

ABSTRACT

APPLICATIONS OF DICAMBA (2-METHOXY-3,6-DICHLOROBENZOIC
ACID) AND 2,4-D (2,4-DICHLOROPHENOXYACETIC ACID)
TO SEVERAL VARIETIES OF WINTER WHEAT
(TRITICUM AESTIVUM L.) AT DIFFERENT
STAGES OF GROWTH

By

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Dicamba (2-methoxy-3,6-dichlorobenzoic acid) and 2,4-D (2,4-dichlorophenoxyacetic acid) provide effective chemical weed control in winter wheat (Triticum aestivum L.) in Michigan. The stage of growth at the time of herbicide applications is critical to avoid crop injury. Field reports in 1974 indicated that Tecumseh, a soft white wheat variety released from Michigan State University in 1973, was susceptible to dicamba applications. Field studies were conducted to establish the response of four winter wheat varieties, Ionia, Yorkstar, Tecumseh and Arthur, to applications of dicamba and 2,4-D at different stages of growth.

Visual injury in 1975 and 1976 and yield reductions in 1975 were dependent on the stage of growth, wheat variety, herbicide and rate applied. Grains per spike and test weight did not account for the yield loss in 1975. A reduction in spikes or tillering per hectare was attributed to the yield loss from herbicide applications in 1975. In 1976 yield was significantly reduced at one location. An increase

in spikes or tillering per hectare caused by a herbicide x environment interaction resulted in an increase in yields in 1976.

There was no correlation between visual injury, yield, and grains per spike. A decrease in test weight correlated with visual injury at one location in 1976.

A wider range of stages of growth and herbicide treatments could be applied to Ionia and Yorkstar compared with Tecumseh and Arthur. The most tolerant stages of growth to apply dicamba and dicamba plus 2,4-D amine in terms of effect on yield are as follows: dicamba 0.28 kg/ha at the resumption of spring growth and fully tillered stages for Ionia, Yorkstar, and Tecumseh, early jointing for Ionia, Yorkstar, Tecumseh, and Arthur and preemergence for Tecumseh; dicamba 0.56 kg/ha at the resumption of spring growth and early jointing stages for Ionia and Yorkstar; dicamba plus 2,4-D amine 0.28 + 0.28 kg/ha at early jointing for all varieties studied and at the fully tillered stage for Ionia.

Other stages of growth and herbicide treatments did not significantly reduce yields from the control but did result in yields significantly less than the most tolerant treatments listed above. They are dicamba 0.28 kg/ha preemergence for Ionia and Yorkstar and at the resumption of spring growth and fully tillered stages for Arthur. Dicamba plus 2,4-D amine 0.28 + 0.28 kg/ha at the resumption of spring growth for Ionia and at the fully tillered stage for Yorkstar and Arthur.

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Old weeders never die

They just lose control.

Donny O. 77'

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INTRODUCTION

Effective weed control for winter wheat (Triticum aestivum L.) in Michigan has resulted from the use of 2,4-D (2,4-dichlorophenoxyacetic acid) and dicamba (2-methoxy-3,6-dichlorobenzoic acid). 2,4-D controls annual broadleaf weeds, and dicamba controls many 2,4-D resistant weeds. The combination of dicamba and 2,4-D is often used to control a wide spectrum of weeds, including wild garlic (Allium vineale L.).

Although 2,4-D and dicamba are selective for winter wheat, proper timing of herbicide application is necessary to avoid crop injury. Research of the 1950's indicated that winter wheat was tolerant to 2,4-D at the spring tillering to early jointing stages of growth, and susceptible at the seedling, boot, and flowering stages.

Literature is limited concerning the susceptibility and tolerance of winter wheat to dicamba at different stages of growth. Wheat is tolerant to dicamba applied early in spring from the resumption of spring growth to fully tillered and susceptible at post fully tillered stages.

Yield loss from applications of 2,4-D and dicamba to winter wheat is variable. Phillips (27) observed that the tolerant and susceptible stages of wheat growth differed depending on variety. He found that of seven winter wheat varieties treated with 2,4-D, three varieties yielded higher when treated at the boot stage while the

remaining four varieties yielded higher when treated at the early jointing stage.

