.

Running water is measured by several methods. Rates are usually given as *cubic feet per second;* 1 ft^3/sec is equal to 450 gal/min. Usually the rate of water flow is determined by the use of a weir and gauge.

CHEMICALS USED IN AQUATIC-WEED CONTROL

The more important chemicals used in aquatic-weed control are discussed below. The use of specific chemicals for control of certain aquatic weeds is given in Table 29-1. For more complete discussions of chemicals see Chapters 8 through 21. Trade names are on page 422.

Restrictions on the use of water that has been treated with an aquatic herbicide are extremely important. In potable domestic water supplies, copper has a residue tolerance of 1.0 ppm; 2,4-D, 0.1 ppm; and endothall, 0.1 ppm. Detailed instructions and restrictions are printed on the label. *Those instructions must be followed.*

Acrolein

Acrolein is useful for treating weed-infested drainage ditches and irrigation canals. It controls most submersed water weeds and many snails (see Table 29-1). In small irrigation canals in western states at rates of 1–2.5 gal/ft^3/sec flow of water, this chemical controls weeds from 6 to 20 miles downstream. However, the principal use of acrolein is in large canals where the usual treatment is 0.1–0.6 ppm on a volume basis (ppmv) for 8–48 hr. Weed control with these treatments may extend 20–50 miles downstream.

Treated water did not harm crops when used for irrigation at low concentrations. Higher concentrations may cause injury to susceptible crops, such as cotton. Acrolein is not effective in the control of water-plantain.

Acrolein is a potent irritant and lacrimator. It must be applied by licensed applicators. It may be toxic to fish.

Amitrole

Amitrole is safe to fish at normal rates. It is especially effective on cattails and bulrushes. A special form of amitrole and sodium thiocyanate known as amitrole-T is very effective on waterhyacinth and certain

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Table 29-1. Herbicides[1] Used to Control Several Common Aquatic Weeds

	Class[2]	Acrolein	Amitrole	Aromatic Solvents	Copper Ion	2,4-D	Dichlobenil	Diquat	Endothall	Fenac	Fluridone	Simazine
Algae												
Unicellular	S				X				X			X
Filamentous	S				X			X	X			X
Chara	S				X		X					X
Alligatorweed	E					X						
Arrowhead	E					X					X	
Bladderwort	S	X		X		X	X	X	X	X	X	
Bulrush	E		X			X						
Cattail	E		X			X						
Coontail	S	X		X		X	X	X	X	X	X	X
Duckweed	F					X		X			X	X
Elodea	S	X		X		X	X	X		X	X	
Hydrilla	S				X			X	X		X	
Naiad	S	X		X		X	X	X	X	X	X	X
Pickerelweed	E					X					X	
Pondweed	S	X		X		X	X	X	X	X	X	X
Rush	E					X						
Spikerush	S, E					X				X		
Waterhyacinth	F		X			X		X				
Waterlily	E					X	X				X	
Watermilfoil	S, E	X		X		X	X	X	X	X	X	X
Waterprimrose	S, F					X	X		X	X	X	

[1] See the manufacturer's label for rates, method of usage, species susceptibility, and precautions. Follow the label—regardless of statements in this book.

[2] F = Floating (unattached, tops above water). E = Emersed (rooted underwater or growing on wet soil, tops above water). S = Submersed (usually rooted in soil, tops mostly underwater).

other emergent and floating species. Amitrole is applied at 7–9 lb/acre active ingredient as a foliage spray. It should be applied on cattails between the time of flowering and seed maturity.

Aromatic Solvents

Aromatic oils have been particularly effective in controlling weeds in ditches with running water. These chemicals are deadly to fish, but the movement of water in irrigation canals usually has higher priority than saving fish in the canals. In the West, hand-weeding and dredging costs have been cut 80% with the aromatic solvents.

Aromatic solvents are sold as Varsol, Stoddard's solvent, paint thinners, general solvents, and for dry-cleaning clothes. Commercial forms specially developed for aquatic-weed control are available. The most effective ones had a flash point of not less than 80°F, distillation ranging between 278 and 420°F, and an aromatic content of not less than 85% (Bruns et al., 1955).

Velocity, temperature, exposure time, and rate all affect results in treating ditches. But one should not wait until the ditch is clogged seriously. Water velocities of $\frac{3}{4}$ to $1\frac{1}{4}$ ft/sec produced the best results. Water temperatures should be 70°F or above; in fact, the warmer the water, the lower the concentration required. Aromatic solvents are applied at the rate of 6–10 gal/ft^3 of water per second during 30–60 min. This provides a solvent concentration of 450–750 ppm.

Aromatic solvents strong enough to kill most submersed aquatic weeds caused no important injury when used to irrigate alfalfa, beans, lima beans, carrots, cotton, sorghum, white clover, lettuce, oats, sweet corn, potatoes, sugar beets, or potatoes (Bruns, et al., 1955).

Aromatics are very toxic to fish, crayfish, snails, plankton, and mosquito larvae. These chemicals often kill fish at concentrations as low as 5–10 ppm. If given the opportunity, fish will usually move from treated areas. Aromatics cause strong and persistent off-flavor in fish.

Livestock tend to avoid treated water, so there is no apparent danger to them. Guinea pigs forced to drink treated water showed no ill effects.

Copper Sulfate

Copper sulfate (bluestone, blue copperas, blue vitriol) and chelatec copper (such as ethylenediamine, triethanolamine, and alkanolamine are very effective against most kinds of algae, including chara. Soor after treatment the algae's color changes to a grayish white. Severa days after treatment, the water should be nearly free of algal growtl (see Figure 29-1).

2,4-D

Many aquatic plants are susceptible to 2,4-D dissolved in water at rate of 1–5 ppm by weight (see Table 29-1). To provide a concentration o 1.0 ppm in 1 acre-ft of water, 2.7 lb of 2,4-D (acid equivalent) are re quired. Water-soluble liquid forms of 2,4-D or granular forms may b used.

2,4-D should be exposed in water to susceptible weeds at full concer tration for at least 10 hr. In *nonmoving* water, 2,4-D in water-solubl form will tend to *distribute itself equally* over several days' time for di

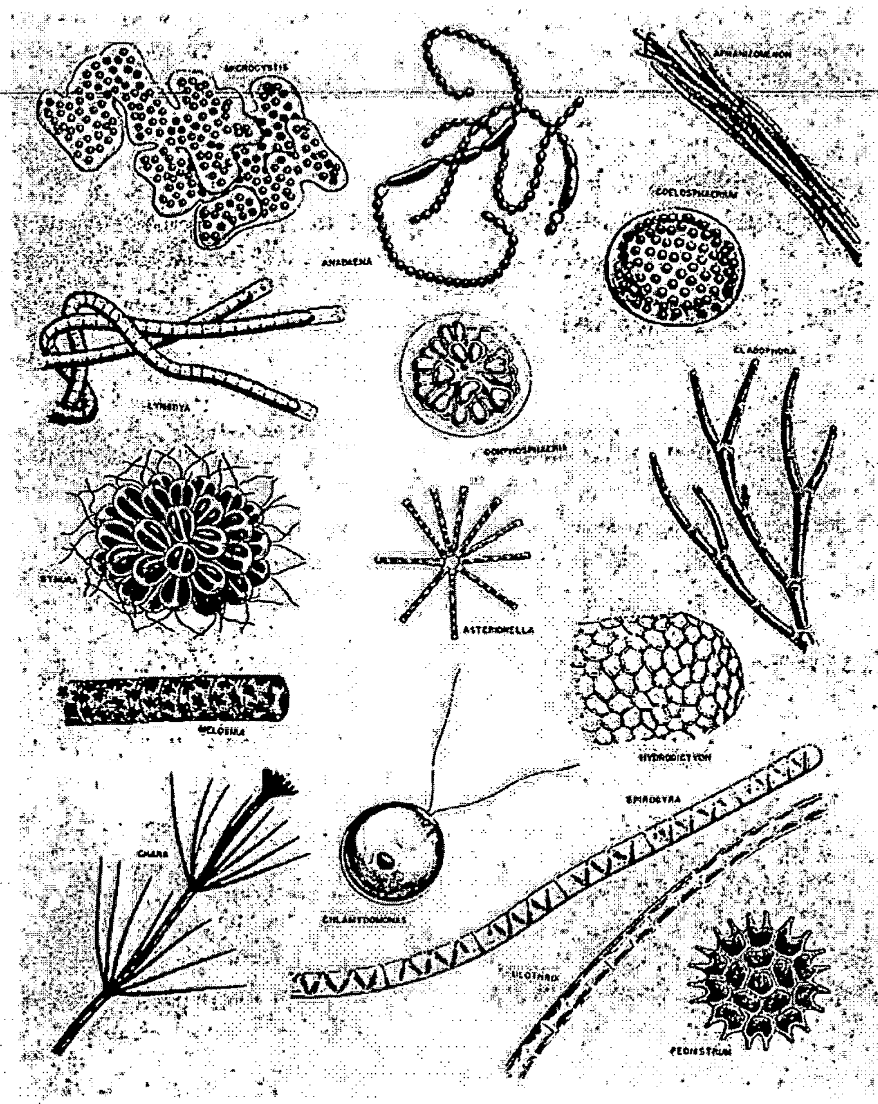

Figure 29-1. Algae often responsible for creating nuisance blooms. (C. M. Palmer and R. A. Taft, U.S. Public Health Service.)

tances up to 40 ft. *In contrast*, the granular form falls to the pond bottom, where a relatively high concentration may develop at the soil–water interface.

Fish were kept in 2,4-D sodium salt solution for one week. The LD_{50} concentration of 2,4-D for minnows 1.5–2.5 in. long was about 2000 ppm; for sunfish 2.5–4 in. long, 1000 ppm; and for catfish 5–6 in. long, 2000 ppm (Harrison and Rees, 1946). Thus 2,4-D sodium salt is considered low in fish toxicity. The same is true of most amine salts of 2,4-D.

Other work has shown ester forms of 2,4-D to be toxic to fish. Fingerling bluegills suffered losses of 40–100% from the butyl ester of

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2,4-D at concentrations of 1–5 ppm (Snow, 1948). Esters are oil-like and oil-soluble materials, and oils are known to be toxic to most fish. Esters may be acting similar to oils, or the oil solvents, emulsifying agents, or other additives may be killing the fish. When pure 2,4-D ester is used in granular form, without surface-active agents, there is considerably less hazard to fish.

For potable water or irrigation water, use of treated water should be delayed for three weeks after treatment or until the water does not contain more than 0.1 ppm of 2,4-D acid.

Dalapon

Dalapon is harmless to fish at normal rates. Lake emerald shiners apparently suffered no ill effects from three days in 3000 ppm of dalapon, but 5000 ppm was fatal.

Dalapon is especially effective against grasses and cattails. It is best applied as a foliage spray. Most species are susceptible if not rooted in standing water. Draining is advisable, if possible, several weeks before treatment with dalapon.

