EVALUATION OF CGA-136872 AND DPX-V9360
FOR POSTEMERGENCE USE IN CORN

by

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(ABSTRACT)

The potential of CGA-136872 (3-[4,6-bis(difluoromethoxy) pyrimidin-2-yl-1-(2-methoxycarbonyl-phenylsulfonyl)urea) and DPX-V9360 (3-pyridinecarboxaminde, 2-(((4,6-dimethoxy pyrimidin-2yl)aminocarbonyl)) aminosulfonyl)))-N,N-dimethyl) were investigated for postemergence use in corn, including corn tolerance, weed control and combinations of CGA-136872 with other postemergence corn herbicides for weed control.

CGA-136872 Applied at rates of 1.2, 2.5, 5.0 and 10.0 times the suggested recommended use rate in corn (variety Southern States 565) caused more injury at the 5-leaf stage than at the 7- and 9-leaf stage of corn. Recovery from injury was rapid and complete at 5 weeks after treatment (WAT) and no yield reduction was observed. Several corn varieties treated with twice the suggested use rate of CGA-136872 and DPX-V9360 showed injury that was both herbicide and variety dependent. Most injury occurred at 1 and 2 WAT. Corn recovery was complete at 5 WAT, but yield

reduction on some varieties was observed with CGA-136872 treatments.

In the weed control study, both herbicides showed high activity on johnsongrass (Sorghum halepense (L.) Pers.), giant foxtail (Setaria faberi Herr.), common lambsquarters (Chenopodium album L.) and redroot pigweed (Amaranthus retroflexus L.), particularly with early applications. However, johnsongrass rhizome regrowth prevented full season control of this species with early postemergence applications.

Combinations of CGA-136872 with several other herbicides resulted in significant benefit in control of common lambs-quarters and redroot pigweed while johnsongrass and giant foxtail control was not improved. Reduced control of john-songrass was observed when CGA-136872 was applied in combi-nation with paraquat (1,1'-dimethyl-4,4'-bipyridilium ion). Similar results were observed for giant foxtail control when CGA-136872 was applied with 2,4-D ((2,4-dichloro-phenoxy) acetic acid) and dicamba (3,6-dichloro-2-methoxy-benzoic acid).

Results of this research indicate that both CGA-136872 and DPX-V9360 have good potential for postemergence use in corn, and could represent an important supplement to exist-ing postemergence corn herbicides.

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INTRODUCTION AND LITERATURE REVIEW

I. INTRODUCTION

Corn (Zea mays L.)is among the five major crops produced worldwide in terms of acreage and total yield (35). Problems associated with corn production include diseases, insects and weeds. In major corn producing areas of the United States, there have been many shifts in weed species associated with this crop, primarily due to the frequent use of this plant in rotations and corresponding repeated use of corn herbicides (58). The first shift in weed species infesting corn fields was from annual broadleaf weeds to annual grasses such as foxtails (Setaria spp) due to the continuous use of 2,4-D ((2,4-dichlorophenoxy)acetic acid) (58). The introduction and wide spread use of atrazine (6-chloro-N-ethyl-N'-(1-methylethyl) -1,3,5-triazine-2,4-diamine) caused a second shift from foxtail to fall panicum (Panicum dichotomiflorum Michx.) and crabgrass (Digitaria spp) (58). Due to the increasing acreage of no-till corn, the current shift is towards perennial weeds including johnsongrass (Sorghum halepense (L.) Pers.). Johnsongrass infestation has already been reported in many states (Figure 1). This weed is very difficult to control in corn because of lack of selective herbicides (75). In soybeans, several herbicides are currently available for

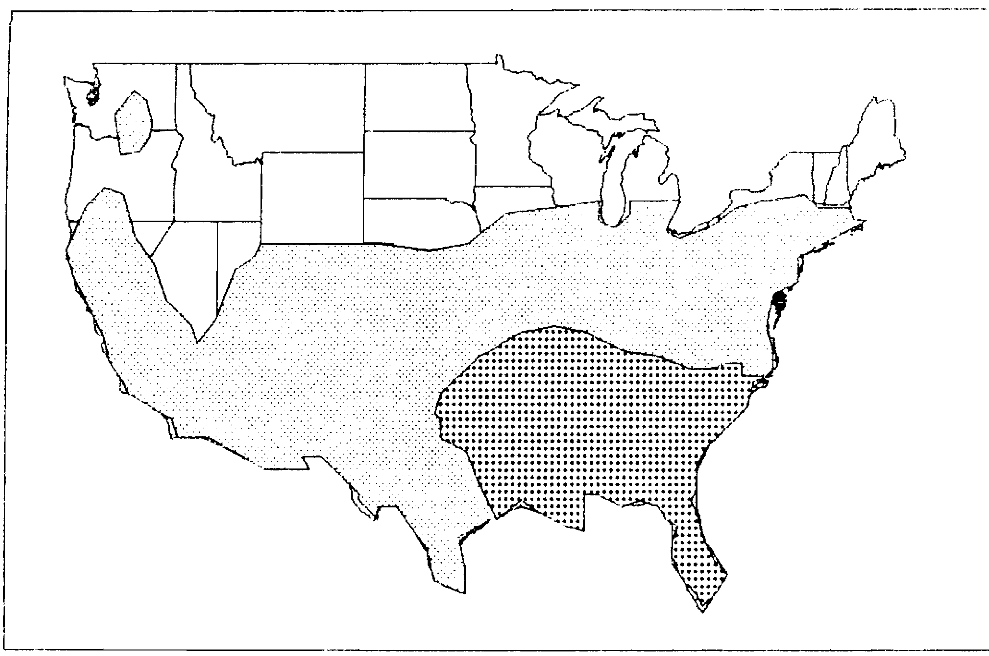


FIGURE 1. General distribution of johnsongrass in the United States. The denser hatching indicates the area where johnsongrass is of greatest importance (43).

postemergence johnsongrass control and include sethoxydim (2-[1-(sethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one), fluazifop ((±)-2-[4 [[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid) and glyphosate (N-(phosphonomethyl)glycine). In corn however, there are no effective postemergence treatments for control of this weed. Up to 100% reduction in corn yield has been reported in heavy johnsongrass infestations (5).

This research was conducted to determine the potential of two experimental herbicides, DPX-V9360 and CGA-136872, to control johnsongrass postemergence in corn. Specific objectives of these studies were:

1. To evaluate different rates and timings of DPX-V9360 and CGA-136872 for rhizome and seedling johnsongrass control as well as for control of giant foxtail (*Setaria faberi* Herrm.), common lambsquarters (*Chenopodium album* L.), and redroot pigweed (*Amaranthus retroflexus* L.).

2. To determine corn varietal tolerance to DPX-V9360 and CGA-136872.

3. To investigate the effect of different rates and application timings of CGA-136872 on corn injury.

4. To evaluate CGA-136872 in combination with other postemergence corn herbicides for control of johnsongrass, giant foxtail, common lambsquarters and redroot pigweed.

II. LITERATURE REVIEW

II-1. JOHNSONGRASS

Johnsongrass is native to the Mediterranean region and was introduced in the United States around 1800 for use as a forage crop (29, 30, 41, 47). It ranks sixth among the world's worst weeds (29) and is one of the three most serious weeds in corn in the United States (5). This perennial weed can reproduce by subterranean rhizomes and by seed production. Horowitz (30) observed a mean increase of 1.3 m^2/month for johnsongrass rhizomes and an average of 28,000 seed per plant. Lateral rhizome growth of 120-180 m/month has been reported (42). In instances of heavy infestation, johnsongrass can yield 7 tons of rhizomes and 600 kg of seed per hectare (42). Johnsongrass has become a major problem in corn as a result of inadequate control measures, minimum tillage practices and the continuous use of triazines and other broadleaf herbicides (58). This weed can reduce yield directly by competition for sunlight, water and nutrients (1, 5, 30, 42), or indirectly as a host and reservoir for two destructive viruses of corn: maize chlorotic dwarf virus (MCDV) and maize dwarf mosaic virus (MDMV) (5, 30, 34, 52, 55, 67). Allelopathic effects of johnsongrass have been reported in soybeans (<u>Glycine max</u> L.) (37).

II-2. JOHNSONGRASS CONTROL IN CORN

Bendixen (5) showed that corn yield was eliminated by johnsongrass infestations. In some crops such as soybeans, adequate johnsongrass control can be obtained with sethoxydim, fluazifop or glyphosate. Lack of selectivity of these herbicides however, prevent their use in corn (75). Most management practices for control of johnsongrass in corn are based on primary and secondary cultivation in combination with preplant incorporated and preemergence herbicide treatments (58). In conventional corn, maximum johnsongrass control is obtained when fields are cultivated at 4 to 5 weeks intervals (42). When incorporated before corn planting, EPTC (S-ethyl dipropylcarbamothioate) and butylate (S-ethyl bis(2-methylpropyl)carbamothioate) provide excellent control of seedling and some control of rhizome johsongrass (58). Alachlor (2-chloro-N-(2,6-diethylphenyl) -N-(methoxymethyl)acetamide), metolachlor (2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide) and pendimethalin (N-(1-ethylpropyl)-3,4-dimetyhl-2,6-dinitrobenzenamine) can provide some seedling control if preplant incorporated or applied preemergence.

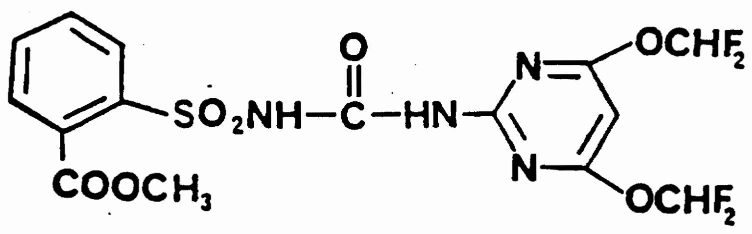
Two experimental herbicides DPX-V9360 and CGA-136872 have shown very good potential for selective postemergence control of johnsongrass in corn (2, 3). During the 1987 and 1988 growing seasons, these herbicides were tested extensively in the United States. They provide good control of johnsongrass (80-100%) as well as a high level of safety to corn (6, 21, 29, 32, 33, 44, 45, 46, 50, 63, 71). These compounds also show activity on other grasses including quackgrass (*Agropyron repens* (L.) Beauv.), shattercane (*Sorghum bicolor* (L.) Moench), wild proso millet (*Panicum miliaceum* L.), foxtails (*Setaria spp*), barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.) (9, 12, 14, 18, 23, 32, 38, 43, 46, 48, 49, 57, 70, 72), and many broadleaf weeds (4, 19, 38, 44, 45, 48, 72, 79).

II-3 REVIEW OF DPX-V9360 AND CGA-136872

II-3.1 CHEMISTRY

DPX-V9360 is formulated as water dispersible granule with 75% active ingredient (75% WDG) (2) . It is a product of E. I. du Pont de Nemours Co. and Inc., and the chemical name is 2-[[[4,6-dimethoxypyrimidin-2-yl]aminocarbonyl] aminosulfonyl] -N,N-dimethyl-3-pyridinecarboxamide monohydrate. The proposed trade name is Accent.

CGA-136872 is also formulated as water dispersible granules with 75% active ingredient. It is produced by CIBA-GEIGY corporation (3), and has the following structure.



The proposed common name is primisulfuron, the proposed trade name is Beacon and the chemical name is 3-[4,6-bis(difluoromethoxy)-pyrimidin-2-yl-1-(2-methoxy carbonyl-phenylsulfonyl)-urea.

Both DPX-V9360 and CGA-136872 belong to the family of sulfonylurea herbicides (2, 3).

II-3.2 USE RATE AND ADJUVANTS

The recommended use rates for experimental purposes are 20 to 40 g ai/ha and 17.5 to 70 g ai/ha for CGA-136872 and DPX-V9360 respectively (2, 3). High rates are required for rhizome johnsongrass control, while lower rates can be used for seedling johnsongrass control. Within this use rate range, weed control is improved with increasing rates of the herbicides but very high rates may result in corn injury.

Recommendations for both products include the use of non-ionic surfactant or crop oil concentrate (COC) (2, 3, 38, 74). Woznica and Nalewaja (74) showed that green foxtail (<u>Setaria</u> <u>viridis</u> (L.) Beauv.) control with DPX-V9360 increased from 52% to about 85% by addition of non-ionic surfactant at 0.25% (v/v). In another study, Lux et al. (38) demonstrated that the activity of DPX-V9360 on giant foxtail was increased from 77-95% to 85-96% by addition of COC or non-ionic surfactant. Woznica and Nalewaja (74) reported that non-ionic surfactant increases the level of activity of DPX-V9360 when application is followed by a rain.

III-3.3 CROP TOLERANCE

Research results indicate a high level of tolerance of corn to CGA-136872 and DPX-V9360 (9, 12, 31, 33, 43, 44, 45, 53, 63, 69). Using the corn varieties Golden Harvest and Pioneer 3902, Miller et al. (43, 44, 45) observed no injury 25 days after treatment with 40 g ai/ha CGA-136872 and 70 g ai/ha DPX-V9360 when applications were made at the 2- to 7-leaf stage of corn. The same type of result has been reported by Orr (53) on variety Pioneer 3377, Bhowmik and Germond (9) on variety Agway 584S and Smart et al. (63) on varieties Pioneer 3377, 3475, 3379 and 3183. Using the same rates, Vidrine et al. (69) also found no corn injury when treatments were performed six weeks after planting. Johnson et al. (31) showed that corn was tolerant to 250-280 g ai/ha of DPX-V9360 when treatments were made at several growth stages. In one study, CGA-136872 rates as high as 400 g ai/ha were used by Brown et al. (12) without significant injury to corn 3 weeks after treatment.

Some reports, however, indicate significant corn injury with both herbicides (28, 46, 48, 51, 72, 73). With corn variety Dekalb 689, Herman et al.(28) found significant crop injury with early applications of DPX-V9360 and no symptoms with CGA-136872. No yield reduction was detected, however. Two weeks after application of 280 g ai/ha DPX-V9360 to 5- to 6-leaf corn, Miller and Eberlin (46) recorded 15% injury and no significant yield reduction. Mueller et al. (51) found 10% corn stunting with 140 g ai/ha DPX-V9360 and 13-16% stunting with 40 g ai/ha CGA-136872. The same type of response was observed by Worsham and Saunders(73) with corn variety Funk's G4734. Wilson (72) showed that corn was more susceptible to CGA-136872 and DPX-V9360 at early growth stages (2-leaf) than later stages. Mitich and Smith (48) found that corn was able to recover from 30% injury caused by 400 g ai/ha of CGA-136872 without yield loss.

II-3.4 ACTIVITY

High levels of activity for CGA-136872 and DPX-V9360 have been reported on many grass weeds (9, 12, 14, 18, 23, 32, 38, 43, 46, 49, 51, 57, 69, 73).

For quackgrass, Bruce and Kells (14) found 80% control with 76 g ai/ha DPX-V9360. Gillespie et al. (23) observed 87% control of quackgrass with 20 g ai/ha CGA-136872. Bhowmik and Germond (9) recorded more than 90% control with different rates of DPX-V9360.