Based on the knowledge at hand, new wheat varieties may respond differently to previously established safe herbicide application recommendations.

In 1973 a new soft white winter wheat variety, Tecumseh, was released from Michigan State University. In 1974 field reports indicated that the Tecumseh variety was susceptible to dicamba applications. Reports were widespread that Arthur and Arthur-type varieties were also susceptible to dicamba applications.

The majority of the winter wheat acreage in Michigan is of the soft white commercial classification. Soft red winter wheat is grown on 20 percent of the Michigan wheat acreage, mostly southern counties.

Tecumseh is the first high yielding soft white wheat adapted to Michigan which combines a short plant height, resistance to lodging and a high test weight. Tecumseh has improved winter hardiness, rust, mildew, and Hessian fly resistance and has a high milling quality. Tecumseh has Arthur parentage in its pedigree and, like Arthur, has some natural resistance to loose smut. Arthur is a soft red wheat grown in southern Michigan.

Field research was initiated in the fall of 1974 and continued through the 1976 crop year. The objective was to determine which stages of growth and rates and combinations of dicamba and 2,4-D resulted in the least injury to four wheat varieties grown in Michigan.

Tecumseh was compared with two other soft white wheats, Ionia and Yorkstar. A soft red wheat Arthur, which is closely related to Tecumseh, was also studied.

LITERATURE REVIEW

Selective weed control in winter wheat and spring wheat (Triticum aestivum L.) with 2,4-D (2,4-dichlorophenoxyacetic acid) and dicamba (2-methoxy-3,6-dichlorobenzoic acid) has often caused injury to the wheat. The following topics are reviewed concerning this matter: yield; components of yield; quality of yield; formulation of 2,4-D; visual abnormalities; and selectivity of dicamba.

Yield

Research has established tolerant and susceptible stages of wheat growth for 2,4-D and dicamba applications. Shaw and Willard (33) treated Thorne winter wheat with 2,4-D at nine growth stages. No yield loss occurred at the spring tillering, spring fully tillered, jointing, or milk stages. Yields were significantly reduced at the fall three-leaf, fall five-leaf, spring late jointing, fully headed, and blooming stages. In another report, Shaw and Willard (35) observed that the most serious yield reductions resulted from 2,4-D applied at the fall five-leaf, spring late jointing and fully headed stages. They commented that these stages of growth appeared to represent susceptible stages in development of meristematic tissue.

Bernard and Willard (5) applied 2,4-D to Thorne winter wheat at five fall and eight spring stages. Yields at all of the fall and spring boot stages were significantly reduced. Klingman (20,21)

reported significant yield reductions for Pawnee winter wheat treated at four spring growth stages with 2,4-D. He noted less yield loss at the late boot and jointing than at the early boot and fully headed stages. Woestemeyer (45) found significant 2,4-D yield loss for Pawnee at the late boot and not at the fully tillered or post bloom stages. Willard (44) observed 2,4-D yield loss at the jointing and heading but not from the spring rosette and bloom stages. Phillips (27) stated significant 2,4-D yield loss at the early jointing and mid boot stages.

Quimby and Nalewaja (29) applied dicamba to Selkirk spring wheat at seven stages of growth in a two-year study. No yield reductions occurred from dicamba 0.28 kg/ha applied at preemergence or 2-4 leaves. In 1963 significant yield reductions occurred at the boot stage and from high rates of dicamba at late tiller and flower stages. In 1964 yields were significantly reduced from the early tiller to the flowering stages from all dicamba rates. Friesen (15) growing Thatcher spring wheat found significant yield reductions from all dicamba rates at the four, five and six-leaf stages. Only the highest dicamba rates reduced yields at the two-leaf stage. Significant yield reduction at the two-leaf stage did occur if dicamba was applied in combination with 2,4-D.

Binning (7) observed no significant yield loss with Genesee winter wheat from a split application, dicamba applied at the resumption of spring growth stage and 2,4-D applied at the fully tillered stage. Significant yield loss did occur from the single application of 2,4-D at the resumption of spring growth and dicamba at the fully tillered stage. Friesen (16) noted that dicamba yield reductions at

the five-leaf stage of growth in Thatcher spring wheat were comparable to 2,4-D yield loss at the three-leaf stage. Others (38,39,40) report yield loss at the two- to five-leaf stage from 2,4-D and at the six-leaf stage from dicamba.