Dichlobenil

Granular dichlobenil controls many aquatic weeds in static water such as lakes and ponds. It is particularly effective on elodea, watermilfoil, coontail, chara, and pondweeds (*Potamogeton* spp.). It is applied in early spring at rates of 7–10 lb/acre before weeds start to grow. Although it does not harm fish at these rates, humans may not eat these fish until 90 days after treatment. It cannot be used in commercial fish or shellfish waters. It should not be applied to water that will be used for irrigation, livestock, or human consumption.

Diquat

Diquat controls many submersed aquatic weeds and algae in static water. Bladderwort, coontail, elodea, naiad, pondweeds, watermilfoil, spirogyra, and pithophora are among the species controlled. It is applied at rates of 1–4 lbs/surface acre.

Diquat can be applied by pouring directly from the container into the water while moving slowly in a boat. Early in the season strips 40 ft apart are suggested, later in the season 20 ft. For best results, it should be applied before weeds reach the surface of the water. Because diquat is a contact spray, repeated applications may be necessary to give seasonlong control.

It should not be used in muddy water because diquat is rendered ineffective by its tight adsorption on soil particles. Treated water should not be used for irrigation, agricultural sprays, swimming, or domestic purposes within 10 days after treatment. For human consumption, treated water should not be used for at least 14 days. It is not harmful to most fish at the recommended rate. In heavy weed infestations only $\frac{1}{3}$–$\frac{1}{2}$ of the area should be treated to avoid fish kill through oxygen depletion.

Endothall

Endothall is available as a number of derivatives and in several liquid and granular formulations. It controls most algae and submersed aquatic weeds in static and in some flowing waters. However, elodea is not controlled. It is applied at a broad range of rates—from 0.3 to 14 lb/acre-ft of water. Lower rates are for algae control and higher rates for coontail, watermilfoil, pondweeds, naiad, bass weed, and burreed control. Treated water should not be used for irrigation, agricultural sprays, animal consumption, or domestic purposes within seven days. Fish may be used as food three days after treatment.

Fenac

Fenac controls most submersed aquatic weeds where water can be removed from the area. Unlike other aquatic herbicides, fenac is applied to the soil surface, not to the water. Water is drawn down to expose the area where weeds root. Only exposed soil is treated. Water is kept down for three weeks after treatment. It is particularly useful in drainage ditches, ponds, and margins of lakes. However, it is not permitted where these waters are used for irrigation, livestock consumption, or domestic needs. Applications can be made anytime, but a treatment in the fall before freezing weather gives the best results. The rate is 15–20 lb/acre.

Fluridone

Fluridone is a new herbicide for aquatic-weed control. It controls at least 14 submersed and emersed plants. After application, chlorosis and a pinkish color show up in 7–10 days, but full herbicidal effects may take up to 60 days. About four weeks after treatment, susceptible weeds begin to sink to the bottom. This slow herbicidal response reduces the potential of fish kill from oxygen depletion.

Fluridone is adsorbed by the hydrosoil (lake-bottom soil), reaching a maximum one to four weeks after treatment. These hydrosoil residues declined to a nondetectable level after 16–52 weeks.

Simazine (Aquazine®)

Simazine may be used in ponds for control of several submerged and floating aquatic weeds and algae. Control of weeds is usually seasonlong. Algae may be controlled for one to three months or may require retreatment later in the season. Simazine may be used in ponds containing fish. It should be used only in ponds that will have little or no outflow after treatment. Simazine should not be used as a spot treatment.

Ponds are treated after seasonal flow has ceased early in the weed and algae growth period. They should be treated when 5–10% of the pond surface is covered with scum (algae mats) or floating weeds, and/or while submerged aquatic weeds are actively growing and before they reach the surface of the water. As a general rule, ponds in northern areas may be treated between May 1 and June 15. In southern areas, where water warms up and weed growth is earlier, ponds may be treated between April 1 and May 15.

High water temperatures cause more-rapid natural decay of dead weeds and algae that can cause fish distress; therefore, simazine should be applied before water temperatures exceed 75°F.

Ponds having an extremely heavy infestation of weeds and algae such as occurs in mid and late summer should not be treated, since rapid decomposition of heavy growth greatly reduces the oxygen content of the water, and this can cause fish distress and/or death.

Algae control requires 1.40–3.40 lb/acre-ft; submerged weeds, 2.7–6.8 lb; and floating weeds 2.7–5.4 lb.

Use of Fish and Water Following Use of Simazine

1. Fish taken from treated ponds may be used for human consumption.
2. Treated ponds may be used for swimming.
3. Water from treated ponds may not be used for irrigation or spraying of agricultural crops, lawns, or ornamental plantings, or for watering cattle, goats, hogs, horses, poultry, or sheep, or for human consumption until 12 months following treatment.
4. *Precaution:* Ponds that have bordering trees with roots visibly extended into the water must not be treated, since injury to these trees may occur. Usually, trees 50 ft or more from the pond's edge will not be injured.

AQUATIC WEEDS OF SPECIAL IMPORTANCE

Aquatic weeds are commonly classified by their growth habits: (1) *floating,* (2) *emersed,* and (3) *submersed.* Floating aquatic weeds are not attached to soil, and their tops are above water. Emersed aquatic weeds are rooted in soil with their tops above water. Submersed aquatic weeds are usually rooted in soil with their tops entirely or mostly under water. Table 29-1 gives the classification of 20 common aquatic weeds and herbicides that effectively control them. See Figures 29-2 and 29-3. Following are descriptions of some of the more important aquatic weeds.

Algae

Algae are so tremendously important as aquatic weeds that you might read more about them in an encyclopedia or botany book. Algae may annoy bathers, causing a type of dermatitis and symptoms of hay fever. Blue-green algae have been known to cause poisoning of horses, cattle, sheep, hogs, dogs, and poultry. Odors and fishy tastes often result from decaying algae in water reservoirs. Extremely heavy algae growth may suffocate fish by depleting the supply of oxygen in the water at night.

Algae are thallus-like plants with chlorophyll (green color). They may consist of a single cell, a single filament, branched filaments, or they may grow 200 ft long like the giant algae of the Pacific (known as kelp) (see Figure 29-1). They are often called pond scums or seaweeds.

Plankton algae are microscopic, free-floating (unattached) organisms. They frequently cause "water bloom" of mid to late summer. They may become so numerous that they give the water a thickened, green, pea-soup appearance.

Algae are extremely important synthesizers (producers) of food. They are the "original" sources of food and energy for most fish and aquatic

Figure 29-2. Several submersed aquatic weeds. *Left to right*: Watermilfoil, coontail, eelweed, pondweed, and largeleaf pondweed. (King and Penfound, 1946.)

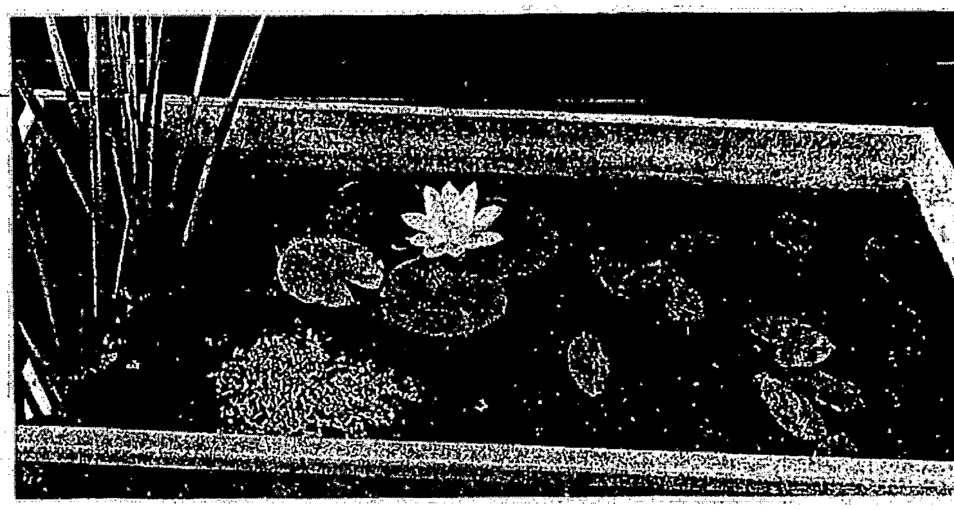


Figure 29-3. Emersed and floating aquatic weeds. *Left to right*: Burreed, duckweed, white waterlily, floating pondweed. (King and Penfound, 1946.)

animals. Algae live under moist conditions on land, in the soil, or in water—both salt and fresh.

Chara (*Chara* spp.)

Chara is a large, green algae characterized by branched, erect stems that have cylindrical whorls of branches along the stem. It is anchored to the bottom. In general appearance it resembles a higher plant. There are many different species (see Figure 29-1). These plants reproduce both vegetatively and by sexual fruiting bodies. After chara becomes encrusted with calcareous deposits, the plant takes on a coarse, gritty feeling and a gray-green shade. Chara, a submersed aquatic weed, thrives best in clear, hard water, and is found in water up to 20 ft deep.

Alligatorweed

Alligatorweed (*Alternanthera philoxeroides*) grows mostly along the coast from Texas to Virginia, reaching 25–150 miles inland, and it has been reported in California. It is widely distributed in the tropical areas of Central and South America.

It is a coarse, fleshy plant, forming dense mats in shallow water and on mud flats. It has narrow, opposite leaves and short spikes of whitish flowers (see Figure 29-4).

Alligatorweed depends on vegetative reproduction (stems) for its spread. Broken-off branches root easily and spread rapidly.

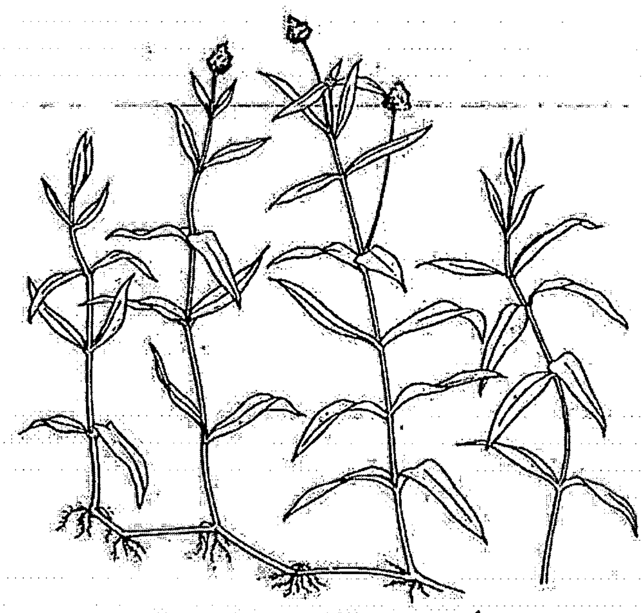
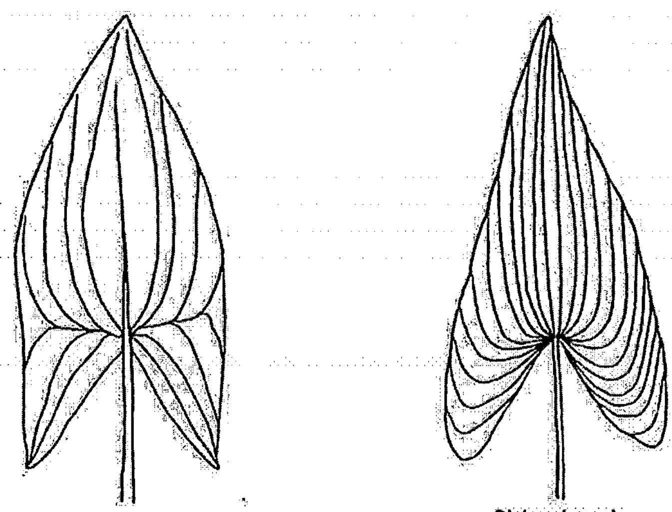


Figure 29-4. Alligatorweed.