For shattercane, Kapusta et al. (32) obtained 90-99% control with 35 g ai/ha DPX-V9360. Brown et al. (12) found more than 80% control with 35 g ai/ha DPX-V9360 or 30 g ai/ha CGA-136872. With different rates of the two herbicides, Roeth and Martin (57) recorded 89 to 99% control of shattercane.

For giant foxtail, Kapusta et al. (32) found 90% control with 40 g ai/ha CGA-136872 and more than 95% control with 17.5 g ai/ha DPX-V9360 when treatment was made at the 5- to 8-leaf stage of corn.

For johnsongrass, Kapusta et al. (32) observed 65-99% control of rhizomes with DPX-V9360 at 17.5 to 35 g ai/ha. Vidrine et al. (69) obtained 95% and 86% control of seedling johnsongrass with DPX-V9360 at 110 g ai/ha and CGA-136872 at 50 g ai/ha, respectively. Johnsongrass control of more than 70% with 50 g ai/ha CGA-136872 and more than 90% with 140 g ai/ha DPX-V9360 has been reported by Mueller et al. (51). Worsham and Saunders (73) obtained 90 to 100% control of johnsongrass with varying rates of the two herbicides.

Reduced activity of both herbicides has been reported on johnsongrass and quackgrass with early applications (9, 28, 33, 36, 56). Bhowmik and Germond (9) found that control of quackgrass was lower when the herbicides were applied at the 1- to 3-leaf stage of the weed as compared to the 4- to 10-leaf stage. For johnsongrass control, Herman et al. (28) observed more activity when the herbicides were applied 24 rather than 18 days after planting. With treatments at the 3- to 4-leaf stage of johnsongrass, Kaufman and Ritter (33) found more regrowth than when applications were made at the 6-to 8-leaf stage. At 28 days after treatment with both herbicides, Locke et al. (36) recorded

79-89% control of seedling johnsongrass and 70-80% control of rhizome johnsongrass with late applications, but only 35% and 24% control of seedling and rhizome johnsongrass respectively with early applications. Due to this regrowth problem, Kaufman and Ritter (33) and Brown et al. (12) showed that johnsongrass control was improved with sequential applications rather than a single early or late post-emergence treatment.

Many broadleaf weeds have been effectively controlled with CGA-136872 and DPX-V9360 (4, 19, 31, 38, 48, 69, 72). One month after treatment with 70 g ai/ha DPX-V9360, Arnold et al. (4) observed 100% control of Russian thistle (Salsola iberica Sennen & Pau) and prostrate pigweed (Amaranthus blitoides S.Wats.), 99% control of redroot pigweed and 88% control of kochia (Kochia scoparia (L.) Schrad). With 40 g ai/ha CGA-136872, Evans and Janks (20) recorded 91% control of 2.5 to 7.5 cm tall common lambsquarters and redroot pigweed. Using the same rate, Wilson (72) found 95 and 75% control of redroot pigweed and common lambsquarters respectively. More than 80% control of other weed species including morningglory (Ipomea spp), hemp sesbania (Sesbania exaltata (Raf.) Rydb. ex A.W.Hill), spotted spurge (Euphorbia maculata L.) and prickly sida (Sida spinosa L.) with both herbicides has been reported by Johnson et al. (31), Vidrine et al. (69) and Wilson (72).

II-3.5 ENVIRONMENTAL CONDITIONS

The activity of herbicides is influenced by the environmental conditions during application. Rainfall, relative humidity, temperature and soil moisture have been shown to affect the activity of CGA-136872 and DPX-V9360 (2, 3, 32, 50, 51, 74).

Application of both herbicides is not recommended if rainfall is expected shortly (2, 3). In a study with simulated rainfall, Woznica and Nalewaja (74) found that activity of DPX-V9360 on green foxtail was reduced by about 50% if rain occured immediatly after treatment. The use of the non ionic surfactant however, reduced the loss of activity.

High relative humidity (96-100%) compared to low humidity (40-50%) was shown by Woznica and Nalewaja (74) to improve green foxtail and redroot pigweed control. In the same study, control was greater when temperature was 20 C after treatment than when temperature was 30 C or 10 C after treatment.

Low activity of both herbicides has been reported under low soil moisture (32, 50, 51). Moshier et al. (50) found 86 and 90% control of johnsongrass with CGA-136872 and DPX-V9360, respectively, under high soil moisture and only 32 and 79% control, respectively, under low soil moisture. Mueller et al. (51) observed more than 70% control of johnsongrass with CGA-136872 under high soil moisture and less than 50% control under low soil moisture.

II-3.6 COMBINATIONS

The major objective of herbicide combinations is to broaden the spectrum of activity. Other advantages include: cost reduction, residue minimization, extended period of activity and synergistic reactions. Unfortunately, not all herbicides are compatible in tank-mixing. Antagonistic reactions of herbicide combinations are documented in the literature (62, 78, 25).

CGA-136872 and DPX-V9360 have been shown to be compatible with most corn herbicides such as 2,4-D, atrazine, cyanazine (2-[[4-chloro-6-(ethylamino)-1,3,5-triazin-2-yl] amino]-2-methylpropmanenitrile), bromoxynil (3,5-dibromo-4-hydroxybenzonitrile), and dicamba (3,6-dichloro-2- methoxybenzoic acid) for the control of many weed species in corn (4, 19, 44, 53, 79).

Evans and Jenks (19) showed that addition of atrazine to CGA-136872 improved control of green foxtail from 59 to 93%. For many broadleaf weeds including common lambsquarters and kochia, Miller et al. (44) observed less than 60% control with DPX-V9360. However, more than 90% control was obtained when the compound was tank-mixed with several other herbicides. Orr (53) found that johnsongrass control with CGA-136872 (30 g ai/ha) was improved from 33 and 45% for seedlings and rhizomes, respectively to 45 and 70% when the herbicide was applied with atrazine. Zao et al. (79) effectively controlled triazine-resistant smooth pigweed with tank-mixtures of DPX-V9360 and atrazine.

Antagonistic reactions of CGA-136872 and DPX-V9360 with other herbicides have been reported on some weed species (23, 49). Gillespie et al. (23) observed loss of activity of CGA-136872 on quackgrass when tank-mixed with either atrazine or cyanazine. On the same weed species, however, no difference in activity was found whether the herbicide was applied alone or in combination with 2,4-D, dicamba or bentazon (3-(1-methylethyl)-(1H)-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide). Morton and Harvey (49) also reported antagonistic reactions from tank-mixtures of DPX-V9360 with cyanazine and dicamba for the control of wild proso millet, shattercane and giant foxtail.

II-3.7 MODE OF ACTION AND BASIS OF SELECTIVITY

The primary symptom of sulfonylurea herbicides on susceptible species is growth inhibition due to the inhibition of cell division (8, 10). Secondary symptoms involve chlorosis and necrosis (2, 8, 10). Studies with previous sulfonylureas indicate that the primary site of action of these herbicides in higher plants is acetolactate synthase (ALS), the common enzyme involved in the synthesis of branched chain amino acids valine, leucine and isoleucine (8, 10, 15, 20, 21, 22, 27, 39, 41, 60, 76, 77). These herbicides inhibit the enzyme by binding to a site similar to the quinone binding site of pyruvate oxidase (60).

Factors such as absorption, translocation and metabolism greatly affect herbicide selectivity. In the case of sulfonylureas, the rate of absorption and translocation has been shown to be the same in tolerant and susceptible species (7, 8, 10).

Bestman et al. (7) reported that the same amount of ^{14}C-chlorsulfuron (2-chloro-N-[[(4- metoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbanyl] benzenesulfonamide) was absorbed and translocated in tolerant grasses such as wheat and susceptible broadleaves such as flax (Linum sativum L.).

The difference in sensitivity of the target enzyme for sulfonylurea herbicides is not high enough to explain the difference between tolerant and susceptible plants (8). There is, however, a positive correlation between the level of tolerance and the rate of herbicide metabolism by different species (8, 10, 65). Sweetser et al. (65) showed that 24 h after treatment with ^{14}C-chlorsulfuron, 80 to 97% of the parent compound was recovered from sensitive species such as soybeans, cotton (Gossypium hirsutum L.), mustard (Brassica spp) and sugarbeet (Beta vulgaris L.) while only 5 to 10% was recovered from tolerant species such as wheat, barley, wild oat (Avena fatua L.) and annual bluegrass (Poa annua L.). Beyer et al. (8) found that half-life of chlorimuron (2-[[[[4-chloro-6-methoxy-2- pyrimidinyl)amino] carbonyl] amino]sulfonyl] benzoic acid) was 2-4 h in tolerant soybeans and more than 30 h in sensitive plants such as morningglory and cocklebur (Xanthium strumarium L.).

Major reactions of sulfonylurea detoxification in tolerant plants include ester hydrolysis, hydroxylation and conjugation with glucose or glutathione (8, 10, 54, 65). Ring hydroxylation followed by glucoside formation was proposed by Sweetser et al. (65) to be the main deactivation reaction of chlorsulfuron by wheat varieties. Conjugation of chlorimuron with homoglutathione was demonstrated by Beyer et al. (8) to be the main basis of tolerance of soybeans to this herbicide.

II-3.8 RESISTANCE

In 1987 and 1988, sulfonylurea-resistant weeds (prickly lettuce (Lactuca serriola L.), kochia and russian thistle) were identified (66, 40). Mallory et al. (40) and Thill et al. (66) showed that these weeds were resistant to chlorsulfuron, chlorimuron, sulfometuron (2-[[[[(4,6-dimethyl-2-pyrimidinyl) amino]carbonyl]amino]sulfonyl]benzoicacid) and bensulfuron (2-[[[[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]methyl]benzoicacid) and also showed cross-resistance to several imidazolinone herbicides. All these resistant weeds were found in fields where sulfonylurea herbicides were applied for 3 to 5 years, with a total amount of 88 to 123 g ai/ha (66). The mechanism of resistance is attributed to an altered form of the enzyme ALS with decreased sensitivity to inhibition by the herbicides (66). However, some cases of resistance not attributed to ALS have been reported in annual ryegrass (Lolium spp) by Thill et al. (66). In most cases, resistance was due to a single dominant nuclear mutation, resulting in the substitution of a single amino acid in the ALS enzyme (26, 27, 59, 61, 77). Haugh et al. (27) succesfully transfered the resistant ALS gene from Arabidopsis thaliana (L.) Heynh. to tobacco by means of Ti plasmid.

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Corn (Zea mays) Tolerance to Postemergence Applications of CGA-136872

Abstract. CGA-136872 injured corn more when applied at the 5-leaf stage than when applied at the 7- and 9-leaf stage of corn. Symptoms of herbicide phytotoxicity were primarily stunting and chlorosis. Most injury occurred with high rates (400 g ai/ha) and appeared during the first two weeks following treatment. At five weeks after treatment, corn recovery from injury was complete and no yield reduction was recorded. Yield loss occured in the weedy check, from competition with johnsongrass, giant foxtail, common lambsquarters and redroot pigweed. Nomenclature: CGA-136872, 3-[4,6-bis(difluoromethoxy)pyrimidin-2-yl-1-(2-methoxycarbonyl-phenylsulfonyl)-urea; johnsongrass, Sorghum halepense (L.) Pers. #[1] SORHA; giant foxtail Setaria faberi Herrn. # SETFA; common lambsquarters Chenopodium album L. # CHEAL; redroot pigweed Amaranthus retroflexus L. # AMARE; corn, Zea mays L. Additional index words. Sulfonylurea herbicide, timing, phytotoxicity.

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[1]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Weed Sci. 32, Suppl. 2. Available from WSSA, 309 W. Clark St., Champaign, IL 61820.

INTRODUCTION

Different growth stages of a particular crop or weed may cause differential responses of these plants to herbicides, and should be considered during the development of a new product. The best time to apply an herbicide should correspond to the period where the crop is less susceptible and the weed more susceptible. However, in many instances, the two plants may show parallel responses in susceptibility.

CGA-136872 is an experimental herbicide for postemergence use in corn (1). Research results indicate a high level of corn tolerance to this herbicide (2, 3, 4, 5, 6, 11, 12, 13). With corn varieties Golden harvest and Pioneer 3902, Miller et al. (4, 5, 6) observed no injury at 25 days after treatment with 40 g ai/ha, regardless of the growth stage. Similar results have been reported by Orr (11) with the variety Pioneer 3377, Bohwmik and Germond (2) with the variety Agway 584S and Smart et al. (12) with varieties Pioneer 3377, 3475, 3379 and 3183. Vidrine et al. (13) also reported no corn injury with CGA-136872 with application at six weeks after planting. Brown et al. (3) reported no significant injury to corn 3 weeks after treatment with rates as high as 400 g ai/ha.

Significant corn injury with CGA-136872 has been reported, however, (7, 9, 15). With 20 to 40 g ai/ha, Mueller et al. (9) observed 13-16% corn stunting and 0-8% chlorosis. Mitich and Smith (7) recorded 30% corn injury with 400 g ai/ha. Recovery, however, was rapid, with no yield reduction.

Differential response of corn to CGA-136872 at different growth stages has been reported (6, 14). Wilson (14) showed that corn was more susceptible at the early stages (2-leaf) than later stages. With 70 g ai/ha, Miller et al. (6) observed no symptoms with treatments at the 5- and 8-leaf stage, but 50% injury and 5200 kg/ha yield reduction with treatment at the 2-leaf stage.

The objective of this study was to evaluate corn tolerance to postemergence applications of CGA-136872, as influenced by herbicide rate and application timing.

MATERIALS AND METHODS.

Field experiments were conducted in 1988 and 1989 in Blacksburg, Va to evaluate the response of corn to CGA-136872, using a factorial combination of application timings and herbicide rates.

The site consisted of a Ross loam (fine-loamy, mixed, mesic cumulic Hapludolls) of 2% organic matter and pH 6.1. A natural infestation of johnsongrass, giant foxtail, common lambsquarters and redroot pigweed was present. Corn variety Southern States 565 was planted in 75 cm rows using a commercial planter adjusted to a population of one seed per 18 cm of row. Corn was grown using conventional tillage and was planted May 23, 1988 and May 18, 1989.

The experiment contained a two-way rate by timing (5 by 3) factorial in a randomized complete block design of four replications. Herbicide rates were 0, 50, 100, 200 and 400 g ai/ha, corresponding to 0, 1.2, 2.5, 5, and 10X rates, respectively. For the timing factor, CGA-136872 was applied at the 5-, 7- and 9-leaf stages of corn, corresponding to 15-20, 35-40 and 90-110 cm tall plants, respectively. A weedy check was used in 1988 and a weed free check in 1989.

All treatments were applied to 1.5 m wide by 8 m long plots containing 2 rows of corn, with a CO_2-pressurized backpack sprayer delivering 214 L/ha at a pressure of 210 kPa through flat fan spray tips[2].

Non ionic surfactant[3] was added to all treatments at 0.25% v/v. Estimates of percent corn injury were made at 1, 2, 3, 4 and 5 weeks after treatment. Yield data were obtained by hand harvesting one row of corn in each plot. Grain moisture was adjusted to 15.5%.

All data were subjected to analysis of variance and means were separated using Duncan's multiple range test at the 0.05 significance level. Homogeneity of variance procedures did not allow combination of data from separate years.

In individual tables, means have been separated within individual levels of factors when a significant ($\alpha = 0.05$) interaction occurred.