Researchers agree that fall applications of 2,4-D and late spring applications of dicamba result in significant yield reductions. Yields that result from the remaining spring applications of 2,4-D and dicamba are difficult to interpret. This is due to the lack of precise definitions of spring stages of wheat growth. What one describes as the fully tillered stage may be inclusive of what another describes as the tillering, fully tillered, and early jointing stages. Researchers' results may also differ depending on the wheat varieties studied.

Shaw and Willard (34) treated six winter wheat varieties at one fall and two spring stages. They observed that yield losses from 2,4-D were varietal. Price and Klingman (28) applied 2,4-D to twenty-seven winter wheat varieties at two growth stages. Significant yield loss occurred at the fall fully tillered stage but not for all varieties. No significant yield reductions occurred at the spring fully tillered stage. They concluded that yield reductions from 2,4-D treatment were dependent on variety and the stage of growth for each variety. Woestemeyer (46) observed a 2,4-D X variety interaction of six winter wheat varieties treated at one fall and three spring stages. A variety yield X stage of growth interaction occurred between fall and spring. Significant yield reductions occurred at the fall tiller stage for all varieties. The degree of yield loss was varietal, three varieties

averaged 51 percent of the check and the remaining varieties averaged 71 percent.

Phillips (27) noted a variety X spring stages of growth interaction in seven winter wheat varieties treated with 2,4-D. Three varieties yielded higher from treatment at the boot stage while the other varieties yielded highest when treated at the early jointing.

Elder (13) applied 2,4-D to six winter wheat varieties at four stages. Fall tiller was treated on the same date for all varieties. The spring tiller, boot and dough stages were treated according to variety development. Yields were reduced at the fall tiller and spring boot and all varieties responded alike.

Robinson and Fenster (31) applied 2,4-D and dicamba to two winter wheat varieties at two stages. A higher yield loss occurred at early boot than at the spring 6-8 tiller stage. Yield losses at both stages were greater for the Scout variety than for the Lancer variety.

Keys (17) treated three spring wheat varieties with dicamba at four to six leaves. Only high rates decreased yields and Canthatch spring wheat was affected least in a two-year study. Molberg (25) also used Canthatch. He found no significant yield reductions with dicamba applied at four-leaf and jointing. Behrens and Johnston (4) treated nine wheat varieties at the four-leaf stage with dicamba. They ranked the varieties in three yield groups: low; medium; and high.

Components of Yield

Components of yield were measured by researchers to determine what effect 2,4-D and dicamba had on wheat plants that may account for a reduction in yield.

Andersen and Hermansen (2) found no significant yield loss in winter wheat treated with 16 kg/ha of 2,4-D. They did observe significant visual injury. An investigation of yield components revealed a decrease in straws per square meter, an increase in kernels per straw, a decrease in weight of grain, and an increase in kernels per spikelet. They concluded that a decrease in straw caused by the 2,4-D resulted in better growing conditions for the remaining straw, which accounts for the increase in kernels per straw and kernels per spikelet. The increased number of kernels per plant outweighed the decrease in straw per square meter and weight of the grain. No net difference in yield occurred.

Klingman (21) reported a direct correlation between yields and kernels per head. As yields decreased from 2,4-D treatments, kernels per head also decreased. No differences were found in culms or heads per foot row. Slife and Fuelleman (37) observed that yield reductions of 2,4-D fall treated wheat were due to shorter spikes, sterile spikelets and stand reduction. Wiese and Rea (43) stated that a decrease in bushel weight and tillering accounted for yield reductions in 2,4-D fall treated wheat. Andersen and Hermansen (2) noted a decrease in sterility at the pre-fully tillered stage and an increase in sterility at the fully headed and flowering stages for 2,4-D

treated wheat. Klingman (21) found a decrease in spikelets per head from wheat treated with 2,4-D at jointing. He stated that the injured heads were on tillers of late development, indicating that the period of susceptibility was of short duration.