Arrowhead (*Sagittaria* spp.)

Leaves of this group of plants give it its general name of arrowhead (see Figure 29-5). These plants are usually perennial, reproducing by seed and tuber-bearing rootstocks. Indians used the tubers as food. The stems usually have a milky juice. The plant is best adapted to shallow water or muddy shores. It can usually be found near the edges of the pond as a marginal weed.



Arrowhead (*Sagittaria latifolia*) | Pickerelweed (*Pontederia cordata*)

Figure 29-5. *Left*: Common arrowhead. *Right*: Pickerelweed.

Bulrush (*Scirpus* spp.)

~~The Bulrush genus has about 150 species, widely distributed.~~ The genus *Scirpus* is a member of the sedge family and is not a true rush. Most grow in marshes, ponds, and lakes. The stems are either triangular or rounded and sheathed at the base.

Cattails (*Typha* spp.)

Cattails dominate extensive marshy areas of the world. They are tall, grasslike plants with fleshy leaves having no midvein. They spread rapidly by rhizomes and by small, airborne seeds. Seeds remain viable for five years or more.

Small areas of cattails can be eliminated by pulling. Repeated underwater mowing is also effective. They should be cut when the first spikes reach two-thirds full size; this should be repeated when the cattail is again 2 ft tall. Most kinds of cattail are killed if submerged in 4 ft of water; *T. domingensis* requires deeper flooding.

Common Coontail (*Ceratophyllum demersum*)

Coontail is a submersed aquatic herb with whorls of finely dissected leaves (see Figure 29-2). In the spring the lower stem may anchor in the mud with the plant growing upright. Later the plant may become a tangled mass with filamentous algae. Leaves are crowded toward the tip of the stem, giving it the coontail appearance. The plant spreads by both seed and vegetative growth.

Coontail is common in shallow lakes, ponds, and sluggish streams. It is favored by water rich in organic material.

Duckweed Family (*Lemnaceae*)

Duckweeds are small, stemless, floating plants. They lack true leaves, but have thickened or rounded fronds. The family includes the smallest of the flowering plants. Duckweeds propagate mainly from vegetative growth that develops at the edge or base of the parent frond. Also, during the fall, small bulblets may develop at the edge of the leaf. These sink to the pond bottom, live through the winter, and germinate the next spring. Seed is usually produced sparingly, or not at all (see Figure 29-3).

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Elodea (*Elodea canadensis*)

Elodea, also known as waterweed, is a common plant of home aquariums. The leaf is veinless; leaf margins have microscopic teeth. Its leaves are attached to the stem in a whorled arrangement. Stems are floating and usually rooted to the bottom.

The plant is dioecious. Male flowers break loose or grow to the surface to shed their pollen. Female flowers grow to the surface after fertilization and produce up to five spindle-shaped seeds. See Figure 29-6.

Hydrilla (*Hydrilla verticillata*)

Hydrilla was first found in the United States near Miami, Florida, in 1960. It is now widely spread and has become a troublesome aquatic weed in southern United States and in California.

Figure 29-6. Egeria (*left*), hydrilla (*center*), and American elodea (*right*) have similar growth habits. Although individual plants of all three species vary in length and number of leaflets in whorls and in the distance between whorls, the scratchy feel of hydrilla readily distinguishes it. (Jack K. Clark, University of California, Davis.)

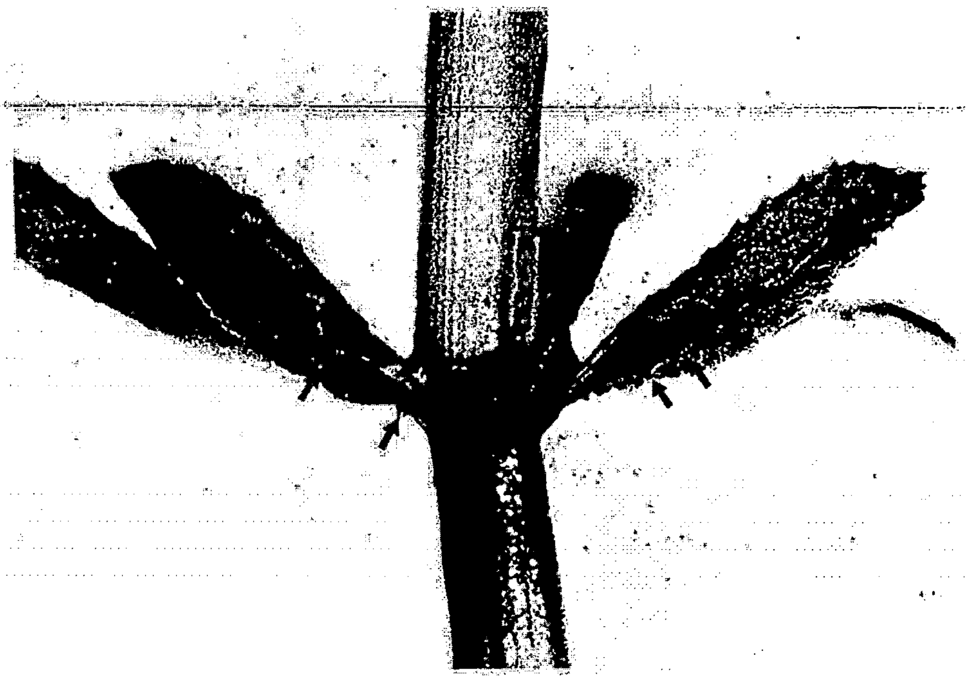

Figure 29-7. Small thornlike projections, occasionally black on the tips, that protrude from the midrib on the lower side of the leaf are characteristic of hydrilla. (Jack K. Clark, University of California, Davis.)

Hydrilla is a submersed vascular aquatic weed, rooted to the bottom with long branching stems. The lower leaves are opposite and small, whereas the medium and upper leaves are in whorls of fours and eights. Leaves are verticillate and narrow lanceolate. Hydrilla is easily confused with elodea and egeria. Hydrilla has sharply toothed leaf margins, small thornlike projections from the lower side of the leaf midrib, and a "harsh" feel. The flowers have a threadlike pedicel. See Figures 29-6 and 29-7. Vegetative reproduction from broken shoots, subterranean shoots, and turions are more important in its spread than seeds. Hydrilla grows in water up to 50 ft deep.

Pickerelweed (*Pontederia cordata*)

Pickerelweed has fleshy, heart-shaped to lance-shaped leaf blades that are easily confused with arrowhead (see Figure 29-5). It has thick, creeping rootstocks, strongly rooted to the bottom. The flowers are blue spikes.

Pickerelweed grows primarily as a marginal weed in shallow water, and it reproduces by creeping rootstocks and from seed.

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Pondweed (*Potamogeton* spp.)

~~*Potamogeton*, with 60 species, is the largest genus of true aquatic seed~~ plants of temperate regions (Muenscher, 1944).

Pondweed plants grow in both fresh and salt water. They grow best in water 1–2 ft deep, but some species grow in water 6 ft deep or more. Some species have two different kinds of leaves. Those remaining submerged are usually thick, transparent, long, and slender. Those emerging are firm and leathery and are usually attached to the stem by a petiole, with leaves alternately arranged. The stems are jointed, with roots forming at the lower nodes (see Figure 29-2).

Pondweeds reproduce by seed, by turions and tubers that develop in the leaf axils of some species, and from rootstock, which may produce tubers.

Deep water with appropriate fertilization will help to control pondweed.

Waterhyacinth (*Eichornia crassipes*)

Waterhyacinth includes five species, but only one is of major importance in the United States. It is a tropical plant, confined primarily to the Southern Coastal States and to California. It is found principally in ponds and quiet streams.

Waterhyacinth has a blue flower that is somewhat funnel-shaped and two-lipped. The plant is normally free-floating, buoyed by bladderlike, inflated leaf petioles. It forms a matlike growth. The leaf blade may be kidney-shaped to somewhat rounded.

The plant reproduces mainly by vegetative offsets. Several thousand new plants may develop during one season from one original plant. Some reproduction results from seed.

Watermilfoil (*Myriophyllum* spp.)

Watermilfoil includes 20 different species with parrotfeather (*Myriophyllum brasiliense*) and eurasian watermilfoil (*M. spicatum*) being troublesome species. The lower leaves are finely divided and threadlike, each leaf resembling a small, green feather, whereas the upper leaves may resemble bracts (see Figure 29-2). The plant usually grows submersed in water, but stems often emerge above water during the last half of the summer. Flowers and seeds are produced sessile in the leaf axils.

Reproduction is from seed, creeping rhizomes, and broken stem parts that take root.

Pond fertilization will help to control watermilfoil species. Light infestations and small areas can be removed by hand.

SUGGESTED ADDITIONAL READING

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Burkhalter, A. P., L. M. Curtis, R. L. Lazor, M. L. Beach, and J. C. Hudson, 1974, *Aquatic Weed Identification and Control Manual,* Florida Department of Natural Resources, Tallahassee.

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Snow, J. R., 1948, Thesis, Alabama Polytechnic Institute.

Timmons, F. L., 1970, *FAO International Conference on Weed Control,* WSSA, Urbana, IL. p. 357. Available from WSSA. See address below.

USDA, 1980, Agricultural Handbook 565.

Yeo, R. R., and T. W. Fisher, 1970, *FAO International Conference on Weed Control,* WSSA, Urbana, IL. p. 450. Available from WSSA. See address below.

Weed Science published by WSSA, 309 West Clark St., Champaign, IL 61820. See index at end of each volume.

Weeds Today. Some availability as above.

FAO International Conference on Weed Control, 1970. Same availability as above.

Regional Weed Science research reports and proceedings. Available in the libraries of most land grant universities. Published annually.

Obtain weed control bulletins, leaflets, and so forth, from your State University or college of agriculture on weed control in aquatic areas.

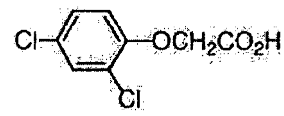
For chemical use, see the manufacturer's label for method and time of application, rates to be used, weeds controlled, and special precautions. *Label recommendations must be followed—regardless of statements in this book.* Also see the Preface. Inclusion or omission of a product name does not constitute recommendation or nonrecommendation of a product.