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[2]Teejet 8003 tips, Spraying Systems Co., North Avenue, Wheaton, IL 60287.

[3]X-77, a mixture of alkylarylpolyoxyethylene glycols, free fatty acids, and isopropanol, marked by Chevron Chemical Co., 575 Market Street, San Francisco, CA 94120.

RESULTS AND DISCUSSION

Symptoms of CGA-136872 injury to corn were primarily stunting and chlorosis. Most injury was observed 1 or 2 weeks after treatment (WAT). However, at 5 WAT, corn recovered completely from injury and showed no observable symptoms (Figures 1 and 2). Applications at the 5-leaf stage generally resulted in the highest level of injury (Table 1, Figures 1 and 2). In 1989, treatments applied at the 7- and 9-leaf stage did not cause significantly different crop injury (Table 1). In 1988, 400 g/ha caused the highest level of injury, irrespective of the application timing (Table 1). Injury levels of 16.3, 12.5 and 10.7% were observed for applications at the 5-, 7- and 9-leaf stage, respectively. No timing effect was observed with 50 g/ha, with 5.6, 2.5 and 6.3% injury for treatments at the 5-, 7-and 9-leaf stage respectively. With 400 g/ha applied at the 5-leaf stage, the greatest injury was recorded during both years. Injury levels of 16.3 and 30.7% were observed in 1988 and 1989, respectively (Table 1).

In general, more injury was observed in 1989 compared to 1988. During the period from one week before the first treatment to one week after the last treatment, rainfall was 110 mm in 1988 and 250 mm in 1989. This difference in rainfall may account for the difference in injury observed during the two years. Roggenbuck and Penner (10) have demonstrated increased injury to corn from postemergence applications of trifluralin {2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl)benzenamine}, when the crop is growing under conditions of high soil moisture.

In 1988, Treated corn produced yield higher than the check (Table 2). In this treatment, corn was allowed to compete with weeds while herbicide application completely suppressed these weeds in other treatments. This result alone indicates that even if the herbicide did reduce grain yield, this reduction was lower than that caused by weed competition. In 1989, the control treatment was kept weed-free, and no significant difference in yield was observed between treatments. This results shows that, with CGA-136872 rates as high as ten times the suggested use rate, corn recovered completely from injury by 5 WAT, with no yield loss. Also, no delay in the date of flowering and maturity date of corn was observed. A similar result has been found by other researchers (8, 9, 15). This suggests a high level of safety of CGA-136872 for postemergence use in corn.

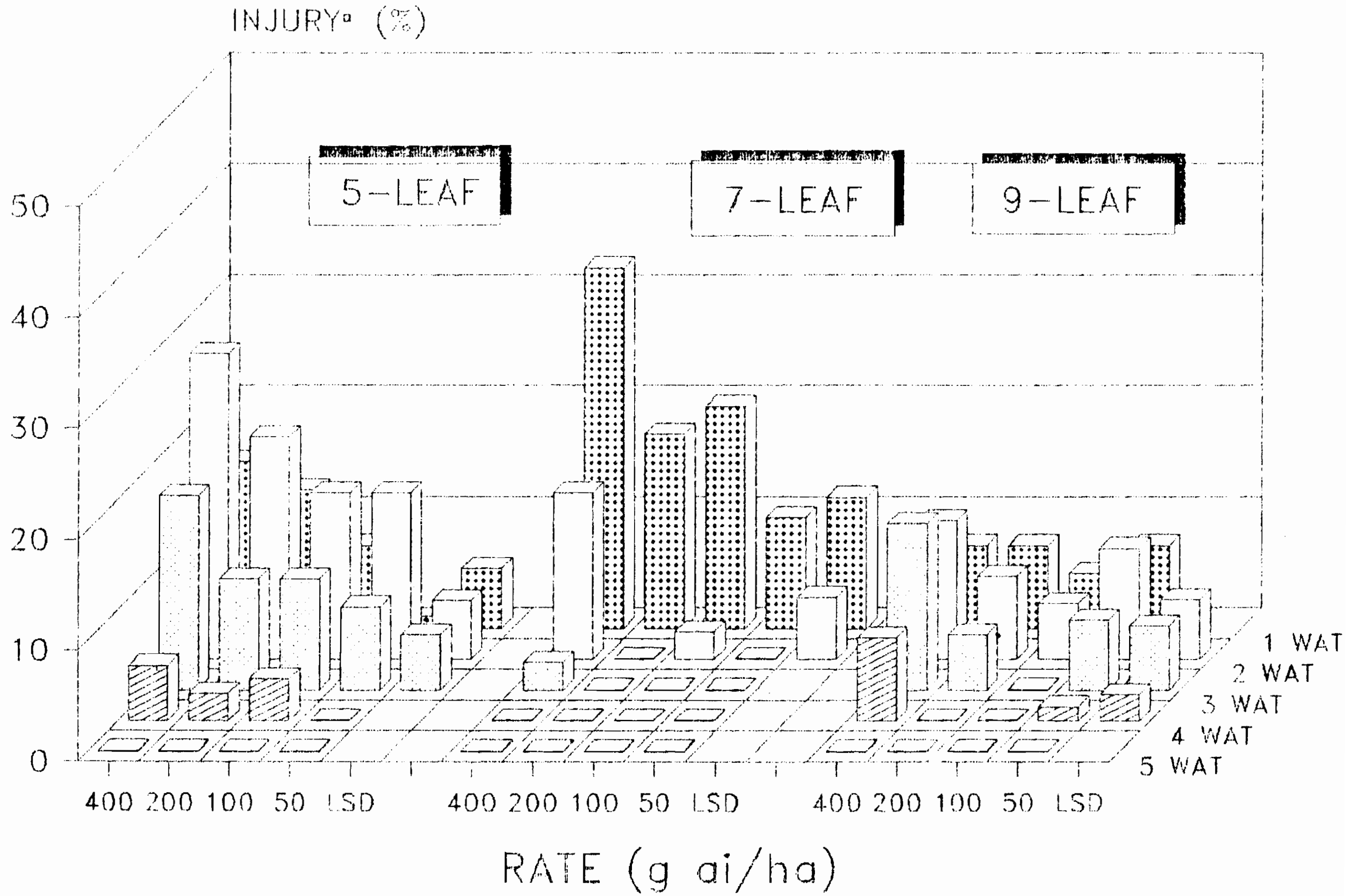

Figure 1. Corn response to different rates and application timings of CGA-136872 in 1988.

[a] No significant difference where LSD is not presented

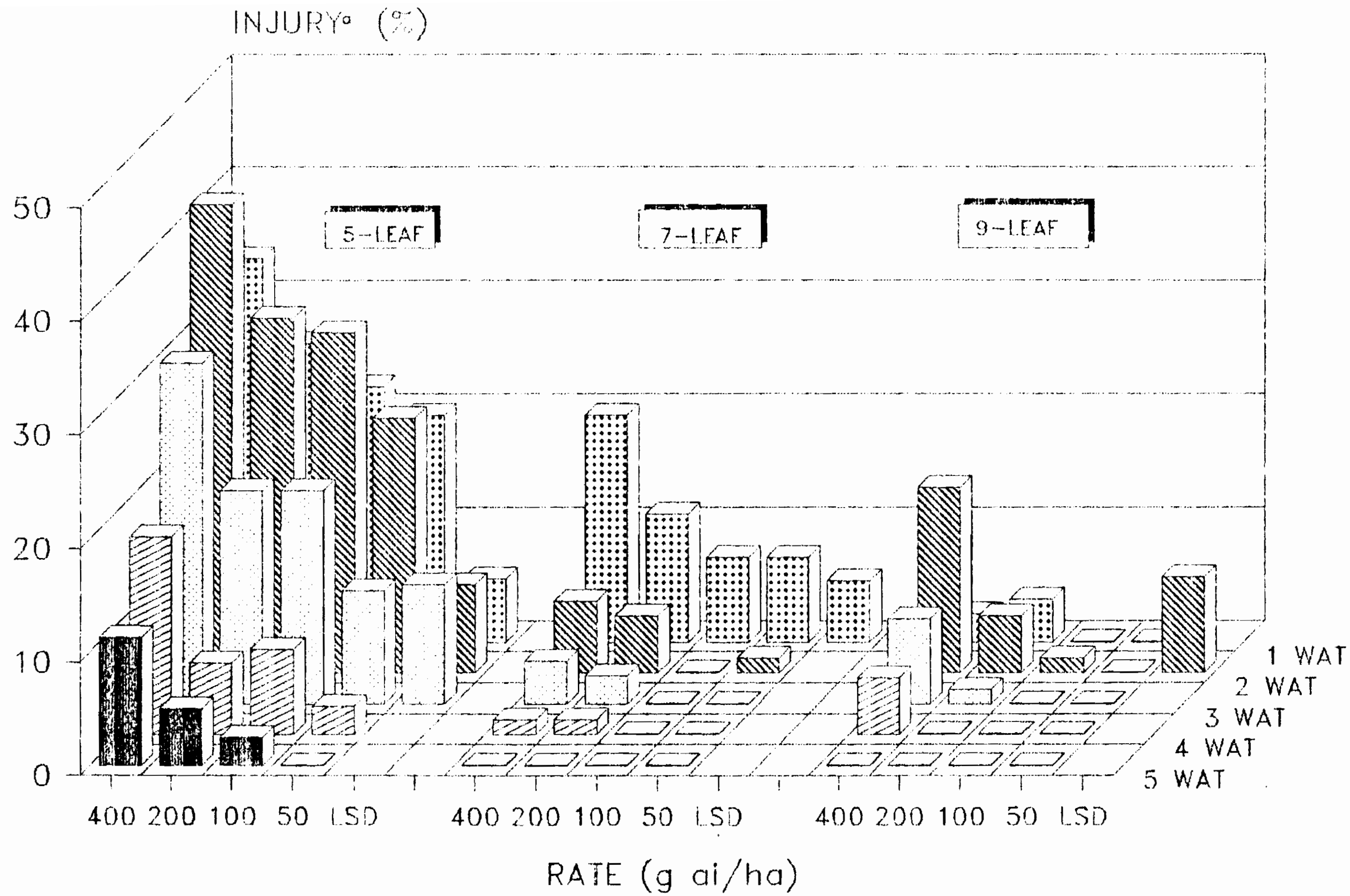

Figure 2. Corn response to different rates and application timings of CGA-136872 in 1989.

[a] No significant difference where LSD is not presented.

TABLE 1. Corn injury following postemergence applications of different rates of CGA-136872 applied at three different growth stages[a].

Year	Rates (g ai/ha)	Growth Stage 5-leaf	7-leaf	9-leaf
		%		
1988				
	0	0 Da	0 Ca	0 Da
	50	6 Ca	2 BCa	6 Ba
	100	9 Ba	6 Bb	2 CDc
	200	11 Ba	4 Bb	5 BCb
	400	16 Aa	12 Aa	11 Aa
1989				
	0	0 Ca	0 Ca	0 Aa
	50	14 Ba	2 Cb	0 Ab
	100	20 Ba	2 Cb	0 Ab
	200	21 Ba	5 ABb	2 Ab
	400	31 Aa	8 Ab	8 Ab

[a]Individual means for herbicide rates within a year and within a column followed by the same upper case letter and timing means within a row followed by the same lower case letter do not differ significantly at the 0.05 level as determined by Duncan's multiple range test. Mean separation procedures performed for levels within a factor due to significant interaction. Each mean represents the average injury over the first four weeks following treatment.

TABLE 2. Corn yield as affected by postemergence applications of different rates of CGA-136872 applied at three different growth stages[a].

Year	Rates (g ai/ha)	Growth Stage 5-leaf	7-leaf	9-leaf	Mean
		kg/ha			
1988					
	0	7870	7870	7870	7870 B
	50	9640	9370	8410	9140 AB
	100	9560	9450	9910	9640 A
	200	10030	12340	8450	10270 A
	400	10680	9720	7850	9410 A
	Mean	9550 a	9750 a	8490 a	
1989[b]					
	0	8420	8420	8420	8420 A
	50	8550	7780	9070	8460 A
	100	8270	8180	8600	8350 A
	200	8660	8630	8870	8720 A
	400	7820	9200	7150	8050 A
	Mean	8340 a	8440 a	8420 a	

[a]In individual years, herbicide rate means within a column followed by the same upper case letter and timing means within a row followed by the same lower case letter do not differ significantly at the 0.05 level as determined by Duncan's multiple range test.

[b]No significant effect of treatments was observed

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Corn (Zea mays) Varietal Tolerance to Postemergence Applications of CGA-136872 and DPX-V9360

Abstract: Field experiments were conducted to evaluate the tolerance of corn varieties to CGA-136872 and DPX-V9360. Herbicide symptoms were primarily chlorosis and stunting, although stand reduction was observed with some varieties. In the absence of weeds, applications of 80 and 140 g ai/ha CGA-136872 and DPX-V9360, respectively, to different corn varieties caused injury that was both herbicide and variety dependent. Most injury occurred one or two weeks following treatment. Recovery was generally rapid, but significant yield reduction in 7 and 6 varieties was observed with CGA-136872 in 1988 and 1989, respectively. No significant yield reduction was observed with DPX-V9360 treatments. Nomenclature: CGA-136872, 3-[4,6-bis (difluoromethoxy)-pyrimidin-2-yl]-1-(2-methoxycarbonyl -phenylsulfonyl)-urea; DPX-V9360, 2-[[[4,6- dimethoxypyrimidin-2-yl]aminocarbonyl]aminosulfonyl]-N,N-dimethyl-3--pyrimidinecarboxamide monohydrate; corn, Zea mays L..
Additional index words: Sulfonylurea herbicides, phytotoxicity.

INTRODUCTION

Differential tolerance of crop cultivars to herbicides is well documented in the literature (9, 14, 15, 16, 20, 21, 22, 26, 27, 29, 32). For a given herbicide, this difference in cultivars response can vary greatly. Hayes and Wax (16) showed that differences in response of soybean cultivars to bentazon {3-(1-methylethyl)-(1H)-2,1,3- benzothiadiazin-4(3H)-one 2,2-dioxide} was due to differences in metabolism of the herbicide. Rate of translocation and metabolism of metribuzin {4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H)-one} by soybeans has also been found by Hardcastle (15), Mangeot et al. (21) and Wax et al. (34) to be responsible for differential varietal susceptibility. Cabanne et al. (9), and Ryan and Owen (29) showed that in wheat, metabolism of chlortoluron {1-(3-chloro-4-methylphenyl)-3,3dimethylurea} was the major cause of differential tolerance.

CGA-136872 and DPX-V9360 are new sulfonylurea herbicides for postemergence use in corn (2, 3). These compounds have shown high potential for selective postemergence control of many grass and broadleaf weeds in this crop (4, 8, 13, 18, 19, 24, 33, 35). Although corn is considered tolerant to both herbicides, some reports indicate that injury may occur following treatment (24, 17, 23, 25). Differential tolerance of corn genotypes to sulfonylurea herbicides has been reported (10, 12). Eberlein et al. (12) found that corn inbred lines varied in tolerance to thiameturon {3-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl) amino] carbonyl] amino]sulfonyl]-2-thiophenecaboxylic acid}. Dekker et al. (10) observed differences in tolerance of corn inbreds to CGA-136872. Other reports, however, indicate no differential response of corn cultivars to CGA-136872 and DPX-V9360 (5, 31). In a test including several inbred and hybrid corn, Bergman et al. (5) found no significant difference with 40 and 140 g ai/ha CGA-136872 and DPX-V9360 respectively. Using 32 g ai/ha of DPX-V9360, Smart et al. (31) observed no difference in susceptibility with Pioneer 3183, 3377, 3379 and 3475. Shaner et al. (30) showed that the level of tolerance of corn lines to sulfonylurea herbicides was correlated with the sensitivity of acetohydroxyacid synthase, the target enzyme for this class of compounds. Eberlein et al. (12), however, found no difference in the sensitivity of the enzyme between tolerant and susceptible corn varieties.