Krall (22) observed shattering in winter wheat caused by 2,4-D applied at early jointing. Shattering increased with an increase in visual injury and both effects were varietal.

Quimby and Nalewaja (29) treated spring wheat with dicamba in a growth chamber study. They reported a reduction in yield per spike from treatment at the late tiller through boot growth stages. However, a reduction in yield per plant occurred at the jointing through the boot stages but not at the late tiller stage. An increase in the number of spikes per plant at late tiller compensated for the reduction in yield per spike. This increase in spikes per plant was not observed in field studies. They proposed that maturation of additional tillers caused by the dicamba may have been prevented by intra-crop competition. In field studies Quimby and Nalewaja (29) found a decrease in culms per foot row from a preemergence treatment of dicamba to spring wheat.

Keys (18) noted that dicamba at 0.14 kg/ha to spring wheat at the four-leaf stage caused an increase in tillers and spikes per plant but yield was not reduced. Dicamba at 0.28 kg/ha at the same stage of growth had no effect on tillers and spikes per plant and a slight reduction in yield. At the flag leaf stage all rates of dicamba significantly reduced yields with no change in tillers or spikes per plant.

Quimby and Nalewaja (29) measured seed weight of dicamba treated spring wheat. A significant increase in seed weight occurred at boot and flower. They attributed this to sterility; fewer seeds per spike were produced, therefore seeds were larger because of less competition for nutrients, photosynthate and space. A significant reduction in seed weight occurred at early tillering.

Robinson and Fenster (31) reported a reduction in seed weight from dicamba treatment of winter wheat at the early boot and spring tillering stages.

Quality of Yield

Many researchers observed an inverse relationship of percent protein to yield from 2,4-D and dicamba treated wheat (14,21,31,34). As yields decreased protein content increased. Shaw and Willard (34) reported a protein varietal response of wheat to 2,4-D. The protein content of one variety remained constant when yield was significantly reduced by 2,4-D. Protein content of all other varieties decreased as yield decreased.

Quimby and Nalewaja (29) reported a decrease in germination from 0.42 kg/ha dicamba at the late tiller stage. Shaw and Willard (36) observed reduced germination at late joint and bloom, from 2,4-D. Others (7,21,24) reported no reduction in germination from 2,4-D or dicamba.

Bode, et al. (6) reported that 4.48 kg/ha 2,4-D at a susceptible stage of growth lowered flour yield and baking quality.

Formulations of 2,4-D

Woofter and Lamb (48) studied the retention effect of different 2,4-D formulations on winter wheat. The triethanolamine salt with 1 percent tergitol 7, and butyl ester formulations resulted in a significantly higher percent spray retention. This increased spray retention at a susceptible stage of growth for Thorne winter wheat caused a significant decrease in yield over other formulations of 2,4-D. Based on vegetative traits 288 varieties were screened in greenhouse studies. Three tolerant and three susceptible varieties were picked for spray retention studies. Susceptible varieties retained significantly greater amounts of 2,4-D as a group in field studies than did tolerant varieties. Although there was a significant yield difference among varieties, this could not be explained by differential 2,4-D retention. The varieties responded differently at different stages of development. Previously tolerant varieties in terms of retention were susceptible in terms of yield and vice versa.

Overland and Rasmussen (26) reported that of three different 2,4-D formulations the order of increasing yield loss was sodium salt, amine salt, and ethyl ester. Elder (13) and Shaw and Willard (33) support this order.

Visual Abnormalities

Visual abnormalities or visual injury are common occurrences in wheat from applications of 2,4-D and dicamba.

Andersen and Hermansen (2) have compiled the most complete report of visual abnormalities in small grains caused by 2,4-D. The symptoms they described in winter wheat are green straws, supernumerary spikelets, opposite spikelets, unilateral spikelets, and big glumes. They reported that the frequency, type, and distribution of abnormalities on a wheat spike is determined by the stage of wheat growth at the time of 2,4-D application. The highest number of abnormalities occur at the five-leaf or resumption of spring growth stage; big glumes are a result of late treatment, and abnormalities occur on spike parts developed after treatment with 2,4-D.