2,4-D (211)

Herbicide

HRAC O **WSSA** 4; phenoxycarboxylic acid

XP-002464634



NOMENCLATURE

2,4-D

Common name 2,4-D (BSI, E-ISO, (*m*) F-ISO, WSSA); 2,4-PA (JMAF)
IUPAC name (2,4-dichlorophenoxy)acetic acid
Chemical Abstracts name (2,4-dichlorophenoxy)acetic acid
CAS RN *[94-75-7]* **EEC no.** 202-361-1 **Development codes** L208 (Marks)

2,4-D-butotyl
IUPAC name 2-butoxyethyl (2,4-dichlorophenoxy)acetate
CAS RN *[1929-73-3]* **EEC no.** 217-680-1

2,4-D-butyl
IUPAC name butyl (2,4-dichlorophenoxy)acetate
CAS RN *[94-80-4]* **EEC no.** 202-364-8

2,4-D-dimethylammonium
IUPAC name dimethylammonium (2,4-dichlorophenoxy)acetate
CAS RN *[2008-39-1]* **EEC no.** 217-915-8

2,4-D-diolamine (2,4-D-diethanolamine)
IUPAC name bis(2-hydroxyethyl)ammonium (2,4-dichlorophenoxy)acetate
CAS RN *[5742-19-8]* **EEC no.** 227-256-8

2,4-D-ethyl
IUPAC name ethyl (2,4-dichlorophenoxy)acetate

2,4-D-2-ethylhexyl
IUPAC name 2-ethylhexyl (2,4-dichlorophenoxy)acetate
CAS RN *[1928-43-4]* **EEC no.** 217-673-3 **Development codes** N208 (Marks)

2,4-D-isobutyl
IUPAC name 2-methylpropyl (2,4-dichlorophenoxy)acetate
CAS RN *[1713-15-1]* **EEC no.** 216-992-5

2,4-D-isoctyl
IUPAC name octyl (2,4-dichlorophenoxy)acetate (mixed octyl isomers)
CAS RN *[25168-26-7]* (formerly *[1280-20-2]*) **EEC no.** 246-704-3

2,4-D-isopropyl
IUPAC name isopropyl (2,4-dichlorophenoxy)acetate
CAS RN *[94-11-1]* **EEC no.** 202-305-6

2,4-D-sodium
IUPAC name sodium (2,4-dichlorophenoxy)acetate
CAS RN *[2702-72-9]* **EEC no.** 220-290-4

2,4-D-trolamine (2,4-D-triethanolamine)
IUPAC name tris(2-hydroxyethyl)ammonium (2,4-dichlorophenoxy)acetate
CAS RN *[2569-01-9]* **EEC no.** 219-911-1

PHYSICAL CHEMISTRY
2,4-D
Composition Tech. is ≥96% pure. **Mol. wt.** 221.0 **M.f.** $C_8H_6Cl_2O_3$ **Form** Colourless powder, with a slight phenolic odour. **M.p.** 140.5 ºC **V.p.** 1.86×10^{-2} mPa (25 °C, OECD 104) **Kow** logP = 2.58-2.83 (pH 1), 0.04-0.33 (pH 5) **Henry** 1.32×10^{-5} Pa m^3 mol^{-1} (calc.) **S.g./density** 1.508 (20 °C) **Solubility** In water 311 (pH 1), 20 031 (pH 5), 23 180 (pH 7), 34 196 (pH 9) (all in mg/l, 25 °C). In ethanol 1250, diethyl ether 243, heptane 1.1, toluene 6.7, xylene 5.8 (all in g/kg, 20 ºC); in octanol 120 g/l (25 °C). Insoluble in petroleum oils. Mono-*n*-butylamine salt: In water 18 g/l (30 ºC). **Stability** 2,4-D is a strong acid, and forms water-soluble salts with alkali metals and amines. Hard water leads to precipitation of the calcium and magnesium salts, but a sequestering agent is included in formulations to prevent this. Photolytic DT_{50} (simulated sunlight) 7.5 d. **pKa** 2.73

2,4-D-butotyl
Mol. wt. 321.2 **M.f.** $C_{14}H_{18}Cl_2O_4$

2,4-D-butyl
Mol. wt. 277.1 **M.f.** $C_{12}H_{14}Cl_2O_3$

2,4-D-dimethylammonium
Mol. wt. 266.1 **M.f.** $C_{10}H_{13}Cl_2NO_3$ **M.p.** decomp. *c.* 120 °C **Solubility** In water 3 kg/l (20 ºC). Soluble in alcohols and acetone. Insoluble in kerosene and diesel oil.

2,4-D-diolamine (2,4-D-diethanolamine)
Mol. wt. 326.2 **M.f.** $C_{12}H_{17}Cl_2NO_5$

2,4-D-ethyl
Mol. wt. 249.1 **M.f.** $C_{10}H_{10}Cl_2O_3$

2,4-D-2-ethylhexyl
Composition Isomeric with 2,4-D-isoctyl; sometimes these names are used interchangeably. **Mol. wt.** 333.3 **M.f.** $C_{16}H_{22}Cl_2O_3$ **Form** Golden yellow, non-viscous liquid, with a sweet, slightly pungent odour. **M.p.** <-37 °C **B.p.** >300 °C (decomp.) **V.p.** 47.9 mPa (25 °C) **Kow** logP = 5.78 (25 °C) **Henry** 1.8 Pa m^3 mol^{-1} (calc.) **S.g./density** 1.148 (20 °C) **Solubility** In water 0.086 mg/l (25 °C). Miscible with most organic solvents. **Stability** Hydrolysis DT_{50} <1 h. Stable to light, DT_{50} >100 d. Stable at 54 °C. **F.p.** 171 °C (Cleveland open cup)

2,4-D-isobutyl
Mol. wt. 277.1 **M.f.** $C_{12}H_{14}Cl_2O_3$

2,4-D-isoctyl
Composition Isomeric with 2,4-D-2-ethylhexyl; sometimes these names are used interchangeably. **Mol. wt.** 333.3 **M.f.** $C_{16}H_{22}Cl_2O_3$ **Form** Yellowish-brown liquid, with a phenolic odour. **B.p.** 317 °C **S.g./density** 1.14-1.17 g/ml (20 °C) **Solubility** In water 10 mg/l. **F.p.** 171 °C

2,4-D-isopropyl
Mol. wt. 263.1 **M.f.** $C_{11}H_{12}Cl_2O_3$ **Form** Colourless liquid. **M.p.** 5-10 ºC and 20-25 ºC (two forms) **B.p.** 130 ºC/1 mmHg **V.p.** 1.4 Pa (25 ºC) **Solubility** Practically insoluble in water. Soluble in alcohols and most oils.

2,4-D-sodium

Mol. wt. 243.0 **M.f.** $C_8H_5Cl_2NaO_3$ **Solubility** In water 18 g/l (20 ºC).

2,4-D-trolamine (2,4-D-triethanolamine)
Mol. wt. 370.2 **M.f.** $C_{14}H_{21}Cl_2NO_6$ **M.p.** 142-144 ºC **Solubility** In water 4.4 kg/l (30 ºC).

COMMERCIALISATION
History The potent effects of its salts on plant growth were first described by P. W. Zimmerman & A. E. Hitchcock (*Contrib. Boyce Thompson Inst.*, 1942, **12**, 321), and its early history is covered in *The Hormone Weedkillers*, C. Kirby (1980). **Manufacturers** Agrochem; Ancom; Atanor; Atul; CAC; Crompton; Crystal; Dow AgroSciences; Krishi Rasayan; Marks; Nitrokémia; Nufarm GmbH; Nufarm Ltd; Nufarm UK; Proficol; Sannong; Sharda; Sundat; United Phosphorus

APPLICATIONS
Biochemistry Synthetic auxin (acting like indolylacetic acid). **Mode of action** Selective systemic herbicide. Salts are readily absorbed by the roots, whilst esters are readily absorbed by the foliage. Translocation occurs, with accumulation principally at the meristematic regions of shoots and roots. Acts as a growth inhibitor. **Uses** Post-emergence control of annual and perennial broad-leaved weeds in cereals, maize, sorghum, grassland, established turf, grass seed crops, orchards (pome fruit and stone fruit), cranberries, asparagus, sugar cane, rice, forestry, and on non-crop land (including areas adjacent to water), at 0.28-2.3 kg/ha. Control of broad-leaved aquatic weeds. The isopropyl ester can also be used as a plant growth regulator to prevent premature fruit fall in citrus fruit. **Phytotoxicity** Phytotoxic to most broad-leaved crops, especially cotton, vines, tomatoes, ornamentals, fruit trees, oilseed rape and beet. **Formulation types** EC; GR; SP; SL.

2,4-D
Compatibility Compatibility depends upon the particular formulation. **Selected products:** 'Agricorn D' (FCC); 'Capri' (Makhteshim-Agan); 'Damine' (Agriphar); 'Deferon' (Milenia); 'Dikamin' (Nitrokémia); 'Dymec' (PBI/Gordon); 'Kay-D' (mixture of sodium and amine salts with ethyl ester) (Krishi Rasayan); 'Palormone' (Unicrop); 'U 46 D' (BASF); 'Weedtox' (Aimco); 'Yerbisol' (amine salt) (Ingenieria Industrial); **mixtures:** 'Novermone' (+ dichlorprop) (Nufarm SA); 'Rogue' (+ butachlor) (Monsanto)

2,4-D-butotyl
Selected products: 'Erbitox LV-4' (Siapa)

2,4-D-dimethylammonium
Selected products: 'Baton' (Nufarm Ltd); 'Ded-Weed' (Crompton); 'Dioweed' (United Phosphorus Ltd); 'DMA 6' (Dow AgroSciences); 'DMA-4' (Dow AgroSciences); 'Haybob II' (Barclay); 'Sanaphen D' (SL) (Dow AgroSciences); 'Spritz-Hormin' (Nufarm GmbH); 'Staff' (Headland); **mixtures:** 'Erbitox Combi' (+ MCPA-dimethylammonium) (Siapa); 'Lancet' (+ fluroxypyr-2-butoxy-1-methylethyl) (Dow AgroSciences); 'U 46 Combi Fluid' (+ MCPA-dimethylammonium) (BASF)

2,4-D-ethyl
Selected products: 'Smash' (Nagarjuna Agrichem)

2,4-D-2-ethylhexyl
Selected products: 'Esteron 6E' (Dow AgroSciences); 'Esteron 99C' (Dow AgroSciences); 'Lentemul' (Nufarm GmbH)

2,4-D-isoctyl
Selected products: 'Esterdefore' (Vapco); 'Sanaphen D' (EC) (Dow AgroSciences)

2,4-D-isopropyl
Selected products: 'Citrus Fix' (Amvac)

2,4-D-sodium
Selected products: 'Safaya' (Devidayal)