The purpose of this study was to evaluate the susceptibility of corn cultivars to postemergence applications of CGA-136872 and DPX-V9360.

MATERIALS AND METHODS

Field experiments were conducted in 1988 and 1989 in Blacksburg, Va to evaluate the tolerance of different corn cultivars to postemergence applications of CGA-136872 and DPX-V9360 under weed free conditions.

The site consisted of a Ross loam (fine-loamy, mixed, mesic cumulic Hapludolls) of 2% organic matter and pH 6.1. Corn was grown using conventional tillage and was planted May 23 1988 and May 21 1989. The entire plot was kept weed free by repeated handweeding.

Corn varieties were planted in 75 cm rows using a commercial planter adjusted to a population of one seed per 18 cm of row. All cultivars were planted side by side (2 rows per cultivar) in plots 8 m long and 1.5 m wide. Herbicide rates were 80 and 140 g ai/ha for CGA-136872 and DPX-V9360, respectively, corresponding to twice the suggested use rate of each herbicide. In 1988, 8 and 37 varieties were tested with CGA-136872 and DPX-V9360, respectively. In 1989, 41 varieties were tested with both herbicides. Treatments were made across all varieties, in 90 cm-wide bands, replicated 4 times (1988) or 3 times (1989), according to the method described by Rose et al. (28). All treatments were applied at the 4- to 5-leaf stage of corn with a CO_2-pressurized backpack sprayer delivering 214 L/ha at 210 kPa through flat fan spray tips[1]. Non ionic surfactant[2] was added to all treatments at 0.25% v/v.

Estimates of percent corn injury were made at 1, 2, 3, 4 and 5 weeks following treatment, using a 0 to 100% scale with 0% indicating no injury and 100% indicating death of the corn plant. The average injury for each cultivar was calculated as the mean injury during the first 4 weeks after treatment. Data on stand reduction were recorded 3 weeks after treatment. Yield data were obtained by hand-harvesting both rows in each plot. Grain moisture was adjusted to 15.5%. To allow the comparison of yield among different varieties, yield reduction was calculated as percentage of the control yield for each variety. A control with 0% yield reduction was then used in the analysis.

All data for corn injury and yield reduction were subjected to the analysis of variance and means were separated using Duncan's multiple range test at the 0.05 significance level.

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[1]Teejet 8003 tips, Spraying Systems Co., North Av., Wheaton, IL 60287

[2]X-77, a mixture of alkylarylpolyoxyethylene glycols, free fatty acids, and isopropanol, marketed by Chevron Chemical Co., 575 Market St. San Francisco, CA 94120.

RESULTS AND DISCUSSION

Corn injury: The observable symptoms of CGA-136872 and DPX-V9360 were primarily chlorosis and stunting although stand reduction was observed with some varieties that were severely injured (Tables 1 and 2). These are symptoms commonly observed with sulfonylurea herbicides (2, 6, 7). Stand reduction was mostly observed with corn plants that showed delayed germination and were at the 2- to 3-leaf stage during treatment, compared to 4- to 5-leaf stage for the majority of plants. This observation indicates that smaller corn plants were more susceptible than taller plants. This suggests that difference in germination rate with different corn varieties may actually account for part of the difference in the observed susceptibility.

Data for corn injury in 1988 are summarized in Tables 3 and 4 for CGA-136872 and DPX-V9360, respectively. Most injury was observed at one week after treatment and corn recovered rapidly by the end of the second week, with no observable symptoms on most of the varieties at the end of the fifth week. Varieties Dekalb DK689, Augusta A403 and McCurdy 7777 showed the most symptoms. Injury of 38, 20, 13 and 3% was observed with variety Dekalb DK689 at 1, 2, 4 and 5 weeks after treatment respectively (Table 3). With Augusta A403, 40, 18, 3 and 0% injury was observed during the same time. Variety McCurdy 7777 showed 50% and no injury at 1 and 4 weeks after treatment, respectively. With this variety, the low level of injury at 4 weeks following treatment was due to the fact that the most seriously injured plants died, as indicated by stand reduction in Table 1.

The average injury during the first 4 weeks after treatment ranged from 1 to 24% for CGA-136872 (Table 3) and from 1 to 12% for DPX-V9360 (Table 4). With CGA-136872, variety Dekalb DK689 was the most injured with 24% injury, followed by Augusta A403 with 20%, Oro EX807 with 19%, McCurdy 7777 with 18% and Southern States 15982 with 17% injury. Average injury with other varieties was lower than 15%, with only 1% for Beck's 85MDM.

In 1989 (Tables 5 and 6), most corn injury was observed at 1 or 2 week after treatment. For most varieties, recovery from injury was complete by the end of the fifth week following application. Average injury ranged from 5 to 32% for CGA-136872 (Table 5) and from 5 to 29% for DPX-V9360 (Table 6). Variety Golden Acres TE6997 showed the greatest injury with both herbicides, with 32 and 29% injury for CGA-136872 and DPX-V9360, respectively.

More injury was observed in 1989 compared to 1988, and the highest level of injury occurred earlier in 1988 than 1989. Corn plants were experiencing drought stress during herbicide applications in 1988. The difference in soil moisture may account for the difference in susceptibility between the two years. The effect of soil moisture on herbicide phytotoxicity has been reported (1, 27). This varies not only with the herbicide but also with the plant under consideration, and is true for both soil and postemergence applied herbicides. Below field capacity, Ahmadim et al. (1) showed that the activity of glyphosate {N-(phosphonomethyl)glycine} on barnyardgrass (Echinochloa crus-galli (L.) Beauv. # ECHCG) was reduced, due to reduced translocation. Roggenbuck and Penner (27) demonstrated that at field capacity, corn was more susceptible to trifluralin {2,6-dinitro-N,N-dipropyl-4- (trifluorometyl)benzenamine}, than when grown at low soil moisture. If water stress did indeed affect corn response in 1988, this effect was by reducing the level of injury.

Yield: Data in Table 1 show that in 1988, CGA-136872 caused significant yield loss with 7 varieties including Pioneer 3147, Golden Acres TE6995A, Southern States 728, Pioneer 3187, Oro EX807, Dekalb DK789 and Augusta A410 with 45, 42, 36, 34, 33, 30 and 29% yield reduction, respectively. During the same year, DPX-V9360 caused 48% yield reduction with Golden Acres TE6995A. In 1989 (Table 2), CGA-136872 caused significant yield loss with 6 varieties including Cargill 8527, Oro EX807, Golden Acres GA35788, Pioneer 3179, Augusta A404 and Kenworthy KLX463 with 35, 31, 30, 28, 28 and 27% yield loss, respectively.

Varieties with the most visual symptoms (Tables 3, 4, 5 and 6) or stand reduction (Tables 1 and 2) did not automatically show the greatest yield loss. Smart et al. (31) showed that herbicide phytotoxicity was not always expressed through visual symptoms. They found that corn cultivars Pioneer 3377 and 3379 treated with 0.18 kg sethoxydim {2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio) propyl]-3-hydroxy-2-cyclohexen-1-one}, had lower photosynthetic rate and lower yield than the control although no difference in symptoms was observed.

Injury with CGA-136872 and DPX-V9360 was both herbicide and variety dependent. However, variety Golden Acres TE6997 showed high level of injury to both herbicides in 1989. Recovery from initial injury was generally rapid and complete but CGA-136872 treatments resulted in yield reduction in 7 and 6 varieties in 1988 and 1989, respectively. No significant yield loss was observed with DPX-V9360 treatments.

TABLE 1: Corn stand and yield reduction resulting from applications of CGA-136872 and DPX-V9360. 1988 data[a].

Variety	CGA-136872		DPX-V9360	
	Stand[b]	Yield	Stand[b]	Yield
	%			
1 DEKALB DK689	0	8 c-h	0	15
2 HY-PERFORMER HS97	10	19 a-h	10	14
3 HY-PERFORMER HS60	0	5 e-h	0	0
4 GOLDEN A. TE6995A	0	42 ab	10	48
5 SUPER CROST 7195	5	0 h	5	0
6 HY-PERFORMER X8800	10	15 b-h	10	20
7 PIONEER 3147	0	45 a	0	2
8 SUPER CROST 5995	5	11 c-h	5	10
9 AUGUSTA A403	0	16 b-h	0	0
10 ORO EX807	0	33 a-e	-	-
11 McCURDY 7777	10	6 d-h	-	-
12 SOUTHERN ST.15982	0	12 c-h	-	-
13 PIONEER 3187	10	34 a-d	-	-
14 AUGUSTA A410	5	29 a-g	-	-
15 DEKALB DK789	0	30 a-f	-	-
16 COKERS 8696	0	25 a-h	-	-
17 DEKALB DK649	0	0 h	-	-
18 PIONEER 3165	0	0 h	-	-
19 PIONEER 3179	0	1 gh	-	-
20 PIONEER 3295	5	7 c-h	-	-
21 DELTAPINE DP5750	5	16 b-h	-	-
22 DELTAPINE DPX9986	0	2 fgh	-	-
23 SOUTHERN ST. 15983	0	0 h	-	-
24 JACQUES 8250	5	3 fgh	-	-
25 CARGILL 130036	5	0 h	-	-
26 HYTEST HT797	5	21 a-h	-	-
27 SOUTHERN ST. 728	0	36 abc	-	-
28 GOLDEN A. TE6997	5	3 fgh	-	-
29 JACQUES 8400	0	10 c-h	-	-
30 ZIMMERMAN Z33	0	3 fgh	-	-
31 SOUTHERN ST. 811	5	17 b-h	-	-
32 JACQUES 8280	0	1 gh	-	-
33 AUGUSTA A402	5	18 a-h	-	-
34 HYTEST HT686	5	3 fgh	-	-
35 SOUTHERN ST. 815	5	19 a-h	-	-
36 JACQUES 8350	0	7 c-h	-	-
37 BECKS 85MDM	0	13 c-h	-	-
38 CONTROL	0	0 h	0	0

[a]Means within a column followed by the same letter do not differ significantly at the 0.05 significance level as determined by Duncan's multiple range test.
[b]No significant difference of treatments.

TABLE 2: Corn stand and yield reduction resulting from applications of CGA-136872 and DPX-V9360. 1989 data[a].

Variety	CGA-136872 Stand	CGA-136872 Yield	DPX-V9360 Stand	DPX-V9360 Yield[b]
	%			
1 GOLDEN A. TE6997	4 ab	22 a-d	0 c	23
2 AUGUSTA A403	0 b	18 a-d	0 c	29
3 ORO EX807	0 b	31 ab	0 c	18
4 JACQUES 8250	0 b	10 a-d	0 c	14
5 DEKALB DK689	4 ab	9 bcd	0 c	9
6 McCURDY 7700	0 b	14 a-d	0 c	11
7 SUPER CROST 7195	0 b	12 a-d	0 c	3
8 HY-PERFORMER HS97	0 b	6 bcd	9 ab	7
9 ORO 151	4 ab	0 d	0 c	21
10 KENWORTHY KLX463	0 bb	27 abc	0 c	22
11 AUGUSTA A404	0 b	28 abc	0 c	14
12 DEKALB DK649	0 b	3 cd	4 bc	14
13 PIONEER 3378	0 b	6 bcd	0 c	0
14 PIONEER 3165	0 b	18 a-d	0 c	19
15 PIONEER 3147	0 b	6 bcd	0 c	29
16 CARGILL 8527	0 b	35 a	0 c	31
17 GOLDEN A. GA35788	4 ab	30 ab	13 a	30
18 McCURDY 7777	0 b	21 a-d	0 c	16
19 ASGROW GO. XP9877	0 b	3 cd	0 c	12
20 PIONEER 3187	0 b	15 a-d	0 c	17
21 AUGUSTA A402	4 ab	25 a-d	0 c	8
22 SUPER CROST 1860	0 b	18 a-d	9 ab	9
23 PIONEER 3328	0 b	12 a-d	0 c	9
24 JACQUES 8280	10 a	8 bcd	4 bc	13
25 HYTEST HT744	0 b	10 a-d	0 c	0
26 ORO X801	0 b	0 d	0 c	4
27 GARST 8388	0 b	0 d	0 c	2
28 SOUTHERN ST. 814	0 b	12 a-d	4 bc	20
29 AUGUSTA A412	0 b	8 bcd	0 c	10
30 PIONEER 3179	0 b	28 abc	0 c	22
31 GOLDEN A. GA35795	0 b	17 a-d	0 c	14
32 BECK'S 85MDM	0 b	8 bcd	0 c	15
33 GARST 8116	0 b	0 d	0 c	0
34 SOUTHERN ST. 844	4 ab	0 d	0 c	0
35 ASGROW GO. XP9118	0 b	18 a-d	0 c	30
36 GARST 8536	4 ab	16 a-d	0 c	8
37 GARST 8344	0 b	14 a-d	0 c	17
38 DELTAPINE DP5750	0 b	8 bcd	4 bc	14
39 HYTEST HT 797	4 ab	8 bcd	0 c	5
40 PIONEER 3176	0 b	6 bcd	0 c	22
41 ORO SUSC.	0 b	18 a-d	4 bc	23
42 CONTROL	0 b	0 d	0 c	0

[a]Means within a column followed by the same letter do not differ significantly at the 0.05 significance level as determined by Duncan's multiple range.

[b]No significant difference of treatments.

TABLE 3: Corn injury following postemergence application of 80 g ai/ha of CGA-136872. 1988 data[a].