Others (12,18,21,22,25,28,29,41,42,46,47) have also reported abnormalities from 2,4-D and dicamba applications which include fused edges of sheaths, incomplete head emergence, decrease in plant height, rolled leaves, crooked rachis internode, branched spikes, spikelets opposite, elongated internodes, supernumerary spikelets, missing spikelets, twisted awns, crooked heads, two heads per culm, delay of maturity, peduncle shortening, leaf sheath shortening, death of main culm, prostrate plants, and floret sterility.

Klingman (21) attributed failure of complete head emergence to tightening of the leaf sheath caused by 2,4-D. Quimby and Nalewaja (29) computed a peduncle leaf sheath ratio to determine if dicamba affected the peduncle length more than the leaf sheath length. The P:S ratios for treated plots were lower than the checks. They attributed failure of head emergence to a direct effect on the peduncle or a combination of leaf sheath tightening and direct effect on the peduncle.

Krall (22) and Woestemeyer (46) observed that short bearded varieties had greater head emergence than long bearded varieties because the heads had less chance of being constricted by the leaf sheath.

Krall (22) reported that an increase in 2,4-D visual injury correlated to an increase in shattering and that these effects were varietal.

Andersen and Hermansen (2) correlated visual injury and yield reduction. They found that the 2,4-D treated growth stage that caused the highest visual injury resulted in the lowest yields. Behrens and Johnston (4) and Lueschen and Strand (23) reported that dicamba visual injury and yield were not correlated. Andersen and Hermansen (2) observed that visual abnormalities such as supernumerary spikelets may be considered as an increase in yield.

Andersen and Hermansen (2) proposed a theory as to the cause of abnormalities in small grains by hormone type herbicides such as 2,4-D and dicamba. They stated that, "the fact that occurrence of abnormalities depends on the stage of development of the plant, seems to indicate that the differentiations of cells forming in the first rudiment of an organ may be profoundly affected by hormone derivatives given at a certain early stage."

Schlehuber (32) observed supernumerary and three seeded spikelets in wheat in Oklahoma under conditions of hot and extremely dry weather. No 2,4-D, dicamba or other chemical had been used on the wheat examined. Andersen and Hermansen (2) concluded, "thus abnormalities are not confined to cereals treated with hormone derivatives, but

concerning the effect of hormone it is interesting to note the violent reactions of the plant at certain stages of development."

Aberg and Denward (1) proposed that environmental conditions could bring about hormone production in the cells of plants and that the action of this hormone and hormone type herbicides may be the same. The similarities between abnormalities caused by 2,4-D (2) and dicamba (29) and environmental conditions (32) support this theory. Aberg and Denward (1) also proposed that genes act by means of hormones and that these hormones are similar to those used in weed control.

The reason for varietal responses of wheat to 2,4-D and dicamba at different stages of growth and inconsistent yield data over years of varying environmental conditions may be explained by the similar properties of 2,4-D and dicamba to endogenous wheat hormones.

Selectivity of Dicamba

Selectivity of dicamba in wheat is attributed to rapid metabolism and even translocation in the symplast and apoplast systems (10, 30). Chang and VandenBorn (10) reported that a decrease in absorption of dicamba in wheat over susceptible species is a selective mechanism. Quimby and Nalewaja (30) found no difference in absorption of dicamba by wheat and susceptible species after 80 minutes.

Broadhurst, et al. (9) stated that 90 percent of dicamba applied to wheat plant was found as the 5-hydroxy-2-methoxy-3,6-dichlorobenzoic acid metabolite of dicamba within 18 days of application. They suggested that the methoxy group on the dicamba molecule

made it subject to attack by wheat plants. Chlorine in place of methoxy group resulted in a loss of selectivity.

Quimby and Nalewaja (30) also noted that dicamba accumulated in the tips of wheat leaves and that main culms had higher concentrations than tillers. They proposed that this may explain the increase in damage of main culms observed in the field (29). The intercalary meristems of wheat may have obstructed the translocation of dicamba from the main culms to the tillers.

Arnold and Nalewaja (3) observed an increase in RNA and protein content in wheat and wild buckwheat (Polygonum Convolvulus L.) from treatment with dicamba at susceptible growth stages. They attributed the increase in RNA as a result of dicamba removing histone from the DNA template by means of a DNA-histone-dicamba complex.