OTHER PRODUCTS
2,4-D
'Amicide' (Nufarm Ltd); 'BEE-4' (Dow AgroSciences); 'Crisalamina' (Crystal); 'Crisamina' (Crystal); 'Dacamine' (GB Biosciences); 'Dicotox' (Bayer CropScience); 'Diserbone E 54' (ester) (Chemia); 'Dormone' (Bayer CropScience); 'Easel' (Nufarm UK); 'Estercide' (Nufarm Ltd); 'Hedonal' (Bayer CropScience); 'Herbamine' (Agrochem); 'Herbifen Super' (Atanor); 'King' (ester) (Chemiplant); 'Maton' (Headland); 'Mortal' (CAS); 'Novertex' (Nufarm SA); 'Patonok' (Palo); 'Ragox' (ester) (Nufarm UK); 'Statesman' (Dow AgroSciences); 'Syford' (Vitax); 'Weedar' (Bayer CropScience, Sedagri, Nufarm SA); 'Weedkiller 4D' (Dow AgroSciences); 'Weedone 2D' (Nufarm SA) **mixtures:** 'Atladox HI' (+ picloram) (Nomix-Chipman); 'Campaign' (+ glyphosate-isopropylammonium) (2,4-D also as isopropylamine salt) (Monsanto); 'Certrol DS' (+ ioxynil octanoate) (Nufarm SA); 'Combatran' (+ picloram-triisopropanolammonium) (2,4-D also as triisopropanolammonium salt) (Dow AgroSciences); 'Curtail' (+ clopyralid-olamine) (2,4-D as triisopropanolammonium salt) (Dow AgroSciences); 'Drago 3.4' (+ flufenacet) (Bayer CropScience); 'Esteron 638' (+ 2,4-D-butotyl) (Dow AgroSciences); 'Flash' (+ picloram-triisopropanolammonium) (2,4-D also as triisopropanolammonium salt) (Dow AgroSciences); 'Glymix' (+ glyphosate-isopropylammonium) (2,4-D as the triisopropylammonium salt) (Dow AgroSciences); 'Grazon P+D' (+ picloram-triisopropanolammonium) (2,4-D also as triisopropanolammonium salt) (Dow AgroSciences); 'Hat-Trick' (+ glyphosate) (Ancom); 'Holster' (+ dicamba+ fluroxypyr) (SumiAgro); 'KambaMaster' (+ dicamba) (Nufarm Americas); 'Kuron M' (+ picloram-triisopropanolammonium) (2,4-D also as triisopropanolammonium salt) (Dow AgroSciences); 'Landmaster' (+ glyphosate-isopropylammonium) (2,4-D also as isopropylamine salt) (Monsanto); 'Lonpar' (+ clopyralid-olamine+ MCPA) (2,4-D and MCPA as amine salts) (Dow AgroSciences); 'New Estermone' (+ dicamba) (Vitax); 'Nox-D' (+ propanil) (Crystal); 'Nu-Shot' (+ dicamba+ triclopyr) (Nufarm UK); 'Pasture MD' (+ dicamba+ metsulfuron-methyl) (Nufarm Americas); 'Pathway' (+ picloram) (Dow AgroSciences); 'Phenoxy 088' (+ 2,4-D-butotyl) (Agriliance); 'Polo' (+ MCPA) (Headland); 'RT Master' (+ glyphosate-isopropylammonium) (2,4-D as the triisopropylammonium salt) (Monsanto); 'Sound' (+ metosulam) (Dow AgroSciences, Bayer CropScience); 'Supertox' (+ mecoprop) (Bayer CropScience); 'Sydex' (+ mecoprop-P) (Vitax); 'Top Gun' (+ metribuzin) (Platte); 'Tordon 101' (+ picloram) (Dow AgroSciences); 'Tordon RTU' (+ picloram) (as triisopropylammonium salts) (Dow AgroSciences); 'UPL Camppex' (+ dichlorprop+ MCPA+ mecoprop-P) (United Phosphorus); 'Weedone 638 Solventless' (+ 2,4-D-2-ethylhexyl) (Nufarm Ltd); 'Weedone 638' (+ 2,4-D-butotyl) (Nufarm Ltd); 'Weedone DPC Amine' (+ dichlorprop-dimethylammonium) (2,4-D as triisopropanolammonium salt) (Nufarm Ltd); 'Weedone' (+ dichlorprop) (Nufarm SA); 'Xrm-5202 Premium' (+ clopyralid+ triclopyr-triethylammonium) (2,4-D and clopyralid as triisopropanolammonium salts) (Riverdale) **Discontinued products:** 'Destox' * (MTM); 'For-ester' * (Vitax); 'Herbifen' * (Compania Quimica) **mixtures:** 'Broadshot' * (+ dicamba+ triclopyr) (Cyanamid); 'Broadstrike Post' * (+ clopyralid+ flumetsulam) (Dow AgroSciences); 'Camppex' * (+ dichlorprop+ MCPA+ mecoprop) (United Phosphorus Ltd); 'Cleanrun' * (+ mecoprop) (Zeneca); 'Scorpion III' * (+ clopyralid+ flumetsulam) (Dow AgroSciences); 'SWK 333' * (+ dicamba) (Keychem); 'Sydex' * (+ mecoprop) (Vitax); 'Weed and Brushkiller' * (+ dicamba+ mecoprop) (Vitax)

2,4-D-butotyl
'Aqua-Kleen' (Nufarm Ltd) **mixtures:** 'Crossbow' (+ triclopyr-butotyl) (Dow AgroSciences); 'Esteron 638' (+ 2,4-D) (Dow AgroSciences); 'Phenoxy 088' (+ 2,4-D) (Agriliance); 'Weedone 638' (+ 2,4-D) (Nufarm Ltd) **Discontinued products mixtures:** 'Envert 171' * (+ dichlorprop-butotyl) (Rhône-Poulenc); 'Weedone 170' * (+ dichlorprop-butotyl) (Rhône-Poulenc); 'Weedone CB' * (+ dichlorprop-butotyl) (Rhône-Poulenc)

2,4-D-butyl
'Drago ester' (Agricultura Nacional)

2,4-D-dimethylammonium

'Agro D-Amin' (AgroSan); 'Depitox' (Nufarm UK); 'Desormone' (Bayer CropScience); 'Dicopur' (Nufarm GmbH); 'Dri-Clean' (Riverdale); 'Fito amina' (Agricultura Nacional); 'Formula 40' (mixture with triisopropanolammonium) (Dow AgroSciences, Bayer CropScience); 'Herboxone' (Marks, Headland); 'HY-D' (Agrichem Int.); 'Saber' (Platte); 'Savage' (Platte); 'Weed Rhap A-4D' (Helena); 'Weedar 64' (Nufarm Ltd); 'Weedar IVM 44' (Nufarm Ltd) **mixtures:** 'Dicopur Combi' (+ MCPA-dimethylammonium) (Nufarm GmbH); 'DPD-Amine' (+ dichlorprop-dimethylammonium) (Nufarm Ltd); 'Range' (+ dicamba-dimethylammonium) (Albaugh); 'Weedmaster' (+ dicamba-dimethylammonium) (BASF, Syngenta) **Discontinued products mixtures:** '2 Plus 2' * (+ mecoprop) (mecoprop also as dimethylammonium salt) (ISK Biosciences)

2,4-D-diolamine (2,4-D-diethanolamine)
'EH 1330' (PBI/Gordon)

2,4-D-ethyl
'Weedkill' (BEC)

2,4-D-2-ethylhexyl
'Barrage' (Helena); 'Brush-Rhap' (Helena); 'Fivestar' (Albaugh); 'Low Vol 4 Ester' (UAP); 'Salvo' (Platte); 'Weed Rhap LV-4D' (Helena); 'Weedone LV4' (Nufarm Ltd); 'Weed-Rhap' (Helena) **mixtures:** 'Adrenalin' (+ imazamox) (Canada) (BASF); 'B-4' (+ bromoxynil heptanoate+ bromoxynil octanoate) (Agsco); 'Broadsword' (+ dicamba+ triclopyr-butotyl) (dicamba as butotyl ester) (United Phosphorus Ltd); 'Oasis' (+ imazapic) (BASF); 'Shotgun' (+ atrazine) (UAP, Platte); 'Tiller' (+ fenoxaprop-P-ethyl+ MCPA-2-ethylhexyl) (Bayer CropScience); 'Weedone 638 Solventless' (+ 2,4-D) (Nufarm Ltd)

2,4-D-isoctyl
'Agro D-Ester' (AgroSan) **mixtures:** 'Lotus D' (+ cinidon-ethyl) (BASF) **Discontinued products:** 'Dicotox Extra' * (Rhône-Poulenc); 'Dicotox' * (Rhône-Poulenc); 'Esteron' * (Rhône-Poulenc); 'No-Sol 400' * (Rhône-Poulenc); 'Supramone' * (Rhône-Poulenc); 'Weedone Lo Vol 6' * (Rhône-Poulenc) **mixtures:** 'Tiller' * (+ fenoxaprop-P-ethyl+ MCPA-2-ethylhexyl) (AgrEvo)

2,4-D-isopropyl
'Alphaset' (Nufarm Ltd); 'Hivol' (Amvac)

2,4-D-sodium
'Dikonirt' (Nitrokémia) **mixtures:** 'Trik' (+ amitrole+ diuron) (Nufarm UK)

ANALYSIS
Product analysis of 2,4-D, salts, esters and mixed combination products by acid-base titration, by glc (*CIPAC Handbook*, 1985, **1C**, 2060, 2257; 1994, **F**, 292-319; *Herbicides 1977*, pp. 6-21), by rplc (*AOAC Methods*, 17th Ed., 971.07, 976.03, 978.05, 984.07; *CIPAC Handbook*, 1985, **1C**, 2060; 1988, **D**, 51), by hplc (*ibid.*, 1983, 1757), or by i.r. spectrometry (*ibid.*, 1998, **H**, 131). Free phenol impurity determined by glc (*CIPAC Handbook*, 1994, **F**, 197), hplc (*ibid.*, 1994, **F**, 362) or electrochemically (*ibid.*, 1994, **F**, 368). **Residues** determined by glc of derivatives (*Pestic. Anal. Man.*, 1979, **I**, 201-D; *Anal. Methods Pestic. Plant Growth Regul.*, 1972, **6**, 630) or by hplc (M. Meier *et al.*, *Fresenius Z. Anal. Chem.*, 1989, **334**, 235). In **drinking water**, by conversion to methyl ester with diazomethane, then glc with ECD (*AOAC Methods*, 17th Ed., 992.32).

MAMMALIAN TOXICOLOGY
Reviews FAO/WHO 77, 79, 80, 82, 92 (see part 2 of the Bibliography). Toxicity and hazards to man, domestic animals and wildlife have been reviewed (J. M. Way, *Residue Rev.*, 1969, **26**, 37). **IARC** ref. 15, 41; Suppl. 7 class chlorophenoxy herbicides classified as 2B, based on epidemiology of production. More recent evidence (M. Kogevinas *et al.*, *Am. J. Epidemiol.*, **145**(12), 1061 (1997)) relates this to dioxin contamination of early production. Not relevant to current processes.