	Variety	Weeks After Treatment 1	2	4	5	Average[b]
		%				
1	DEKALB DK689	38 bc	20 a	13 a	3 ab	24 a
2	AUGUSTA A403	40 b	18 ab	3 c	0 c	20 ab
3	ORO EX807	26 b-g	20 a	11 ab	4 a	19 abc
4	McCURDY 7777	50 a	5 c	0 c	0 c	18 a-d
5	SOUTHERN ST.15982	30 b-e	15 abc	5 bc	3 ab	17 a-e
6	PIONEER 3187	18 d-j	20 a	5 bc	0 c	14 b-f
7	AUGUSTA A410	33 bcd	6 abc	3 c	0 c	14 f-g
8	PIONEER 3147	28 b-f	10 abc	3 c	0 c	13 b-g
9	DEKALB DK789	28 b-f	5 abc	0 c	0 c	11 b-h
10	COKERS 8696	18 d-j	13 abc	3 c	0 c	11 b-h
11	DEKALB DK649	18 d-j	13 abc	3 c	0 c	11 b-h
12	HY-PERFORMER HS60	18 d-j	13 abc	3 c	0 c	11 b-h
13	PIONEER 3165	15 e-k	18 ab	0 c	0 c	11 b-h
14	PIONEER 3179	20 d-i	10 abc	3 c	0 c	11 b-h
15	PIONEER 3295	30 b-e	0 c	3 c	0 c	11 b-h
16	GOLDEN A. TE6995A	15 e-k	10 abc	5 bc	1 bc	10 c-i
17	DELTAPINE DP5750	20 d-i	8 abc	0 c	0 c	9 d-j
18	DELTAPINE DPX9986	13 f-k	13 abc	3 c	0 c	9 d-j
19	SOUTHERN ST. 15983	10 g-k	15 abc	3 c	0 c	9 d-j
20	JACQUES 8250	15 e-k	8 abc	0 c	0 c	8 e-j
21	CARGILL 130036	23 c-h	0 c	0 c	0 c	8 e-j
22	HYTEST HT797	20 d-i	0 c	0 c	0 c	7 f-j
23	SOUTHERN ST. 728	20 d-i	0 c	0 c	0 c	7 f-j
24	GOLDEN A. TE6997	10 g-k	3 bc	3 c	0 c	6 f-j
25	HY-PERFORMER HS97	10 g-k	3 bc	3 c	1 bc	5 f-j
26	JACQUES 8400	13 f-k	3 bc	0 c	0 c	5 f-j
27	SUPER CROST 7195	13 f-k	0 c	0 c	0 c	4 g-j
28	ZIMMERMAN Z33	5 ijk	3 bc	5 bc	0 c	4 g-j
29	SOUTHERN ST. 811	8 h-k	3 bc	3 c	0 c	4 g-j
30	SUPER CROST 5995	10 g-k	3 bc	0 c	0 c	4 g-j
31	HY-PERFORMER X8800	13 f-k	0 c	0 c	0 c	4 g-j
32	JACQUES 8280	8 h-k	3 bc	0 c	0 c	3 hij
33	AUGUSTA A402	8 h-k	0 c	3 c	0 c	3 hij
34	HYTEST HT686	5 ijk	5 abc	0 c	0 c	3 hij
35	SOUTHERN ST. 815	0 k	3 bc	3 c	0 c	2 hij
36	JACQUES 8350	5 ijk	0 c	0 c	0 c	2 hij
37	BECKS 85MDM	3 jk	0 c	0 c	0 c	1 ij
38	CONTROL	0 k	0 c	0 c	0 c	0 j

[a]Means within a column followed by the same letter do not differ significantly at the 0.05 significance level as determined by Duncan's multiple range test.
[b]Averege injury during the first four weeks after treatment.

TABLE 4: Corn injury following postemergence application of 140 g ai/ha of DPX-V9360. 1988 data[a].

Variety	Weeks After Treatment				Average[b]
	1	2	4	5	
	%				
1 DEKALB DK689	25 a	5 ab	5 ab	1 a	12 a
2 HY-PERFORMER HS97	18 ab	10 a	0 b	0 a	9 ab
3 HY-PERFORMER S60	13 bc	8 ab	0 b	0 a	7 abc
4 GOLDEN A. TE6995A	13 bc	5 ab	0 b	0 a	6 bcd
5 SUPER CROST 7195	8 bcd	3 ab	8 a	1 a	6 bcd
6 HY-PERFORME X8800	3 cd	10 a	0 b	0 a	4 b-e
7 PIONEER 3147	5 cd	0 b	0 b	0 a	2 cde
8 SUPER CROST 5995	3 cd	0 b	0 b	0 a	1 de
9 CONTROL	0 d	0 b	0 b	0 a	0 e

[a]Means within a column followed by the same letter do not differ significantly at the 0.05 significance level as determined by Duncan' multiple range test.
[b]Average injury during the first four weeks after treatment.

TABLE 5: Corn injury following postemergence application of 80 g ai/ha of CGA-136872. 1989 data[a].

	Variety	Weeks After Treatment 1		2		3		4		5		Average[b]	
		%											
1	GOLDEN A.TE6997	38	a	40	a	35	a	13	a	7	a	32	a
2	AUGUSTA A403	30	bcd	30	b	20	b-e	8	abc	3	b	22	b
3	ORO EX807	22	e-h	30	b	23	bc	10	ab	2	bc	21	bc
4	JACQUES 8250	32	abc	30	b	22	bcd	0	e	0	c	21	bcd
5	DEKALB DK689	33	ab	30	b	15	c-h	0	e	0	c	20	b-e
6	McCURDY 7700	17	f-j	25	b-e	25	b	8	abc	0	c	19	b-f
7	SUPER CROST 7195	27	b-e	25	b-e	15	c-h	3	cde	0	c	18	b-g
8	HYPERFORMER HS97	25	c-f	28	bc	12	e-j	2	de	0	c	17	b-h
9	ORO 151	22	e-h	22	b-g	18	b-f	5	b-e	0	c	17	b-h
10	KENWORTHY KLX463	23	d-g	27	bcd	12	e-j	3	cde	2	bc	16	b-i
11	AUGUSTA A404	18	f-j	23	b-f	15	c-h	5	b-e	2	bc	15	b-j
12	DEKALB DK649	20	e-i	27	bcd	12	e-j	2	de	0	c	15	b-j
13	PIONEER 3378	17	f-j	20	b-h	22	bcd	0	e	0	c	15	c-j
14	PIONEER 3165	32	abc	25	b-e	2	jk	0	e	0	c	15	c-j
15	PIONEER 3147	18	f-j	23	b-f	13	d-i	3	cde	0	c	15	c-j
16	CARGILL 8527	22	e-h	20	b-h	15	c-h	0	e	0	c	14	c-k
17	GOLDEN A.GA35788	18	f-j	18	c-h	18	b-f	0	e	0	c	14	d-l
18	McCURDY 7777	18	f-j	25	b-e	10	e-j	2	de	0	c	14	d-l
19	ASGROW G. XP9877	20	e-i	20	b-h	15	c-h	0	e	0	c	14	d-l
20	PIONEER 3187	18	f-j	22	b-g	12	e-i	3	cde	0	c	14	d-l
21	AUGUSTA A402	18	f-j	18	c-h	17	b-g	2	de	0	c	13	e-m
22	SUPER CROST 1860	15	g-j	23	b-f	12	e-j	2	de	0	c	13	e-n
23	PIONEER 3328	13	hij	18	c-h	20	b-e	0	e	0	c	13	e-n
24	JACQUES 8280	15	g-j	12	ghi	12	e-i	8	abc	2	bc	12	f-o
25	HYTEST HT744	18	f-j	22	b-g	7	g-k	0	e	0	c	12	f-o
26	ORO X801	13	hij	18	c-h	13	d-i	0	e	0	c	11	g-o
27	GARST 8388	10	j	23	b-f	12	e-i	0	e	0	c	11	g-o
28	SOUTHERN ST. 814	18	f-j	13	f-i	12	e-i	0	e	0	c	11	g-o
29	AUGUSTA A412	15	g-j	25	b-e	3	ijk	0	e	0	c	11	g-o
30	PIONEER 3179	17	f-j	18	c-h	8	f-k	0	e	0	c	11	g-o
31	GOLDEN A.GA35795	13	hij	17	d-h	5	h-k	7	bcd	0	c	10	g-o
32	BECK'S 85MDM	12	ij	17	d-h	10	e-j	2	de	0	c	10	h-o
33	GARST 8116	15	g-j	15	e-i	8	f-k	2	de	0	c	10	h-o
34	SOUTHERN ST.844	15	g-j	13	f-i	8	f-k	0	e	0	c	9	i-o
35	ASGROW G. XP9118	13	hij	13	f-i	5	h-k	2	de	0	c	8	j-o
36	GARST 8536	17	f-j	7	ij	5	h-k	0	e	0	c	7	k-o
37	GARST 8344	13	hij	12	ghi	2	jk	0	e	0	c	7	l-p
38	DELTAPINE DP5750	12	ij	12	ghi	2	jk	0	e	0	c	6	m-p
39	HYTEST HT 797	10	j	10	hi	5	h-k	0	e	0	c	6	m-p
40	PIONEER 3176	12	ij	12	ghi	0	k	0	e	0	c	6	nop
41	ORO SUSC.	10	j	10	hi	0	k	0	e	0	c	5	op
42	CONTROL	0	k	0	j	0	k	0	e	0	c	0	p

[a]Means within a column followed by the same letter do not differ significantly at the 0.05 significance level as determined by Duncan's multiple range test.

[b]Average injury during the first 4 weeks after treatment

TABLE 6: Corn injury following postemergence application of 140 g ai/ha of DPX-V9360. 1989 data[a].

	Variety	Weeks After Treatment 1		2		3		4		5		Average[b]	
		%											
1	GOLDEN A. TE6997	38	a	43	a	23	abc	10	ab	3	b	29	a
2	GOLDEN A. GA35788	32	ab	25	b-e	30	a	13	a	7	a	25	ab
3	McCURDY 7700	25	b-f	30	b	27	ab	8	abc	2	bc	23	abc
4	JACQUES 8280	27	b-e	28	b-c	27	ab	8	abc	2	bc	23	abc
5	JACQUES 8250	28	a-d	28	bc	18	cde	0	c	0	c	19	bcd
6	PIONEER 3187	20	c-i	27	bcd	20	bcd	8	abc	2	bc	19	bcd
7	DEKALB DK 689	30	abc	25	b-e	10	f-i	0	c	0	c	16	cde
8	ASGROW G. XP9877	20	c-i	20	c-h	18	cde	7	abc	2	bc	16	cde
9	AUGUSTA A403	18	d-i	25	b-e	15	def	5	bc	0	c	16	cde
10	PIONEER 3147	20	c-i	27	bcd	10	f-i	3	bc	0	c	15	def
11	KENWORTHY KLX463	22	b-h	25	b-e	12	e-h	0	c	0	c	15	def
12	PIONEER 3165	30	abc	20	c-h	8	f-i	0	c	0	c	15	def
13	SOUTHERN ST. 814	23	b-g	13	g-j	13	d-g	7	abc	2	bc	14	d-g
14	ORO X807	18	d-i	15	f-i	15	def	7	abc	0	c	14	d-h
15	BECK'S 85MDM	13	g-j	18	d-i	13	d-g	7	abc	2	bc	13	d-i
16	DEKALB DK649	15	f-j	25	b-e	10	f-i	0	c	0	c	13	d-i
17	AUGUSTA A404	18	d-i	20	c-h	7	g-j	5	bc	0	c	13	d-i
18	ASGROW G. XP9118	18	d-i	20	c-h	8	f-i	3	bc	0	c	13	d-i
19	SUPER CROST 1860	12	hij	23	b-f	10	f-i	3	bc	0	c	12	d-j
20	ORO X801	12	hij	17	e-i	15	def	3	bc	2	bc	12	d-i
21	AUGUSTA A402	15	f-j	15	f-i	13	d-g	2	c	0	c	11	e-j
22	ORO 151	13	g-j	17	e-i	10	f-i	3	bc	0	c	11	e-j
23	HYTEST HT744	17	e-i	22	b-g	5	hij	0	c	0	c	11	e-j
24	PIONEER 3378	10	ijk	13	ghi	18	cde	0	c	0	c	10	e-j
25	SUPER CROST 7195	20	c-i	12	hij	10	f-i	0	c	0	c	10	e-j
26	ORO SUSC.	12	hij	25	b-e	5	hij	0	c	0	c	10	e-j
27	AUGUSTA A412	17	e-i	20	c-h	5	hij	0	c	0	c	10	e-j
28	PIONEER 3328	17	e-i	10	ij	10	f-i	3	bc	0	c	10	e-j
29	CARGILL 8527	18	d-i	13	g-j	8	f-i	0	c	0	c	10	e-j
30	GARST 8116	17	e-i	18	d-i	3	ij	2	c	0	c	10	e-j
31	PIONEER 3179	17	e-i	18	d-i	5	hij	0	c	0	c	10	e-j
32	GOLDEN A. GA35795	15	f-j	15	f-i	7	g-j	3	bc	0	c	10	e-j
33	SOUTHERN ST. 844	13	g-j	13	g-j	12	e-h	0	c	0	c	10	e-j
34	HY-PERFORMER HS97	17	e-i	13	g-j	7	g-j	2	c	0	c	10	e-j
35	McCURDY 7777	15	f-j	15	f-i	7	g-j	0	c	0	c	9	e-j
36	GARST 8388	5	jk	20	c-h	5	hij	0	c	0	c	8	f-j
37	PIONEER 3176	12	hij	13	ghi	3	ij	0	c	0	c	7	g-j
38	HYTEST HT797	10	ij	10	ij	7	g-j	0	c	0	c	7	hij
39	GARST 8536	15	f-j	5	jk	3	ij	0	c	0	c	6	ijk
40	DELTAPINE DP5750	12	hij	12	hij	0	j	0	c	0	c	6	ijk
41	GARST 8344	10	ij	10	ij	0	j	0	c	0	c	5	jk
42	CONTROL	0	k	0	k	0	j	0	c	0	c	0	k

[a]Means within a column followed by the same letter do not differ significantly at the 0.05 sgnificance level as determined by Duncan's multiple range test.
[b]Average injury during the first 4 weeks after treatment.

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Postemergence Weed Control and Corn (*Zea mays*) Injury with CGA-136872 and DPX-V9360

Abstract. Corn injury caused by CGA-136872 or DPX-V9360 was very low and occurred primarily with early postemergence treatments. Control of all weed species was dependent on stage of growth. Both herbicides showed high activity on johnsongrass, particularly with early applications. However, these treatments did not provide full season control of this species, due to regrowth of rhizomes and continuous germination of new seeds. Applications to 13-20 cm tall johnsongrass were more effective than early or late applications. Giant foxtail control was highly dependent on application time. All rates of both herbicides provided excellent control of this weed with early treatments (<5 cm tall weeds). At 13 cm and above, only high rates of DPX-V9360 gave acceptable giant foxtail control. Common lambsquarters and redroot pigweed control was dependant on application timing. These weeds were more effectively controlled with early applications. Nomenclature: CGA-136872, 3-[4,6-bis(difluoromethoxy) -pyrimidin-2-yl-1-(2-methoxycarbonyl-phenylsulfonyl)-urea; DPX-V9360, 2-[[[4,6-dimethoxypyrimidin-2-yl]aminocarbonyl] aminosulfonyl]-N,N-dimethyl-3-pyridinecarboxamide monohy-

drate; johnsongrass, Sorghum halepense (L.) Pers. #[1] SORHA; giant foxtail Setaria faberi Herr. # SETFA; common lambsquarters Chenopodium album L. # CHEAL; redroot pigweed Amaranthus retroflexus L. # AMARE; corn, Zea mays L. Additional index words. Johnsongrass, giant foxtail, common lambsquarters, redroot pigweed, timing, sulfonylurea herbicides.

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[1]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Weed Sci. 32, Suppl. 2. Available from WSSA, 309 W. Clark St., Champaign, IL 61820.