Chen, et al. (11) reported on the effect of 2,4-D and dicamba on nucleohistones in cucumber (Cucumis sativas L.) and wheat roots. In susceptible cucumbers, dicamba caused an increase in RNA and this increased RNA was incapable of translating for protein synthesis. No effects of RNA in wheat were reported. They also noted that two of the nucleohistone patterns in cucumbers were not detectable after treatment with 2,4-D or dicamba. They attributed the increase of RNA in cucumbers to an increase in DNA sites available for transcription because of a change in histone patterns. It was concluded that the site of action of auxin type herbicides appears to be the nucleus and particularly the nucleohistones as exhibited by cucumbers. Also that the selective phytotoxicity may be explained by the differential effect of auxin type herbicides at the nucleohistones in susceptible and tolerant species.

The sensitivity of nucleohistones in different species may be due to the different ratios of amino acid components and/or a different capacity in reconstitution of histone-DNA complexes.

MATERIALS AND METHODS

Field studies were initiated in the fall of 1974 and continued through 1976. Four winter wheat varieties were evaluated with herbicide applications made at two fall and three spring stages of growth. Evaluations were based on visual injury, yield, grains per spike, and test weight.

One location in Ionia County in 1974-75 and seven locations in Ingham, Clinton and Huron Counties in 1976 were selected for study.

Three of the winter wheat varieties were of the soft white commercial classification: Ionia, Yorkstar, and Tecumseh. The Arthur variety of winter wheat was of the soft red commercial classification. All four winter wheat varieties were evaluated at location 1 in 1974-75 and at location 2 in 1976. The varieties evaluated at the remaining locations were Tecumseh and Yorkstar at location 3, Ionia at locations 4 and 5, and Tecumseh at locations 6, 7, 8.

The herbicides were dicamba, trade name Banvel,¹ applied as the dimethylamine salt; 2,4-D applied as the alkanolamine salt (of the ethanol and isopropanol series) and as the propylene glycol butyl ether esters (low volatile ester).

¹Banvel is a product of the Velsicol Chemical Corporation, Chicago, Illinois.

The Herbicide treatments by location were:

Location 1, Ionia County, 1974-75.

1. no treatment
2. dicamba 0.28 kg/ha
3. dicamba 0.56 kg/ha
4. dicamba + 2,4-D amine 0.28 + 0.28 kg/ha
5. dicamba + 2,4-D amine 0.28 + 0.56 kg/ha

Location 2, Ingham County, 1976.

1. no treatment
2. dicamba 0.28 kg/ha
3. 2,4-D ester 0.84 kg/ha
4. dicamba + 2,4-D amine 0.28 + 0.56 kg/ha
5. dicamba + 2,4-D ester 0.14 + 0.42 kg/ha
6. dicamba + 2,4-D ester 0.28 + 0.56 kg/ha

Locations 3, 4, 6 and 7, Clinton County, 1976, Treatments 1-12 listed below.

Locations 5 and 8, Huron County, 1976, Treatments 1-16.

1. no treatment
2. dicamba 0.28 kg/ha
3. 2,4-D amine 0.84 kg/ha
4. 2,4-D ester 0.84 kg/ha
5. dicamba + 2,4-D amine 0.14 + 0.42 kg/ha
6. dicamba + 2,4-D amine 0.28 + 0.28 kg/ha
7. dicamba + 2,4-D amine 0.28 + 0.56 kg/ha
8. dicamba + 2,4-D amine 0.28 + 0.84 kg/ha
9. dicamba + 2,4-D ester 0.14 + 0.42 kg/ha
10. dicamba + 2,4-D ester 0.28 + 0.28 kg/ha
11. dicamba + 2,4-D ester 0.28 + 0.56 kg/ha
12. dicamba + 2,4-D ester 0.28 + 0.84 kg/ha
13. dicamba 0.14 kg/ha
14. dicamba 0.42 kg/ha
15. 2,4-D amine 0.56 kg/ha
16. 2,4-D ester 0.56 kg/ha

Two fall stages were treated at location 1, 1974. Three spring stages were treated at location 1, 1975 and location 2, 1976. Two spring stages were treated at locations 3, 4, 5, 6, 7, and 8 in 1976. All herbicide treatments were applied to each stage of growth, except

treatment no. 5 at location 1 was applied only to the last spring stage.