2,4-D
Oral Acute oral LD_{50} for rats 639-764, mice 138 mg/kg. **Skin and eye** Acute percutaneous LD_{50} for rats >1600, rabbits >2400 mg/kg. Skin and eye irritant (rabbits). A skin sensitiser (guinea pigs). **Inhalation** LC_{50} (24 h) for rats >1.79 mg/l. **NOEL** (2 y) for rats and mice 5 mg/kg b.w.; (1 y) for dogs 1 mg/kg b.w. **ADI** (JMPR) 0.01 mg/kg b.w. [2001, 1997]; 0.01 mg/kg b.w. [1996] (sum of 2,4-D and its salts and esters, as 2,4-D); [EEC] 0.05 mg/kg b.w. (2001). **Water GV** 30 µg/l (based on ADI). **Toxicity class** WHO (a.i.) II; EPA (formulation) II **EC classification** Xn; R22| Xi; R37, R41| R43| R52, R53: (for salts Xn; R22| Xi; R41| R43| N; R51, R53; for esters Xn; R22| R43| N; R50, R53)

2,4-D-dimethylammonium
Oral Acute oral LD 50 for rats 949 mg/kg. **Skin and eye** LD_{50} for rats >2000 mg/kg; not a skin irritant (rabbits); severe irritant to eyes (rabbits). **Inhalation** LC_{50} (4 h) for rats >3.5 mg/l air.

2,4-D-2-ethylhexyl
Oral Acute oral LD_{50} for rats 896 mg/kg. **Skin and eye** Dermal LD_{50} for rabbits >2000 mg/kg. Slight eye irritant. A skin sensitiser (guinea pigs). **Inhalation** LC_{50} (4 h) for rats >5.4 mg/l air. **ADI** Due to toxicological equivalence to 2,4-D, ADI is assumed to be equivalent to that for 2,4-D.

2,4-D-isoctyl
Oral Acute oral LD_{50} for rats 650 mg/kg. **Skin and eye** Acute percutaneous LD_{50} for rats >3000 mg/kg. **NOEL** for rats 1250, dogs 500 mg/kg diet.

2,4-D-isopropyl
Oral Acute oral LD_{50} for rats 700 mg/kg.

2,4-D-sodium
Oral Acute oral LD_{50} for rats 666-805 mg/kg.

ECOTOXICOLOGY
2,4-D
Birds Acute oral LD_{50} for wild ducks >1000, Japanese quail 668, pigeons 668, pheasants 472 mg/kg. LC_{50} (96 h) for mallard ducks >5620 mg/l. **Fish** Some formulations (e.g. esters) are toxic to fish, whilst others are not. LC_{50} (96 h) for rainbow trout >100 mg/l. **Daphnia** LC_{50} (21 d) 235 mg/l. **Algae** EC_{50} (5 d) for *Selenastrum capricornutum* 33.2 mg/l. **Other aquatic spp.** EC_{50} (14 d) for *Lemna gibba* 0.58 mg/l. **Bees** Not toxic to bees; LD_{50} (oral) 104.5 µg/bee. **Worms** LC_{50} (7 d) 860 mg/kg; NOEC (14 d) 100 g/kg. **Other beneficial spp.** Harmless to *Trichogramma cacoeciae*, *Poecilus cupreus*, *Aleochara bilineata*.

2,4-D-dimethylammonium
Birds Acute oral LD 50 for bobwhite quail 500 mg/kg. Oral LC_{50} for bobwhite quail >5620 ppm. **Fish** LC_{50} (96 h) for rainbow trout 100 mg/l. **Algae** EC_{50} for *Selenastrum capricornutum* 51.2 mg/l. **Bees** LD_{50} (contact) >100 µg/bee; (oral) *c.* 94 µg/bee.

2,4-D-2-ethylhexyl
Birds Acute oral LD_{50} for mallard ducks 663 mg/kg. Dietary LC_{50} (5 d) for bobwhite quail and mallard ducks >5620 ppm. **Fish** LC_{50} for fathead minnow, bluegill sunfish and rainbow trout greater than solubility in water. **Daphnia** EC_{50} (48 h) 5.2 mg/l. **Algae** EC_{50} for *Skeletonema costatum* 0.23, *Navicula pelliculosa* 4.1, *Selenastrum capricornutum* and *Anabaena flos-aquae* >30 mg/l. **Other aquatic spp.** EC_{50} (14 d) for *Lemna gibba* 0.5 mg/l. **Bees** LD_{50} (contact) >100 µg/bee; (oral) >100 µg/bee.

2,4-D-isoctyl
Fish LC_{50} (96 h) for cut-throat trout 0.5-1.2 mg/l.

2,4-D-sodium
Birds Acute oral LD_{50} for wild ducks >2025 mg/kg.

ENVIRONMENTAL FATE
2,4-D
EHC 29 (WHO, 1984), 84 (WHO, 1989). EHC 84 concludes that, when used as recommended, 2,4-D does not appear to produce direct toxic effects on any animal species. **Animals** In rats, following oral administration, elimination is rapid, and mainly as the unchanged substance. Following single doses of up to 10 mg/kg, excretion is almost complete after 24 hours, although, with higher doses, complete elimination takes longer. The maximum concentration in organs is reached after *c.* 12 hours. **Plants** In plants, metabolism involves hydroxylation, decarboxylation, cleavage of the acid side-chain, and ring opening. **Soil/Environment** In soil, microbial degradation involves hydroxylation, decarboxylation, cleavage of the acid side-chain, and ring opening. Half-life in soil <7 d. K_{oc} *c.* 60. For a review of environmental aspects of 2,4-D, see *Environmental Health Criteria 84* (WHO, 1989). Rapid degradation in the soil prevents significant downward movement under normal conditions.

2,4-D-2-ethylhexyl
Soil/Environment Rapidly hydrolysed in soil and water to the parent acid; DT_{50} <1 d.

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Response of Two Alligatorweed Biotypes to Quinclorac

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ABSTRACT

Greenhouse studies evaluated the influence of foliar applications of quinclorac (3,7-dichloro-8-quinolinecarboxylic acid) on two morphologically distinct alligatorweed biotypes. Quinclorac was applied at 0.3 and 0.6 kg/ha to well-rooted plants that had been cut back and allowed to regrow for two, four, or six weeks to simulate treatment at different stages of regrowth. Herbicide damage and overall effects on growth were significantly greater in the slenderstem than in the broadstem biotype, probably reflecting greater leaf surface are per unit of shoot biomass in the slenderstem biotype. Regrowth from roots and rhizomes was similar for both biotypes, and no herbicide symptoms were observed on the new growth, suggesting poor basipetal translocation. The relative growth rates of slenderstem alligatorweed were reduced sigificantly more than those of the broadstem biotype following either root or leaf treatment. The results of this study suggest that certain alligatorweed biotypes may be more tolerant to herbicides than others and may provide a partial explanation for the variability observed in the response of alligatorweed to herbicides.

Key words: Alternanthera philoxeroides, herbicide resistance, morphology, growth.

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INTRODUCTION

Alligatorweed, *Alternanthera philoxeroides* (Mart.) Griseb. has been very difficult to manage with herbicides. Early studies with compounds such as sodium or potassium arsenite and sodium or potassium chlorate reported top kill, but rapid regrowth occurred from underwater stems (Penfound 1940, zur Burg et al. 1962, 1967). Systemic herbicides developed since the 1940's have been only partially effective because of limited translocation to the underground and underwater biomass (Weldon 1960, Anonymous 1968, Julien and Broadbent 1980). Poor herbicide translocation in alligatorweed has been attributed to several factors. Zur Burg et al. (1961) indicated that abnormal growth of root cell primordia at the nodes blocked vascular tissues and prevented herbicide translocation. Axillary buds seem partially resistant to herbicides, apparently because of the lack of direct connection to the parent plant's vascular system (Zur Burg et al. 1967). Pate et al. (1965) reported that dichlobenil (2,6-dichlorobenzonitrile) and dicamba (2-methoxy-3,6-dichlorobenzoic acid) produced herbicidal activity in axillary buds of alligatorweed only when the vascular tissues between the axillary buds and the stems were well differentiated. Studies using radiolabelled 2,4-D (2,4-dichlorophenoxyacetic acid) (Earle et al. 1951) and glyphosate [*N*-(phosphonomethyl)glycine] (Tucker et al. 1986) showed that basipetal translocation of herbicides was very low, suggesting that a physiological barrier to herbicide translocation may exist in alligatorweed. In a subsequent study, 17 percent of leaf-applied imazapyr (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-phyridinecarboxylic acid) was recovered in the root system eight days after treatment in contrast to only one percent of glyphosate (Tucker et al. 1987).

Evidence exists that at least two morphologically distinct forms of alligatorweed are present in the United States (Quimby et al. 1976, Kay and Haller 1982). These forms exist in geographically-isolated areas and maintain their morphological integrity when cultured under identical conditions. Results of laboratory growth studies (Quimby et al. 1976, Kay and Haller 1982), differences in isozyme patterns (Wain and Martin 1984), and differences in response to a plant growth regulator, brassinolide (2*a*, 3*a*, 22*a*-tetrahydroxy-24*a*-methyl-B-homo-7-oxa-5*a*-cholestan-6-one) (author's unpublished data), suggest that these morphologically distinct forms may represent physiologically distinct biotypes. These and other physiological differences could be responsible for the wide variation in the response of alligatorweed to herbicides under field conditions as noted previously by Spencer (1967). To date, no studies have been conducted to compare the response of morphologically distinct alligatorweed biotypes to herbicides.

Quinclorac recently was introduced by BASF Corporation for weed control in rice and is indicated by the manufacturer to have activity on alligatorweed. The objective of this study was to determine whether or not two morphologically distinct alligatorweed biotypes would respond similarly to quinclorac application.

MATERIALS AND METHODS

Two greenhouse studies (spring and summer) were conducted in 1989 to evaluate the responses of two morphologically distinct alligatorweed biotypes to quinclorac. A broadstem biotype (terminology after Kay and Haller 1982) originally collected from Tangipahoa, Louisiana (designated BSA), and a slenderstem biotype originally collected from Bryant's Swamp near Bladenboro, North Carolina (designated SSA), were grown hydroponically in small pools in a greenhouse during the fall and winter of 1988 using a full-strength modified Hoagland's nutrient (Quimby and Kay 1977).

Foliar application tests. Prior to the initiation of each test, five 10-cm stem cuttings of either BSA or SSA were placed into 15-cm pots containing Metromix 220®[2] potting medium. The pots were placed into hydroponic culture in pools as described above to allow the plant cuttings to establish a good root system prior to treatment. During the first test (April 10 to June 5, 1989), plants were cut back to the surface of the substrate either 4 or 8 weeks prior to treatment and allowed to regrow. This was done to simulate two different stages of plant regrowth (4 and 8 weeks) from the root/rhizome system, which occurs in the field during the early and late spring in each growing season. A 2-week regrowth stage was added during the second test (August 1 to September 19, 1989) to simulate very early season growth. Plants were maintained at 30 ± 3 C under a natural photoperiod throughout the rooting period and for the duration of both studies.