INTRODUCTION

CGA-136872 and DPX-V9360 are new experimental herbicides for postemergence use in corn (1, 2). Although these compounds have primarily been investigated for johnsongrass control, they also show activity on many other grasses and broadleaf weeds (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 17, 18, 19,). Gillespie et al. (8) observed 87% control of quackgrass (Agropyron repens (L.) Beauv.) with 20 g ai/ha CGA-136872, and Bhowmik and Germond (4) recorded more than 90% control with varying rates of DPX-V9360. For shattercane (Sorghum bicolor (L.) Moench), more than 80% control with both herbicides has been reported by Kapusta et al. (11), Brown et al. (5), and Roeth and Martin (17). Giant foxtail control of 90 and 95% has been obtained by Kapusta et al. (11) for CGA-136872 and DPX-V9360, respectively. With 70 g ai/ha of DPX-V9360, Arnold et al. (3) observed 100% control of Russian thistle (Salsola iberica Senen & Pau) and prostrate pigweed (Amaranthus blitoides S.Wats.), 99% control of redroot pigweed and 88% control of kochia (Kochia scoparia (L.) Schrad.). With 40 g ai/ha of CGA-136872, Evans and Jenks (7) recorded 91% control of common lambsquarters and redroot pigweed. More than 80% control of other broadleaf weeds including morningglory (Ipomea spp), hemp sesbania (Sesbania exaltata (Raf.) Rydb. ex A.W.Hill), spotted spurge (Euphorbia maculata L.) and prickly sida (Sida spinosa L.) with both herbicides has been reported by Johnson et al. (10), Vidrine et al. (18) and Wilson (19). CGA-136872 and DPX-V9360 activity on many weed species has been shown to be dependent not only on the herbicide rate, but also on the growth stage of the weed during application. In most situations, optimum weed control is obtained with high rates applied in early stages of weeds growth. However, due to regrowth problems, control of rhizome johnsongrass has been found to be greatest with split applications (5, 12) or with high rates of these herbicides applied late in the season when johnsongrass is actively growing (9, 13, 16). Within a wide range of DPX-V9360 rates, smooth pigweed control was found to be independent of the application time (10). Research results on the activity of DPX-V9360 on giant foxtail are conflicting. Some reports indicate no rate and timing effect (11), while others show more activity when the herbicide is applied before the 6-leaf stage (15). Giant foxtail control with CGA-136872 was found to be greatest with high rates of the herbicide applied early in the season (11).

The primary objective of this research was to evaluate the activity of CGA-136872 and DPX-V9360 on johnsongrass, giant foxtail, common lambsquarters and redroot pigweed. The second objective was to determine the optimum rates and timings of application for control of each weed species.

MATERIALS AND METHODS

This study was conducted in 1988 and 1989 in Blacksburg, Va. The site consisted of a Ross loam (fine loamy, mixed, mesic cumulic Hapludolls) with 2% organic matter and pH 6.1. The experimental plot had a natural infestation of johnsongrass, giant foxtail, common lambsquarters and redroot pigweed. Common lambsquarters infestation was very heavy in the test plot. Johnsongrass and giant foxtail infestations were moderate while redroot pigweed density was low but uniform. Corn variety Southern States 565 was planted in 75 cm rows using a commercial planter adjusted to a population of one seed per 18 cm of row. The crop was grown using conventional tillage and was planted May 23, 1988 and May 18, 1989.

The experiment contained a two-way herbicide by timing factorial in a randomized complete block design with four replications. Herbicide rates were 20, 30 and 40 g ai/ha for CGA-136872 and 17.5, 35 and 70 g ai/ha for DPX-V9360. Three application timings were used and included early postemergence (EP), mid postemergence (MP) and late postemergence (LP) treatments. Table 1 shows the respective growth stages of corn and weeds during each herbicide application. Individual plots were 1.6 m wide and 8 m long and consisted of two rows of corn. The entire plot received 125 kg/ha of nitrogen fertilizer.

All treatments were applied with a CO_2-pressurized backpack sprayer delivering 214 L/ha at a pressure of 210 kPa through flat fan spray tips[2]. Non ionic surfactant[3] was added to all treatments at 0.25% v/v. Estimates of weed control and corn injury were made at 2, 5, 7 and 9 weeks after treatment (WAT) on a 0 to 100% scale, with 0% indicating no crop injury or weed control and 100% indicating complete kill of the plant. Yield data were obtained by hand-harvesting one row of corn in each plot. Grain moisture was adjusted to 15.5%.

Data on corn injury , weed control and grain yield were subjected to analysis of variance and means separated using Duncan's multiple range test at the 0.05 significance level. Homogeneity of variance procedures did not allow combination of data from separate years. In individual tables, means have been separated within levels of factors when a significant ($\alpha = 0.05$) interaction occurred.

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[2]Teejet 8003 tips, Spraying Systems Co., North Avenue, Wheaton, IL 60287.

[3]X-77, a mixture of alkylarylpolyoxyethylene glycols, free fatty acids, and isopropanol, marked by Chevron Chemical Co., 575 Market Street, San Francisco, CA 94120.

RESULTS AND DISCUSSION

Corn injury: Except for the early applications, no major crop injury was recorded. Symptoms were generally stunting and chlorosis, and varied between 3 to 10% (Table 2). Those symptoms were transitory and in most cases, disappeared completely by 3 WAT.

Johnsongrass control: Most of the johnsongrass present in the study site originated from seed. In 1988, timing of herbicide application did not have any effect on the control of this weed (Table 3). With CGA-136872 treatments, control ratings of 93-95, 60-95 and 80-90% were observed for the EP, MP and LP applications, respectively. DPX-V9360 provided 78-98, 93-95 and 90-93% control of johnsongrass for the EP, MP and LP treatments, respectively. For both herbicides, the lowest rate resulted in lower johnsongrass control. Control levels of 78, 90 and 93% were observed for 20, 30 and 40 g ai/ha of CGA-136872, respectively. With DPX-V9360, 87, 96 and 94% control were recorded for 17.5, 35 and 70 g ai/ha, respectively.

In 1989, more activity was observed with the EP treatment, with 93-100% control, compared to 85-100 and 43-70% for the MP and LP treatments, respectively. Timing of application and herbicide rates interacted significantly during the 1989 season. With the EP and MP application timing the activity of both herbicides was high, regardless of rate. In 1989, weed control with the LP timing of application was low (40-70%). Johnsongrass was more than 30 cm tall at that time. Increasing rates of herbicides resulted in higher activity, but no adequate level of control was obtained with the highest rates.

In general, johnsongrass control was good when CGA-136872 and DPX-V9360 were applied at all timings in 1988 and the Ep and MP timings in 1989 when evaluated at 5 WAT. However, at 9 WAT, a decline in control for the EP treatments and an improvement in control for the LP treatments was observed (data not presented). The loss of activity with EP treatments was due in large part to regrowth from rhizomes and the continuous germination of new seeds. The LP application provided excellent control of johnsongrass but prior to treatment, the weed had become tall enough to compete with the crop. Only the MP timing provided full-season johnsongrass control without significant competition between the weed and the crop prior to treatment.

Regrowth of johnsongrass rhizomes has been reported by other investigators (9, 12, 13, 16). Also, continuous germination of seedlings has occurred to reduce late-season johnsongrass control with CGA-136872 and DPX-V9360 (16). In an attempt to solve this problem, split applications have been proposed (5, 12). This, however, requires additional trips through the field, and the second application might be less effective, due to greater corn height and corresponding interception of spray by the crop. A compromise may be the use of high rates in the mid-season when corn is at the 6- to 7-leaf stage, and johnsongrass at the 4- to 5-leaf stage.

Giant foxtail control: Table 4 contains data on giant foxtail control for 1988 and 1989. In 1988, CGA-136872 provided 75-85, 55-85 and 53-68% control of giant foxtail for the EP, MP and LP applications, respectively. With DPX-V9360, 80-93, 88-98 and 88-93% control for the EP, MP and LP treatments, respectively. Control from the first two applications was not significantly different while control with the LP treatment was significantly reduced, particularly with CGA-136872. DPX-V9360 provided 85, 94 and 93% control of giant foxtail with 17.5, 35 and 70 g/ha , repectively, while CGA-136872 failed to provide adequate control (61-76% control). Generally, DPX-V9360 at all rates provided better giant foxtail control than any CGA-136872 rate. No interaction between application timing and herbicide rates was observed in 1988.

In 1989, all herbicides and rates provided 100% control of giant foxtail with the EP treatment. With the MP application, DPX-V9360 provided 90-100% control while CGA-136872 failed to provide adequate control (50-68%). None of the herbicides and rates showed an acceptable level of control with the LP application. Control ratings of 25-50% for CGA-136872 and 50-78% for DPX-V9360 were observed with the LP treatments. During the two years, giant foxtail was severely stunted with the LP herbicide applications, but not killed. Small inflorescences developed, and seed was formed by the end of the season

These results indicate that control of 1 to 2-leaf giant foxtail can be obtained with both herbicides. However, at the 3- to 5-leaf stage only DPX-V9360 provided adequate control. Neither of the herbicides provided commercially acceptable control if giant foxtail is larger than 7-leaf stage. The activity of CGA-136872 and DPX-V9360 has been reported to be excellent on giant foxtail (11, 15). Kapusta et al. (11) found that DPX-V9360 efficacy on this species decreases with increasing weed size.

Common lambsquarters control: In 1988, the EP and MP applications of CGA-136872 provided the highest level of common lambsquarters control (Table 5). Control with DPX-V9360 was not dependent on the application timing. In 1989, the EP application resulted in very high activity of herbicides on common lambsquarters, with 83-100% control. As the weed became larger, its susceptibility to the herbicides decreased. Over the two growing seasons, a rate response was observed with both herbicides. In most instances, high rates were consistently more active, but not always significantly different from lower rates. A significant interaction was found between herbicides and application timings for both years. In 1988, the best control was obtained with 30 and 40 g/ha of CGA-136872 applied early in the season or 70 g/ha of DPX-V9360 applied either during the EP or the MP application timing. In 1989, excellent control was observed with both herbicides and all rates during the first timing. With CGA-136872, 95, 98 and 100% control was recorded for 20, 30 and 40 g/ha, respectively. DPX-V9360 provided 83, 93 and 100% control for 17.5, 35 and 70 g/ha, respectively.

These results show that CGA-136872 and DPX-V9360 exhibit a high level of activity on common lambsquarters, particularly in early growth stages. The same type of result has been reported by Evans and Jenks (7), where 91% control was observed with CGA-136872 applied to 1-3 inch plants. This is, however, in contradiction with the results of Miller et al. (14), who observed little activity with CGA-136872 and DPX-V9360 on 1-2 inches common lambsquarters.

Redroot pigweed control: Control of redroot pigweed was dependent on the growth stage during herbicide treatment (Table 6). The weed was found to be more susceptible at early stages. For the EP, MP and LP timings, an average of 86, 79 and 69% control, respectively, was observed in 1988. During the three timings, high rates resulted in greater control. However, over a single EP application, no rate effect was found and 100% control with all herbicide rates was observed. This result indicates that the use of high rates of these herbicides for control of 3- to 4-leaf redroot pigweed was not needed. After the 8-leaf stage, however, increasing rates were required for adequate control of the weed.

Both CGA-136872 and DPX-V9360 showed high activity on redroot pigweed within a wide range of rates and application times. The same type of response has been found elsewhere (10, 12, 20). This is a very promising result because these compounds could be used as an alternative control measure for triazine-resistant pigweed species (12, 20). Their use in combination with triazine herbicides may also be considered.

__**Yield:**__ In 1988, all LP treatments resulted in significantly lower corn yields (Table 7). This relates very well with weed control data which showed reduced efficacy on all species with the latter treatment timing. Herbicide rate did not have any effect on yield. This is probably due to corn tolerance of high rates and high activity of the herbicides at low rates on most weed species. The interaction between herbicide and application timing was significant. CGA-136872 (40 g/ha) applied EP resulted in the highest yield (9350 kg/ha). The lowest yield (5400 kg/ha) was obtained with 30 g/ha CGA-136872 applied at the LP timing.

No significant effect of herbicide treatments on corn yields were observed in the 1989 experiment (Table 7). However lower yield was observed with the lowest rate of DPX-V9360 (17.5 g/ha) applied EP and the lowest rate of CGA-136872 (20 g/ha) applied LP.

TABLE 1: Corn and weed growth stages at the time of herbicide applications[a].

Plants	EP		MP		LP	
	Leaf Stage	Height (cm)	Leaf stage	Height (cm)	Leaf stage	Height (cm)
corn	4-5	13-20	6-7	35-50	9-11	>30
johnsongrass	1-2	3-7	4-5	13-20	5-7	12-15
foxtail	1-2	1-5	3-5	3-13	7-9	8-12
lambsquarters	3-4	2-5	8-14	3-20	>30	12-20
pigweed	3-4	1-5	6-8	3-15	>15	12-18

[a]EP = Early postemergence, MP = mid postemergence, LP = late postemergence.

TABLE 2: Corn injury with varying rates of CGA-136872 and DPX-V9360 applied at three different timings[a, b].

Year	Herbicide	Rate (g/ha)	Timing[c] EP	MP	LP	Average
			%			
1988						
	CGA-136872	20	0	3	0	1 B
	CGA-136872	30	5	-	0	3 AB
	CGA-136872	40	10	5	0	5 A
	DPX-V9360	17.5	0	0	0	0 B
	DPX-V9360	35	3	0	0	1 B
	DPX-V9360	70	5	3	0	3 AB
	Control	0	0	0	0	0 B
	Average		3 a	2 ab	0 b	
1989						
	CGA-136872	20	0	0	0	0 A
	CGA-136872	30	8	0	0	3 A
	CGA-136872	40	8	0	0	3 A
	DPX-V9360	17.5	0	0	0	0 A
	DPX-V9360	35	0	0	0	0 A
	DPX-V9360	70	8	0	0	3 A
	Control	0	0	0	0	0 A
	Average		3 a	0 b	0 b	

[a]In individual years, herbicide rate means within a column followed by the same upper case letter and timing means within a row followed by the same lower case letter do not differ significantly at the 0.05 significance level as determined by Duncan's multiple range test.

[b]Data were recorded two weeks after treatment.

[c]EP = early postemergence, MP = mid postemergence and LP = late postemergence.

TABLE 3: Johnsongrass control with varying rates of CGA-136872 and DPX-V9360 applied at three different timings[a, b].

Year	Herbicide	Rate (g/ha)	Timing[c] EP	MP	LP	Average
			------------- %	-------------	-------------	-------------
1988						
	CGA-136872	20	93	60	80	78 D
	CGA-136872	30	93	-	87	90 BC
	CGA-136872	40	95	95	90	93 ABC
	DPX-V9360	17.5	78	93	90	87 C
	DPX-V9360	35	98	98	93	96 A
	DPX-V9360	70	98	95	90	94 AB
	Control	0	0	0	0	0 E
	Average		79 a	76 a	75 a	
1989						
	CGA-136872	20	93 Aa	85 Aa	50 BCb	-
	CGA-136872	30	100 Aa	88 Aa	43 Cb	-
	CGA-136872	40	98 Aa	100 Aa	55 ABCb	-
	DPX-V9360	17.5	95 Aa	88 Aa	48 BCb	-
	DPX-V9360	35	100 Aa	85 Aa	65 ABb	-
	DPX-V9360	70	100 Aa	93 Aa	70 Ab	-
	Control	0	0 Ba	0 Ba	0 Da	-

[a]Individual means for herbicide rates within a year and within a column followed by the same upper case letter and timing means within a row followed by the same lower case letter do not differ significantly at the 0.05 level as determined by Duncan's multiple range test. Mean separation procedures were performed for levels within a factor (1989 data) due to significant interaction.