The stages of wheat growth, dates of application, wheat plant heights, and locations were as follows:

Preemergence--

October 7, 1974, Ionia County, location 1 (planted October 4)

Fall tiller--

November 12, 1974, 10-13 cm, Ionia County, location 1

Resumption of spring growth--

March 26, 1975, 10-13 cm, Ionia County, location 1

March 25, 1976, 5-8 cm, Ingham County, location 2 and 8-10 cm, Clinton County, location 6

Fully tillered--

May 3, 1975, 13-18 cm, Ionia County, location 1

April 21, 1976, 20-25 cm, Ingham County, location 2

April 4, 1976, 10-15 cm, Clinton County, locations 3, 4, 7

April 17, 1976, 13-18 cm, Huron County, locations 5, 8

Early jointing--

May 9, 1975, 20-25 cm, Ionia County, location 1

April 28, 1976, 28-33 cm, Ingham County, location 2

April 29, 1976, 20-33 cm, Clinton County, locations 3, 4, 6, 7

April 30, 1976, 25-30 cm, Huron County, locations 5, 8

Herbicides were applied with a tractor mounted sprayer delivering 215 liters per hectare. Locations 1 and 2 were planted with a custom four-row planter, with 30 cm row spacings. Locations 3, 4, 5, 6, 7, and 8 were planted with grain drills ranging from 18 to 22 holes. Row spacings were 17.8 cm except at location 8, 15 cm row spacings were planted.

The plots at locations 1 and 2 were 8 rows wide by 5.5 meters long. The plots at locations 3, 4, 5, 6, 7, and 8 were one drill width wide and 10.6 meters long.

The experimental design was a split split plot with four replications at location 1, two replications at location 2, and three replications at location 3. Locations 4, 5, 6, 7, and 8 were split plot designs in three replications.

The fertilization program at each location was:

Location 1, 336 kg/ha of 5-20-20 at planting and 112 kg/ha of 12-12-12 topdress in the spring.

Location 2, 336 kg/ha of 5-20-20 at planting and 22.4 kg/ha of N as ammonium nitrate topdress in the spring.

Location 3, 336 kg/ha of 8-32-16 at planting and 33.6 kg/ha of N as urea topdress in the spring.

Location 4, 280 kg/ha of 8-32-16 at planting.

Location 5, 448 kg/ha of 6-24-24 at planting and 22.4 kg/ha of N as ammonium nitrate topdress in the spring.

Location 6, 196 kg/ha of 6-24-24 at planting and 22.4 kg/ha of 19-19-19 topdress in the spring.

Location 7, 336 kg/ha of 8-32-16 at planting and 50.4 kg/ha of N as urea and 112 kg/ha of potash topdress in the spring.

Location 8, 448 kg/ha of 6-24-24 at planting and 28 kg/ha of N as aqua ammonia and 22.4 kg/ha of 16-16-16 topdress in the spring.

Visual injury ratings were recorded one week before harvest.

The morphological abnormalities used as a criteria in rating were twisting of the spike, shortened straws, shortened spikes, stand thinning or less culms per plot, and immaturity. Ratings were based on a scale of 0 to 10 where 0 = no injury and 10 = kill. Ratings are reported as percent visual injury.

Yields were measured at locations 1, 2, 3, 5, 6, 7, and 8. Only Yorkstar was harvested at location 3. At locations 1 and 2 the

four center rows for a length of 3.6 meters were harvested. The wheat at location 1 was cut and bound by a hand-operated mower and thrashed in the field by a portable thrasher. Location 2 was harvested by a custom-built Hege combine. At locations 3, 5, 6, 7, and 8 the four center rows for a length of 4.9 meters in each plot were harvested. The wheat was cut and bound by hand and thrashed in the field by a portable thrasher.