When the plants had reached the proper growth stage (i.e., 2, 4, or 8 wks. regrowth), they were placed into a spraying cabinet at the BASF laboratory at Research Triangle Park, North Carolina, and treated with quinclorac at rates of 0.3 or 0.6 kg a.i./ha. BAS 009 002S surfactant (1.25% v/v) was used with the quinclorac (this is the surfactant contained in the commercial quinclorac formulation, Facet®)[3]. A 1.25% solution of Rodeo®[4] (glyphosate) + 0.5% Induce®[5] surfactant was used as a positive control to compare the response of the plants to that with a known herbicide. Treated plants and controls were placed in the greenhouse for observation. Five pots of untreated plants also were clipped at the surface of the substrate at this time, dried at 70 C for 48 hr, and weighed to estimate the shoot biomass at the outset of the test period. At the time of treatment, all plants had formed a complete leaf canopy over the surface of the pots. Subirrigation was used instead of top watering throughout the study to minimize the downward movement of the herbicide into the root zone and facilitate evaluation of basipetal translocation. Weekly, 100 ml of nutrient solution was added to each pot by subirrigation.

Plant injury was rated visually (0 to 5 scale, where 0 = no damage and 5 = complete kill) one, two, and four weeks after treatment. Injury rating is defined as zero for controls. Above-ground biomass was harvested four weeks

[2]Metromix 220 is a registered trademark of Grace Horticultural Products Co.

[3]Facet is a registered trademark of BASF Corp.

[4]Rodeo is a registered trademark of Monsanto, Inc.

[5]Induce is a registered trademark of Helena Chemical Co.

after treatment. Terminal cuttings (10-cm) from herbicide-damaged stems were placed into test-tubes containing tap water and maintained in a growth chamber for 10 days under a 16-hr photoperiod and 30/25 C day/night temperatures to determine stem viability. The remaining above-ground biomass was separated into live and dead tissues, dried, and weighed as described previously. Stem cuttings used for the stem viability test were dried and weighed after the evaluation period, and dry weights were added to the total biomass. The pots containing the root systems were left in the greenhouse and watered via subirrigation for four additional weeks to observe regrowth. All regrowth was harvested, dried, and weighed as described above.

These tests were established in a completely randomized factorial design having 2 biotypes, 2 or 3 (test 2) growth stages, and three herbicide rates with five replicates per treatment. Growth data and visual ratings were subjected to an analysis of variance using a three-way interactive model. The controls were not included in the analysis of visual herbicide injury symptoms, as control ratings were arbitrarily set as zero and had 0 variance.

Comparison of leaf and stem characteristics. An additional 10 stems of each biotype were collected from the greenhouse stock cultures to determine possible differences in leaf areas per unit weight of shoots. Stems for this procedure were clipped at the base of the internode below the sixth fully-expanded leaf pair. This position was chosen because it represents the limit of nonsenescent leaf tissue (leaves below this point frequently have abscised in natural or greenhouse populations). Leaves were removed, and leaf areas were measured using a Lambda®,[6] leaf area meter. Lengths of stems and internodes also were measured. Tissues were dried and weighed as described above. Differences between the means were separated using a T-test.

Foliar versus root uptake. Another test was conducted during the spring of 1990 to address questions concerning the route of quinclorac uptake and translocation in these biotypes. Stem cuttings (as described above) were rooted for two weeks in the greenhouse in flasks containing 250 ml of full-strength nutrient solution. Quinclorac was applied either in the nutrient solution or to a single leaf to evaluate root uptake and foliar uptake, respectively. The concentration applied in the nutrient solutions for the root uptake study was 0.4 mg/l (total of 0.1 mg available in each flask containing 250 ml solution). This treatment concentration was determined on the basis of the theoretical concentration (w/v) occurring in the water column if the herbicide was applied at 0.6 kg/ha and was evenly distributed in the upper 15 cm of the water column (roughly equivalent to the depth of the plow layer in a terrestrial application). The exposure rate for foliar uptake was determined similarly on the basis of the amount of herbicide theoretically striking the surface of an upper leaf having a surface area of five cm^2 if 0.6 kg a.i./ha had been applied. A 10-microliter aliquot of a suspension containing a total of 30 micrograms quinclorac was applied with a syringe as a series of ten small droplets, five along each side of the midvein in the center of the leaf lamina of a single leaf from the third fully expanded leaf pair. The treated leaf always was on the longer of the two shoots arising from the apical node of the stem cutting. This shoot henceforth will be designated as the primary shoot. The shorter of the two shoots arising from the apical node of the stem cuttings will be designated as the secondary shoot. Each treatment was replicated five times. The diameters of the nodes immediately above (designated node + 1) and below (node − 1) and adjacent to (node 0) this leaf pair was measured for all plants on the date of treatment and again at harvest. A rubber band was lopped over the leaf to mark the location of the third fully-expanded leaf pair at time 0 for both foliar and root-absorbed herbicide tests to facilitate the relocation of this position for subsequent observations. An additional five replicates were harvested at the outset to determine initial biomass and allow subsequent calculation of relative growth rates (RGR), using the formula $(W_1 - W_0) / (W_0 \times D)$, where W_0 = g dry weight at time 0, W_1 = g dry weight at harvest, and D = the number of days until harvest. Plants were separated into original stem cuttings, roots, leaves, and stems, dried, and weighed for growth determinations. Data were subjected to an analysis of variance, and treatment means were separated using the Duncan's Multiple Range procedure (Steele and Torrie 1960).

RESULTS AND DISCUSSION

Foliar application tests. The two biotypes used in this study (BSA and SSA) differ substantially morphologically when grown under identical conditions in either the field or greenhouse. Internodal diameter, length, and cavity size are larger on the broadstem (BSA) than on the slenderstem (SSA) biotype. The leaves of BSA are longer, narrower, and acutely pointed in contrast to the broader and more rounded leaves of SSA.

Visual symptoms of quinclorac treatment included defoliation, leaf malformation, epinasty of the younger portions of the stems, swelling of nodes, partial kill of the terminal buds and stems, and extensive callous tissue development apically and along the internodes. These symptoms are quite similar to those induced by application of phenoxy herbicides such as 2,4-D on alligatorweed (Sylmosy 1967) and other plants (Ashton and Crafts 1973, Klingman and Ashton 1982, Ross and Lembi 1985). Leaf malformation has been noted previously in studies evaluating quinclorac for broadleaf weed control in broccoli (Herbst and Derr 1988). Damage symptoms were distinctly more pronounced on SSA than BSA in both tests. These symptoms also appeared to be slightly greater on both biotypes following treatment in August.

Exposure to quinclorac reduced total shoot biomass and percent new growth, and increased percent dead tissue in both biotypes (Tables 1 and 2). There were no significant three-way interactions in these tests. Interaction between biotype and herbicide rate was highly significant ($P > F = 0.001$). Differences between biotypes were more pronounced on plants treated at the later stages of growth in both tests ($P > F = 0.05$). This pattern probably is a function of greater leaf surface area for absorption of the

[6]Lambda is a registered trademark of Li-Cor, Inc.

TABLE 1. VISUAL INJURY AND GROWTH OF BROADSTEM (BSA) AND SLENDERSTEM (SSA) ALLIGATORWEED BIOTYPES IN THE GREENHOUSE FOLLOWING QUINCLORAC APPLICATION. DATA SHOWN ARE FOR THE TEST CONDUCTED IN THE SPRING OF 1989.[1]

Treatment	Biotype	Growth Stage	4-wk Visual Ratings	Biomass	% New Growth	% Dead	Regrowth
Control	BSA	4 wks	**[2]	25.3 (4.4)	71.8 (4.2)	1.7 (0.8)	1.2 (0.3)
0.3 kg/ha			2.2 (0.3)	15.2 (4.1)	51.1 (13.5)	8.8 (3.1)	0.6 (0.4)
0.6 kg/ha			2.2 (0.3)	15.3 (2.6)	53.2 (7.6)	13.9 (3.0)	0.3 (0.0)
Control	SSA	4 wks	**	14.7 (3.9)	68.9 (11.6)	0.1 (0.3)	1.4 (0.2)
0.3 kg/ha			3.1 (0.2)	6.8 (1.1)	36.5 (9.8)	27.1 (6.0)	1.1 (0.1)
0.6 kg/ha			3.6 (0.4)	5.4 (1.4)	18.1 (18.8)	46.7 (10.8)	0.8 (0.1)
Control	BSA	8 wks	**	32.7 (14.3)	56.3 (20.5)	1.8 (1.7)	1.7 (0.5)
0.3 kg/ha			2.3 (0.3)	23.3 (5.8)	46.3 (11.4)	7.1 (2.6)	0.6 (0.3)
0.6 kg/ha			2.4 (0.4)	26.1 (10.9)	45.0 (29.4)	12.1 (3.0)	0.3 (0.2)
Control	SSA	8 wks	**	21.4 (2.9)	60.2 (5.5)	0.7 (0.7)	1.4 (0.3)
0.3 kg/ha			3.1 (0.2)	8.1 (1.4)	−6.1 (18.4)	30.3 (5.3)	1.0 (0.2)
0.6 kg/ha			3.4 (0.5)	7.8 (1.2)	−9.5 (17.8)	32.1 (8.9)	0.6 (0.2)

[1]All data are the means of 5 replications; values in parentheses are one standard deviation. Visual ratings are on the scale of 0 to 5, where 0 = no damage and 5 = complete kill. All biomass and growth data are reported as g dry weight. Data for glyphosate are not shown, as plants were consistently killed by the treatment.
[2]Controls not included in the analysis of visual data as ratings are arbitrarily set as zero (variance = 0).

herbicide in the larger (i.e., older) plants but also might represent differences in translocation. Herbicide damage and growth responses within each biotype were somewhat variable and probably reflected the normal variation in plant growth as observed in the plants clipped for the initial biomass at the outset of the tests. Glyphosate gave essentially complete kill of both the shoots and the root/rhizome systems at all stages of growth in both tests (data not shown). Regrowth following quinclorac treatment was significantly reduced in the 8-week-old plants of both biotypes in the first test but not in the second test. Regrowth from glyphosate-treated plants was negligible in both tests (data not shown). These data suggest that basipetal translocation of quinclorac was poor and that differences in regrowth probably were not biologically significant. This would be consistent with the route of absorption of quinclorac, which occurs largely through the root system (Pearson and Carter 1986; Stovicek and Penner 1986), even though some absorption may occur through other portions of the plant (Reeves et al. 1986; Wegener and Muller 1988).

Comparison of the two biotypes at the same stages of growth indicated that growth inhibition by quinclorac was significantly greater on SSA than BSA (Tables 1 and 2).