[b]Data were recorded five weeks after treatment.

[c]EP = early postemergence, MP = mid postemergence and LP = late postemergence.

TABLE 4: Giant foxtail control with varying rates of CGA-136872 and DPX-V9360 applied at three different timings[a, b].

Year	Herbicide	Rate (g/ha)	Timing[c] EP	MP	LP	Average
			------ % ------			
1988						
	CGA-136872	20	75	55	53	61 D
	CGA-136872	30	85	-	68	76 BC
	CGA-136872	40	83	85	50	73 C
	DPX-V9360	17.5	80	88	88	85 AB
	DPX-V9360	35	93	98	93	94 A
	DPX-V9360	70	93	95	93	93 A
	Control	0	0	0	0	0 E
	Average		73 a	71 a	63 b	
1989						
	CGA-136872	20	100 Aa	50 Bb	25 Cc	-
	CGA-136872	30	100 Aa	48 Bb	33 BCb	-
	CGA-136872	40	100 Aa	63 Bb	50 Bb	-
	DPX-V9360	17.5	100 Aa	90 Aa	50 Bb	-
	DPX-V9360	35	100 Aa	100 Aa	70 Ab	-
	DPX-V9360	70	100 Aa	100 Aa	78 Ab	-
	Control	0	0 Ba	0 Ca	0 Da	-

[a]Individual means for herbicide rates within a year and within a column followed by the same upper case letter and timing means within a row followed by the same lower case letter do not differ significantly at the 0.05 level as determined by Duncan's multiple range test. Mean separation procedures were performed for levels within a factor (1989 data) due to significant interaction.

[b]Data were recorded five weeks after treatment.

[c]EP = early postemergence, MP = mid postemergence and LP = late postemergence.

TABLE 5: Common lambsquarters control with varying rates of CGA-136872 and DPX-V9360 applied at three different timings[a, b].

Year	Herbicide	Rate (g/ha)	Timing[c] EP	MP	LP
			%		
1988					
	CGA-136872	20	65 ABa	68 ABa	38 Ca
	CGA-136872	30	85 Aa	-	33 Cb
	CGA-136872	40	83 Aa	75 Aab	53 ABCb
	DPX-V9360	17.5	50 Ba	48 Ba	45 Ca
	DPX-V9360	35	43 Ba	75 Aa	68 ABa
	DPX-V9360	70	80 Aa	85 Aa	78 Aa
	Control	0	0 Ca	0 Ca	0 Da
1989					
	CGA-136872	20	95 Aa	50 Cb	35 Bc
	CGA-136872	30	98 Aa	63 Bb	33 Bc
	CGA-136872	40	100 Aa	75 Ab	38 Bc
	DPX-V9360	17.5	83 Ba	50 Cb	28 Bc
	DPX-V9360	35	93 ABa	63 Bb	65 Ab
	DPX-V9360	70	100 Aa	63 Bb	65 Ab
	Control	0	0 Ca	0 Da	0 Ca

[a]Individual means for herbicide rates within a year and within a column followed by the same upper case letter and timing means within a row followed by the same lower case letter do not differ significantly at the 0.05 level as determined by Duncan's multiple range test. Mean separation procedures were performed for levels within a factor due to significant interaction.

[b]Data were recorded five weeks after treatment.

[c]EP = early postemergence, MP = mid postemergence and LP = late postemergence.

TABLE 6: Redroot pigweed control with varying rates of CGA-136872 and DPX-V9360 applied at three different timings[a, b].

Year	Herbicide	Rate (g/ha)	Timing[c] EP	MP	LP	Average
			------ % ------			
1988						
	CGA-136872	20	100	83	78	87 B
	CGA-136872	30	100	-	80	92 AB
	CGA-136872	40	100	98	85	94 A
	DPX-V9360	17.5	100	85	75	87 B
	DPX-V9360	35	100	95	85	93 AB
	DPX-V9360	70	100	98	83	93 AB
	Control	0	0	0	0	0 C
	Average		86 a	79 b	69 c	
1989						
	CGA-136872	20	100 Aa	58 Db	38 Bc	-
	CGA-136872	30	100 Aa	70 CDb	48 Bc	-
	CGA-136872	40	100 Aa	78 BCb	53 Bc	-
	DPX-V9360	17.5	100 Aa	90 ABa	38 Bb	-
	DPX-V9360	35	100 Aa	98 Aa	75 Ab	-
	DPX-V9360	70	100 Aa	95 Aa	75 Ab	-
	Control	0	0 Ba	0 Ea	0 Ca	-

[a]Individual means for herbicide rates within a year and within a column followed by the same upper case letter and timing means within a row followed by the same lower case letter do not differ significantly at the 0.05 level as determined by Duncan's multiple range test. Mean separation procedures were performed for levels within a factor (1989 data) due to significant interaction.

[b]Data were recorded five weeks after treatment.

[c]EP = early postemergence, MP = mid postemergence and LP = late postemergence.

TABLE 7: Corn yield as affected by different rates of CGA-136872 and DPX-V9360 applied at three different timings[a].

Year	Herbicide	Rate (g/ha)	Timing[b] EP	MP	LP
			------------ kg/ha	--------------	
1988					
	CGA-136872	20	7800 ABCa	9000 Aa	6850 Aa
	CGA-136872	30	8055 ABa	-	5400 Ab
	CGA-136872	40	9350 Aa	8000 Aab	7250 Ab
	DPX-V9360	17.5	7450 ABCa	7550 Aa	6200 Aa
	DPX-V9360	35	7500 ABCa	8800 Aa	6350 Aa
	DPX-V9360	70	5900 Ca	8800 Aa	7350 Aa
	Control	0	6300 BCa	6300 Aa	6300 Aa
1989[c]					
	CGA-136872	20	6450	6300	5000
	CGA-136872	30	6350	6940	6600
	CGA-136872	40	6000	7650	6550
	DPX-V9360	17.5	5450	7600	6900
	DPX-V9360	35	7500	6550	5600
	DPX-V9360	70	6900	6600	7050
	Control	0	5850	5850	5850

[a]Individual means for herbicide rates within a year and within a column followed by the same upper case letter and timing means within a row followed by the same lower case letter do not differ significantly at the 0.05 level as determined by Duncan's multiple range test. Mean separation procedures performed for levels within a factor due to significant interaction.

[b]EP = early postemergence, MP = mid postemergence and LP = late postemergence.

[c]No significant effects of treatments was observed.

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CGA-136872 Combinations with other Herbicides for Postemergence Weed Control in Corn (*Zea Mays*).

Abstract. Field experiments were conducted to evaluate the activity of CGA-136872 in combination with other post-emergence herbicides and to evaluate the effect of spray adjuvants on the activity of CGA-136872 for weed control in corn. Johnsongrass, giant foxtail, common lambsquarters and redroot pigweed control was not significantly different when CGA-136872 was applied with non ionic surfactant or crop oil concentrate. CGA-136872 combinations with cyanazine, atrazine, cyanazine plus tridiphane, atrazine plus tridiphane, bentazon, 2,4-D, dicamba and paraquat improved control of common lambsquarters and redroot pigweed compared to CGA-136872 applied alone. However, reduced control of johnsongrass was observed when CGA-136872 was tank-mixed with paraquat or 2,4-D for johnsongrass control. Reduced control of giant foxtail was also observed when CGA-136872 was combined with 2,4-D or dicamba. Nomenclature: CGA-136872, 3-[4,6-bis(difluoromethoxy) pyrimidin-2-yl-1-(2-methoxycarbonyl-phenylsulfonyl)-urea; 2,4-D, (2,4-dichlorophenoxy)acetic acid; dicamba, 3,6-dichloro-2-methoxy benzoic acid; atrazine, 6-chloro-N-ethyl-N′-(methylethyl)-1,3,5-triazine-2,4-diamine; cyanazine, 2-[[4-chloro-6-(ethylamino)-1,3,5-triazin-2-yl]amino]-2--methylpropanenitrile; tridiphane, 2-(3,5- dichlorophe-

nyl)-2-(2, 2,2-trichloroethyl)oxirane; bentazon, 3-(1-methylethyl)-(1H)-2,1,3-benzothiadiazin-4(3H)-one 2,2-oxide; paraquat, 1,1'-dimethyl-4,4'- bipyridinium ion; johnsongrass, Sorghum halepense (L.) Pers. #[1] SORHA; giant foxtail, Setaria faberi Herr. # SETFA; common lambsquarters, Chenopodium album L. # CHEAL; redroot pigweed, Amaranthus retroflexus L. # AMARE; corn, Zea mays L. Additional index words. 2,4-D, dicamba, atrazine, cyanazine, tridiphane, bentazon, paraquat, johnsongrass, giant foxtail, common lambsquarters, redroot pigweed.

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[1]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Weed Sci. 32, Suppl. 2. Available from WSSA, 309 Clark St., Champaign, IL 61820.

INTRODUCTION

CGA-136872 is a new experimental herbicide for postemergence use in corn (2). Preliminary research results indicate high levels of activity of this herbicide on many grass and broadleaf weeds including johnsongrass, giant foxtail, common lambsquarters, redroot pigweed, quackgrass (Agropyron repens (L.) Beauv.), shattercane (Sorghum bicolor (L.) Meonch), morningglory (Ipomea spp), hemp sesbania (Sesbania exaltata (Raf.) Rydb. ex A.W.Hill) and prickly sida (Sida spinosa L.) (4, 5, 7, 8, 15, 16, 17). However, other researchers have observed litlle activity of CGA-136872 on green foxtail (Setaria viridis (L.) Beauv.) (5), wild proso millet (Panicum miliaceum L.) (17) and common lambsquarters (10). Previous results indicate that combinations of CGA-136872 with other herbicides improve the activity on many weed species (5, 14). Evans and Jenks (5) observed an increase in green foxtail control from 59 to 93% when CGA-136872 was tank-mixed with atrazine. Orr (14) reported that control with CGA-136872 was improved from 33 to 45% for seedling johnsongrass and from 45 to 70% for rhizome johnsongrass when CGA-136872 was applied in combination with atrazine. Kaufman and Ritter (9) effectively controlled triazine-resistant smooth pigweed (Amaranthus hybridus L.) with tank-mixtures of CGA-136872 and atrazine. However, antagonistic interaction of CGA-136872 with other herbicides have been reported for control of some weed species. Gillespie et al. (7) observed loss of quackgrass control when CGA-136872 was tank-mixed with atrazine or cyanazine.

The objective of this research was to investigate the effectiveness of CGA-136872 alone and in combination with other herbicides for postemergence control of johnsongrass, giant foxtail, common lambsquarters and redroot pigweed in corn. The effect of spray adjuvants on the activity of CGA-136872 was also evaluated.

MATERIALS AND METHODS

Field experiments were conducted in Blacksburg, Va in 1988 and 1989 to investigate the effect of spray adjuvants on the activity of CGA-136872, and to investigate the activity of CGA-136872 in combination with other herbicides for postemergence control of johnsongrass, giant foxtail, common lambsquarters and redroot pigweed in corn.

The site consisted of a Ross silt loam (fine-loamy, mixed, mesic cumulic Hapludolls) of 2% organic matter and pH 6.1. The experimental plot had a natural infestation of johnsongrass, giant foxtail, common lambsquarters and redroot pigweed. Common lambsquarters infestation was very heavy. Johnsongrass and giant foxtail infestations were moderate, while redroot pigweed density was low, but uniform. Corn (var. Southern States 565) was planted in 75 cm rows, using a commercial planter adjusted to a population of one seed per 18 cm of row. The crop was grown using conventional tillage and was planted May 23, 1988 and May 18, 1989.

The experiment was a randomized complete block design with four replications. Individual plot consisted of two rows of corn 8 m long and 1.5 m wide. For spray adjuvant effect, CGA-136872 was applied with non ionic surfactant[2]

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[2]X-77, a mixture of alkylpolyoxyethylene glycols, free fatty acids, and isopropanol, marketed by Chevron Chemical Co., 575 Market Street, San Francisco, CA 94120.

or crop oil concentrate[3] (COC). For combination effects, CGA-136872 was tank-mixed with several other herbicides (Table 2). The rates of respective herbicides are indicated in Table 2. Non ionic surfactant at 0.25% v/v or COC at 1% v/v were added as required. Treatments were applied postemergence except for CGA-136872 plus paraquat which was post-directed with a single nozzle. All treatments were applied with a CO_2-pressurized backpack sprayer delivering 214 L/ha at a pressure of 210 KPa through flat fan spray tips[4]. Table 1 indicates the growth stage of corn and weeds during herbicide applications. Estimates of weed control and crop injury were made at 1, 2, 3, 5, 7 and 9 weeks after treatment on a 0 to 100% scale, with 0% indicating no weed control or crop injury, and 100% indicating complete death of the plant. Yield data were obtained by hand-harvesting one row of corn in each plot. Grain moisture was adjusted to 15.5%.

All data were subjected to analysis of variance and means separated using Duncan's multiple range test at the 0.05 significance level. Single degree of freedom contrasts were used to compare the activity of CGA-136872 to that of the tank-mix treatments.

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[3]Agridex, containing 83% parafinic mineral oil and 17% polyoxyethylene sorbitan fatty acid ester, marketed by Helena Chemical Co., 5100 Poplar Ave., Memphis, TN 38137.

[4]Teejet 8003 tips, Spraying Systems CO., North Avenue, Wheaton, IL 60287.

RESULTS AND DISCUSSION

Corn injury: Corn tolerance to herbicides was excellent during both growing seasons. However, significant injury was observed with all treatments containing cyanazine or paraquat (Table 3). Symptoms were necrosis for paraquat and leaf tip burn for cyanazine. These symptoms were transitory, and disappeared completly four weeks after treatment as new leaves developed.

Johnsongrass control: In 1988, Johnsongrass control was lower than 70% for all treatments. The highest control (68%) was obtained with paraquat, followed by CGA-136872 plus bentazon and CGA-136872 plus atrazine plus tridiphane, each with 65% control (Table 4). In 1989, johnsongrass control was generally better than in 1988. Control ratings of 85% and 88% were obtained when CGA-136872 was tank-mixed with cyanazine and atrazine plus tridiphane, respectively (Table 4). During both years, CGA-136872 applied with non ionic surfactant or COC provided similar johnsongrass control ratings (Table 4). No herbicide combination improved johnsongrass control over CGA-136872 alone (Table 5). Reduced control of johnsongrass was observed when CGA-136872 was tank-mixed with paraquat (Table 5). Johnsongrass control was significantly reduced, from 53 to 30% in 1988, and from 70 to 33% in 1989 when CGA-136872 was applied in combination with paraquat. Similar results were observed in 1989 when CGA-136872 was applied with 2,4-D. Apparently, reduced activity resulting from CGA-136872 combination with paraquat was not caused by reduced translocation of CGA-136872 due to the rapid dessication effect of paraquat, since control with the combination was significantly lower that control with either individual herbicide (Table 4). Antagonistic effects of 2,4-D on glyphosate {N-(phosphonomethyl)glycine} have been reported by Flint and Barrett (6) for johnsongrass control.