TABLE 2. VISUAL INJURY AND GROWTH OF BROADSTEM (BSA) AND SLENDERSTEM (SSA) ALLIGATORWEED BIOTYPES IN THE GREENHOUSE FOLLOWING QUINCLORAC APPLICATION. DATA SHOWN ARE FOR THE TEST CONDUCTED IN THE SUMMER OF 1989.[1]

Treatment	Biotype	Growth Stage	4-wk Visual Ratings	Biomass	% New Growth	% Dead	Regrowth
Control	BSA	2 wks	**[2]	10.0 (1.6)	87.1 (2.1)	3.1 (1.1)	0.2 (0.2)
0.3 kg/ha			2.5 (0.6)	4.7 (1.1)	71.8 (7.6)	17.0 (7.5)	0.5 (0.1)
0.6 kg/ha			2.3 (0.3)	4.6 (1.0)	71.7 (5.8)	11.2 (3.4)	0.4 (0.2)
Control	SSA	2 wks	**	4.3 (0.8)	88.5 (2.1)	9.3 (4.1)	0.4 (0.1)
0.3 kg/ha			3.2 (0.4)	1.4 (0.4)	61.0 (17.1)	40.8 (25.4)	0.5 (0.2)
0.6 kg/ha			3.3 (0.3)	1.5 (0.3)	67.6 (5.9)	48.7 (12.8)	0.4 (0.1)
Control	BSA	4 wks	**	26.6 (3.5)	66.1 (0.4)	2.8 (1.0)	0.1 (0.1)
0.3 kg/ha			3.1 (0.5)	17.0 (3.0)	46.5 (8.9)	22.0 (10.8)	0.2 (0.3)
0.6 kg/ha			2.7 (0.4)	20.7 (4.5)	55.4 (9.8)	14.8 (3.2)	0.1 (0.0)
Control	SSA	4 wks	**	14.9 (14.1)	67.7 (10.5)	4.7 (2.0)	0.2 (0.0)
0.3 kg/ha			3.7 (0.4)	10.7 (4.7)	31.3 (24.2)	53.6 (18.6)	0.1 (0.1)
0.6 kg/ha			3.3 (0.4)	13.0 (3.2)	47.6 (12.6)	41.6 (7.3)	0.1 (0.0)
Control	BSA	8 wks	**	54.1 (6.9)	59.9 (5.0)	1.3 (0.5)	0.2 (0.1)
0.3 kg/ha			3.2 (0.4)	27.3 (6.6)	16.7 (25.5)	16.0 (6.8)	0.1 (0.1)
0.6 kg/ha			2.9 (0.2)	28.7 (6.4)	22.1 (19.1)	9.3 (2.6)	0.1 (0.0)
Control	SSA	8 wks	**	34.9 (7.6)	49.5 (14.7)	3.3 (0.9)	0.2 (0.1)
0.3 kg/ha			3.6 (0.5)	17.3 (8.5)	−13.7 (43.8)	38.2 (15.7)	0.1 (0.1)
0.6 kg/ha			3.1 (0.2)	23.2 (4.7)	25.5 (14.2)	23.9 (6.0)	0.1 (0.1)

[1]All data are the means of 5 replications; values in parentheses are one standard deviation. Visual ratings are on the scale of 0 to 5, where 0 = no damage and 5 = complete kill. All weight data are reported as g dry weight. Data for glyphosate are not shown, as almost complete kill occurred on all plants.
[2]Controls not included in the analysis of visual data as ratings are arbitrarily set as zero (variance = 0).

TABLE 3. COMPARISON OF THE LEAF AND STEM CHARACTERISTICS OF BROADSTEM (BSA) AND SLENDERSTEM (SSA) ALLIGATORWEED BIOTYPES.[1]

Characteristic	Biotype SSA	Biotype BSA	Significance
Shoot biomass, g	0.43 ± 0.15	1.29 ± 0.42	**
Total leaf area, cm^2	77.4 ± 21.9	101.8 ± 24.9	*
Average size of leaves, cm^2	4.5 ± 1.2	5.3 ± 1.3	NS
Leaf weight, g	0.21 ± 0.08	0.40 ± 0.13	**
Specific leaf weight, mg/cm^2	2.6 ± 0.4	3.8 ± 0.7	**
Stem length, cm	25.4 ± 5.3	32.1 ± 6.1	*
Stem weight, g	0.23 ± 0.08	0.90 ± 0.33	**
Specific stem weight, mg/cm	8.7 ± 1.7	27.5 ± 7.6	**
Average internode length, cm	3.3 ± 0.6	3.7 ± 0.6	NS
Leaf area:shoot biomass ratio	184.0 ± 24.0	83.0 ± 21.0	**
Leaf area:stem length ratio	3.0 ± 0.5	3.3 ± 0.9	NS
Leaf area:stem weight ratio	358.0 ± 75.0	126.0 ± 51.0	**

[1]Data shown are the means ± 1 standard deviation, where n = 10. Means were compared using a T-Test procedure; means designated with * and ** indicate significance at alpha = 0.05 and 0.01, respectively; NS = not significant.

Significantly greater reduction occurred in total shoot biomass and percent new growth of SSA at the later growth stage in the first experiment. Percent dead tissue also was significantly greater in SSA than BSA at all growth stages in both tests. These biotypic differences in response were reflected in the visual ratings, which effectively integrate quantitative effects on biomass with plant appearance.

Comparison of leaf and stem characteristics. It is uncertain whether or not differences in the responses of these two alligatorweed biotypes to foliar applications of quinclorac are the results of morphological variation or innate physiological differences. A comparison of shoot cuttings taken from untreated, greenhouse-grown plants of both biotypes (Table 3) suggests that biotypic differences in response to quinclorac may partly reflect differences in leaf area ratios (leaf area per unit of shoot biomass), which were greater for SSA than for BSA. Seasonal differences in light quality and photoperiod also affect both the morphology and growth of alligatorweed and may have caused some of the observed differences between the two tests. Differences in results between the two experiments also appear to reflect the innate variability of alligatorweed growth, as substantial varition in plant size was observed within each biotype at the outset of both tests.

Foliar versus root uptake. There were no significant differences between the two biotypes with respect to the time interval until the appearance of epinasty and nodal swelling following either leaf or root treatment with quinclorac in this experiment (data not shown). Both nodal swelling and epinasty appeared more slowly in secondary shoots than in primary shoots following leaf treatment, in contrast to the more rapid and uniform appearance of symptoms in both shoots following root treatment. The appearance of epinasty following quinclorac treatment was slower than that reported previously (several hours) for alligatorweed following 2,4-D applications (Solymosy 1967). The two-week duration of this experiment was not sufficiently long for the development of the tumorous growths and callous tissues observed in the two previous tests.

Dry biomass production was consistently greater in BSA than in SSA regardless of route of treatment (Table 4). Leaf application of quinclorac resulted in significantly greater reduction of new growth in SSA than BSA, whereas there were no significant differences in new growth between the two biotypes following root treatment. The RGR of SSA controls was significantly greater than that of BSA controls, but there were no significant differences in RGR between the two biotypes after either root or leaf application of quinclorac. The differences in response between the two biotypes are quite clear, if the data are expressed as percent reduction in RGR. The reductions in RGR following leaf and root treatment were 15 and 44 percent, respectively, in BSA; RGR reductions for SSA were 33 and 57 percent, respectively. This clearly supports the evidence from the first two tests which indicated that BSA was more tolerant to quinclorac than SSA. The

TABLE 4. EFFECTS OF QUINCLORAC ON GROWTH RATES AND DRY MATTER PRODUCTION OF BROADSTEM (BSA) AND SLENDERSTEM (SSA) ALLIGATORWEED BIOTYPES WHEN APPLIED TO A SINGLE LEAF OR TO THE ROOT SYSTEM. VALUES SHOWN ARE MEANS OF FIVE REPLICATES ± 1 STANDARD DEVIATION).[1]

Variable	SSA/Control	SSA/Leaf	SSA/Root	BSA/Control	BSA/Leaf	BSA/Root
Stem wt., g	0.71 (0.31) b	0.47 (0.20) c	0.22 (0.07) d	1.63 (0.22) a	1.66 (0.22) a	0.71 (0.23) b
Leaf wt., g	0.36 (0.04) bc	0.28 (0.08) cd	0.17 (0.04) d	0.56 (0.07) d	0.52 (0.12) ab	0.47 (0.24) ab
Root wt.,g	1.24 (0.38) a	1.04 (0.32) ab	0.51 (0.07) d	1.00 (0.15) ab	0.79 (0.09) bc	0.64 (0.14) cd
Biomass, g	2.32 (0.64) b	1.78 (0.45) c	0.90 (0.12) d	3.18 (0.28) a	2.97 (0.33) a	1.82 (0.33) c
New growth (g)	1.59 (0.44) a	0.99 (0.34) b	0.44 (0.10) c	1.65 (0.13) a	1.40 (0.18) a	0.67 (0.26) bc
% new growth	68.40 (3.80) a	54.90 (7.80) b	48.30 (5.00) b	51.90 (3.50) b	47.40 (4.60) b	36.10 (10.40) c
RGR (g/g.day)	0.15 (0.02) a	0.08 (0.02) b	0.06 (0.01) bc	0.07 (0.01) b	0.06 (0.01) bc	0.04 (0.02) c

[1]Means in a row followed by the same letter are not significantly different according to Duncan's Multiple Range procedure (alpha = 0.05).

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results of this experiment suggest that root absorption and xylem transport are more important than foliar uptake and phloem transport of quinclorac in alligatorweed and explain the lack of herbicide symptoms on the regrowth in the initial tests. These observations are consistent with those of previous studies with quinclorac on other plants, which indicate that the primary route of uptake would be through the root system (Pearson and Carter 1986). Earlier research also has suggested that herbicide uptake by alligatorweed occurs more readily via the roots than foliar applications (Solymosy 1967). The more rapid responses in both qualitative and quantitative growth characteristics following root treatment as compared with foliar treatment also support the earlier suggestion that biotypic differences in response to foliar applications of quinclorac may have been the result of morphological differences (leaf surface characteristics such as waxes or epidermal hairs) between the biotypes. This conclusion must be accepted with caution, as the actual amount of herbicide entering the plants following root treatment may have been substantially different than that entering the plant via application to a single leaf. Uptake through the roots also may occur more readily than that through the leaves because of the lack of barriers to absorption (cuticular waxes, etc.), which are absent in the roots.

The results of this study suggest that broadstem alligatorweed may be more tolerant to herbicides such as quinclorac than slenderstem alligatorweed and may partly explain the inconsistent patterns of response to herbicides reported previously for alligatorweed. Field testing of quinclorac and other herbicides at locations having different alligatorweed biotypes and experimentation under a wider range of environmental conditions are needed to clearly substantiate differences in herbicide tolerance among alligatorweed biotypes. Micromorphological differences among biotypes which may affect foliar herbicide absorption (cuticle thickness, leaf pubescence, etc.) also should be investigated.

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