Giant foxtail control: In 1988, giant foxtail control was low in all treatments. Paraquat provided the highest control at 75% (Table 4). CGA-136872 combinations did not improve control of giant foxtail (Table 5). In 1989, more than 90% control of giant foxtail was obtained when CGA-136872 was tank-mixed with atrazine, cyanazine, atrazine plus tridiphane, cyanazine plus tridiphane and paraquat (Table 4). Significant increase in control of giant foxtail was observed with combinations of CGA-136872 with cyanazine, atrazine plus tridiphane, cyanazine plus tridiphane and paraquat with 98, 98, 100 and 100% control, respectively (Table 5). Reduced control resulted from combinations of CGA-136872 with 2,4-D and dicamba. These treatments provided 33 and 38% control of giant foxtail, respectively, compared to 73% control for CGA-136872 applied alone. Antagonism of dicamba and DPX-V9360 has been reported by Morton and Harvey (11) for giant foxtail control. During both years, CGA-136872 applied with non ionic surfactant or COC provided equivalent control of giant foxtail (Table 4).

Common lambsquarters control: In 1988, 100% control of common lambsquarters was observed with atrazine, cyanazine, cyanazine plus tridiphane and CGA-136872 combinations with atrazine, atrazine plus tridiphane and cyanazine plus tridiphane (Table 6). Except for bentazon in 1989, all CGA-136872 combinations provided significant improvements in control of common lambsquarters comprared to CGA-136872 applied alone (Table 7) In 1989, control ratings of 100% were obtained with several herbicides or combinations. During both years common lambsquarters control was not significantly different when CGA-136872 was applied with non ionic surfactant or COC (Table 6).

Redroot pigweed control: In 1988, 90% or better control of redroot pigweed was obtained with several herbicides and combinations (Table 6). Significant increase in control of redroot pigweed was observed with all combinations, compared to CGA-136872 alone (Table 7). In 1989, however, no significant benefit was observed with herbicide combinations, due to the high level of activity of CGA-136872 applied alone. Control of 83% was observed in 1989, compared to 33% in 1988 (Table 7). Excellent control of triazine-resistant pigweed with CGA-136872 has been reported by Kaufman and Ritter (9). The type of spray adjuvant used with CGA-136872 did not have a significant effect on redroot pigweed control. Control ratings of 33 and 35% for 1988, and 83 and 75% for 1989 were observed for treatments containing non ionic surfactant and COC, respectively (Table 6).

Generally, most treatments showed more activity on the four weed species in 1989 than in 1988. Low soil moisture observed in 1988 may explain the difference in weed control. Several postemergence herbicides have been reported to show reduced activity under conditions of low soil moisture (1, 3). Drought stress has been reported to reduce johnsongrass control with CGA-136872 (8, 12, 13).

Yield: In 1988, significant increases in corn yield relative to the control were observed when CGA-136872 was applied with atrazine, atrazine plus tridiphane and paraquat (Table 8). Paraquat, 2,4-D and atarazine applied alone also providided yields significantly greater than the control. This increased yield can be attributed to reduced competition from weeds in these treatments, primarily common lambsquarters, which was present in the greatest density. CGA-136872 applied with non ionic surfactant or COC provided similar yields, corresponding to the similar weed control for each species with these treatments (Table 5 and 7). In 1989, herbicide treatments did not affect yield (Table 8).

In summary, significant increases in control of giant foxtail were observed in 1989 when CGA-136872 was tank-mixed with paraquat, cyanazine, cyanazine plus tridiphane and atrazine plus tridiphane. Common lambsquarters and redroot pigweed were more effectively controlled when CGA-136872 was combined with other herbicides. These results indicate that CGA-136872 could represent an important supplement to existing postemergence corn herbicides. Its use to supplement atrazine or cyanazine may represent a significant benefit for control of triazine-resistant common lambsquarters and pigweed biotypes.

TABLE 1. Corn and weed growth stages at the time of herbicide applications.

Plant	Leaf stage	Height (cm)
Corn	6-7	35-50
Johnsongrass	4-5	13-20
Giant foxtail	3-5	3-13
Common Lambsquarters	8-14	3-20
Redroot Pigweed	6-8	3-15

TABLE 2. Herbicide or combinations used and rates of application[a].

Herbicide	Rate (g/ha)	Herbicide	Rate (g/ha)
1. CGA-136872	30	11. 2,4-D	560
X-77	-		
2. CGA-136872	30	12. dicamba	280
COC	-		
3. CGA-136872	30	13. atrazine	2242
2,4-D	560	COC	-
X-77	-		
4. CGA-136872	30	14. cyanazine	2242
dicamba	280	X-77	-
X-77	-		
5. CGA-136872	30	15. bentazon	1121
atrazine	2242	COC	-
COC	-		
6. CGA-136872	30	16. atrazine	1682
cyanazine	2242	tridiphane	560
X-77	-	COC	-
7. CGA-136872	30	17. cyanazine	1682
bentazon	1121	tridiphane	560
COC	-	COC	-
8. CGA-136872	30	18. paraquat	314
atrazine	1682		
tridiphane	560		
COC	-		
9. CGA-136872	30	19. control	-
cyanazine	1682		
tridiphane	560		
COC	-		
10. CGA-136872	30		
paraquat	314		
X-77	-		

[a]X-77 was used at the rate of 0.25% v/v and COC at the rate of 1% v/v.

Table 3. Corn injury following treatment with CGA-136872 alone or in combination with other herbicides[a].

Herbicide[b]	1988			1989		
	1 WAT[c]	2 WAT	3 WAT	1 WAT	2 WAT	3 WAT
	%					
1. CGA + X-77	0 e	0 f	0 d	3 c	0 c	0 b
2. CGA + COC	0 e	0 f	0 d	0 c	0 c	0 b
3. CGA + 2,4-D + X-77	0 e	10 d	10 c	3 c	0 c	0 b
4. CGA + dicamba + X-77	0 e	3 ef	0 d	3 c	3 c	0 b
5. CGA + atrazine + COC	0 e	0 f	0 d	3 c	0 c	0 b
6. CGA + cyanazine + X-77	40 a	40 a	18 a	18 ab	8 bc	5 ab
7. CGA + bentazon + X-77	3 e	5 def	0 d	3 c	3 c	0 b
8. CGA + atrazine + tridiphane + COC	0 e	0 f	0 d	8 bc	0 c	0 b
9. CGA + cyanazine + tridiphane + COC	33 b	28 b	10 c	28 a	18 a	8 a
10. CGA + paraquat + X-77	18 d	5 def	3 d	25 a	8 bc	0 b
11. 2,4-D	0 e	0 f	0 d	0 c	0 c	0 b
12. dicamba	0 e	0 f	0 d	0 c	0 c	0 b
13. atrazine + COC	0 e	0 f	0 d	0 c	0 c	0 b
14. cyanazine + X-77	25 c	18 c	13 bc	8 bc	3 c	0 b
15. bentazon + COC	0 e	0 f	0 d	0 c	0 c	0 b
16. atrazine + COC + tridiphane	0 e	0 f	0 d	0 c	0 c	0 b
17. cyanazine + COC + tridiphane	38 a	35 a	15 ab	20 a	10 b	5 ab
18. paraquat	18 d	8 de	0 d	20 a	8 bc	3 ab
19. control	0 e	0 f	0 d	0 c	0 c	0 b

[a]Means within a column followed by the same letter are not significantly different at the 0.05 significance level as determined by Duncan's multiple range test.
[b]CGA = CGA-136872.
[c]WAT = Weeks after treatment.

Table 4. Johnsongrass and giant foxtail control five weeks after treatment with CGA-136872 in combination with other herbicides[a].

Herbicide[b]	johnsongrass 1988	johnsongrass 1989	giant foxtail 1988	giant foxtail 1989
	%			
1. CGA + X-77	53 bcd	70 ab	43 b-e	73 bc
2. CGA + COC	60 abc	75 a	35 c-f	60 cd
3. CGA + 2,4-D + X-77	53 bcd	43 cd	30 d-h	33 e
4. CGA + dicamba + X-77	48 cd	65 abc	28 d-h	38 de
5. CGA + atrazine + COC	60 abc	78 a	40 cde	93 ab
6. CGA + cyanazine + X-77	45 d	85 a	38 c-f	98 ab
7. CGA + bentazon + COC	65 ab	68 abc	55 abc	43 de
8. CGA + atrazine + tridiphane + COC	65 ab	88 a	48 bcd	98 ab
9. CGA + cyanazine + tridiphane + COC	48 cd	73 a	33 c-g	100 a
10. CGA + paraquat + X-77	30 e	33 d	63 ab	100 a
11. 2,4-D	8 fg	0 e	10 ghi	0 f
12. dicamba	0 g	0 e	3 i	0 f
13. atrazine + COC	15 f	0 e	20 e-i	45 de
14. cyanazine + X-77	13 fg	0 e	28 d-h	90 ab
15. bentazon + COC	8 fg	0 e	8 hi	0 f
16. atrazine + COC + tridiphane	13 fg	0 e	15 f-i	88 ab
17. cyanazine + COC + tridiphane	13 fg	25 de	35 c-f	90 ab
18. paraquat	68 a	45 bcd	75 a	90 ab
19. control	0 g	0 e	0 i	0 f

[a]Means within a column followed by the same letter are not significantly different at the 0.05 significance level as determined by Duncan's multiple range test.
[b]CGA = CGA-136872.

TABLE 5. Effect of herbicide combinations with CGA-136872 for control of johnsongrass and giant foxtail in corn, 5 weeks after treatment[a,b].

Herbicide[c]	Johnsongrass		giant foxtail	
	1988	1989	1988	1989
	%			
1. CGA + X-77	53	70	43	73
2. CGA + COC	60	75	35	60
3. CGA + 2,4-D + X-77	53 =	43 -	30 =	33 -
4. CGA + dicamba + X-77	48 =	65 =	28 =	38 -
5. CGA + atrazine + COC	60 =	78 =	40 =	93 =
6. CGA + cyanazine + X-77	47 =	85 =	38 =	98 +
7. CGA + bentazon + COC	65 =	68 =	55 =	43 =
8. CGA + atrazine + tridiphane + COC	65 =	88 =	48 =	98 +
9. CGA + cyanazine + tridiphane + COC	48 =	73 =	33 =	100 +
10. CGA + paraquat + X-77	30 -	33 -	63 =	100 +
11. control	0	0	0	0

[a]Mean separation was performed using single degree of freedom contrasts. Within each column, = indicates that the activity of herbicides in combination was not significantly different from CGA-136872 applied alone; + indicates that the combination was more active than CGA-136872; and - indicates that the combination was less active than CGA-136872 alone.

[b]All combinations containing X-77 are compared to CGA-136872 plus and those containing COC are compared to CGA-136872 plus COC.

[c]CGA = CGA-136872.

TABLE 6. Common lambsquarters and redroot pigweed control five weeks after treatment with CGA-136872 in combination with other herbicides[a].

Herbicide[b]	Lambsquarters		Pigweed	
	1988	1989	1988	1989
	%			
1. CGA + X-77	20 f	70 b	33 e	83 a
2. CGA + COC	33 ef	60 b	35 e	75 a
3. CGA + 2,4-D + X-77	98 a	100 a	88 abc	100 a
4. CGA + dicamba + X-77	88 ab	100 a	80 abc	100 a
5. CGA + atrazine + COC	100 a	100 a	95 ab	100 a
6. CGA + cyanazine + X-77	98 a	100 a	83 abc	73 a
7. CGA + bentazon + COC	93 ab	63 b	95 ab	83 a
8. CGA + atrazine + tridiphane + COC	100 a	100 a	95 ab	100 a
9. CGA + cyanazine + tridiphane + COC	100 a	100 a	98 a	100 a
10. CGA + paraquat + X-77	65 cd	93 a	78 abc	98 a
11. 2,4-D	95 a	100 a	90 abc	100 a
12. dicamba	50 de	90 a	50 de	88 a
13. atrazine + COC	100 a	100 a	90 abc	45 b
14. cyanazine + X-77	100 a	100 a	68 bcd	28 b
15. bentazon + COC	63 cd	65 b	63 cd	48 b
16. atrazine + COC + tridiphane	77 bc	100 a	78 abc	43 b
17. cyanazine + COC + tridiphane	100 a	100 a	98 a	35 b
18. paraquat	73 bc	43 c	80 abc	88 a
19. control	0 g	0 d	0 f	0 c

[a]Means within a column followed by the same letter are not significantly different at the 0.05 significance level as determined by Duncan's multiple range test.
[b]CGA = CGA-136872.

TABLE 7. Effect of herbicide combinations with CGA-136872 for control of common lambsquarters and redroot pigweed in corn, 5 weeks after application[a,b].

Herbicide[c]	Lambsquarters 1988	Lambsquarters 1989	Pigweed 1988	Pigweed 1989
	%			
1. CGA + X-77	20	70	33	83
2. CGA + COC	33	60	35	75
3. CGA + 2,4-D + X-77	98 +	100 +	88 +	100 =
4. CGA + dicamba + X-77	88 +	100 +	80 +	100 =
5. CGA + atrazine + COC	100 +	100 +	95 +	100 =
6. CGA + cyanazine + X-77	98 +	100 +	83 +	73 =
7. CGA + bentazon + COC	93 +	63 =	95 +	83 =
8. CGA + atrazine + tridiphane + COC	100 +	100 +	95 +	100 =
9. CGA + cyanazine + tridiphane + COC	100 +	100 +	98 +	100 =
10. CGA + paraquat + X-77	65 +	93 +	76 +	98 =
11. control	0	0	0	0

[a]Mean separation was performed using single degree of freedom contrasts. Within each column, = indicates that the activity of herbicides in combination was not significantly different from CGA-136872 applied alone; + indicates that the combination was more active than CGA-136872; and - indicates that the combination was less active than CGA-136872 alone.

[b]All combinations containing X-77 are compared to CGA-136872 plus X-77 and those containing COC are compared to CGA-136872 plus COC.

[c]CGA = CGA-136872.

TABLE 8. The effect of CGA-136872 applied alone and in combination with other herbicides on corn yield[a].

Herbicide[b]	1988	1989[c]
	---------------- kg/ha	------------
1. CGA + X-77	6850 cde	5900
2. CGA + COC	7880 a-e	6060
3. CGA + 2,4-D + X-77	6730 de	5930
4. CGA + dicamba + X-77	6870 cde	5830
5. CGA + atrazine + COC	8480 abc	7300
6. CGA + cyanazine + X-77	6460 de	5480
7. CGA + bentazon + COC	6750 de	5920
8. CGA + atrazine + tridiphane + COC	8780 a	5390
9. CGA + cyanazine + tridiphane + COC	7480 a-e	4920
10. CGA + paraquat + X-77	8680 ab	4910
11. 2,4-D	7920 a-d	6060
12. dicamba	7030 b-e	6560
13. atrazine + COC	8000 a-d	6280
14. cyanazine + X-77	7550 a-e	5980
15. bentazon + COC	7250 a-e	6670
16. atrazine + tridiphane + COC	7810 a-e	7740
17. cyanazine + tridiphane + COC	6690 d-e	5820
18. paraquat	7960 a-d	5600
19. control	6210 e	4880

[a]Means within a column followed by the same letter are not significantly different at the 0.05 significance level as determined by Duncan's multiple range test.
[b]CGA = CGA-136872.
[c]No significant effect of herbicide treatments on corn yield.

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