Grains per spike were measured at locations 1, 3, 5, 6, 7, and 8. Spikes of wheat were collected in the field from the rows adjacent to the harvested wheat. Ten spikes of wheat from each plot were thrashed and the grain collected. The grain was counted by an automatic seed counter. Data were reported as grain per spike.

Test weight was measured at locations 2, 3, 5, and 8. Weight of the grain from a volume of 473 ml was converted to kilograms per hectoliter.

Bundles of Ionia and Tecumseh wheat were collected at location 1 from the following treatments: dicamba 0.28 kg/ha at the resumption of spring growth and fully tillered stages, dicamba 0.56 kg/ha at fully tillered and dicamba plus 2,4-D amine 0.28 + 0.28 kg/ha at early jointing. Each bundle of wheat represents three feet of row, that was adjacent to the rows harvested for yield. Photographs of the wheat bundles were taken to display straw length and bundle size. Photographs of individual spikes display spike size and twisting.

RESULTS AND DISCUSSION

Visual Injury

The degree of visual injury that occurred in 1975 and 1976 was dependent on stage of wheat growth, variety of winter wheat, and rate of herbicide.

In 1975 a higher degree of visual injury occurred from herbicide applications than in 1976. Table 1 lists the average percent visual injury for winter wheat varieties from all locations in 1975 and 1976. In 1975 the average visual injury for all herbicide treatments and varieties at the spring stages of wheat growth were 10 percent at resumption of spring growth, 25 percent at fully tillered, and 25 percent at early jointing. The corresponding averages for 1976 were 3 percent, 6 percent, and 16 percent.

The differences in the degree of percent visual injury in 1975 and 1976 may be explained by environmental conditions. Table 2 lists the degree days and precipitation preceding and following the stages of growth that were treated. The Ionia location in 1975 is compared with the Ingham County, Clinton County, and Huron County locations in 1976.

In 1976 a higher number of degree days accumulated in the twenty-five days preceding herbicide applications at resumption of spring growth than in 1975. The difference in degree days did not appear

Table 1. Visual injury for four winter wheat varieties from herbicide applications made at five stages of growth in 1974-75 and three stages of growth in 1976.

Variety	Stage of Growth				
	Pre-emergence 1974	Fall Tillered 1974	Resumption of Spring Growth 1975	Fully Tillered 1975	Early Jointing 1975
	% Injury	% Injury	% Injury	% Injury	% Injury
Ionia	0.6	7	0.6	16	16
Yorkstar	0.6	10	1	15	13
Tecumseh	6	26	20	38	37
Arthur	8	18	19	32	34
Average	4	15	10	25	25
				6	16

Table 2. Environmental conditions for Ionia County, 1975, and Ingham, Clinton, and Huron Counties, 1976.

Year	County	Calendar Dates	Stages of Growth	Number of Days	Cumulative Degree Days	Average Daily Degree Days	Precipitation in Centimeters
1975	Ionia	March 1-March 26		26	-207	-8.0	3.7
1976	Ingham	March 1-March 25	From March 1 to the resumption of	25	-68	-2.7	8.9
1976	Clinton	March 1-March 25	spring growth	25	-96	-3.8	10.3
1976	Huron	March 1-March 25		25	-144	-5.7	11.4
1975	Ionia	March 27-May 3		38	58	1.5	10.0
1976	Ingham	March 26-April 21	From the resumption of spring growth,	27	231	8.5	6.5
1976	Clinton	March 26-April 9	to fully tillered	15	95	6.3	2.4
1976	Huron	March 26-April 17		23	110	4.7	4.1
1975	Ionia	May 4-May 9		6	92	15.3	0.84
1976	Ingham	April 22-April 28	From fully tillered, to	7	24	3.4	6.2
1976	Clinton	April 10-April 29	early jointing	20	237	11.8	12.2
1976	Huron	April 18-April 30		13	117	9.0	7.8

1975	Ionia	May 10-May 30	20 days following last spray application	20	642	32.1	2.8
1976	Ingham	April 29-May 18		20	207	10.3	6.0
1976	Clinton	April 30-May 19		20	273	13.6	7.7
1976	Huron	May 1-May 20		20	189	9.5	8.3
1975	Ionia	May 31-June 19	21-40 days following last spray application	20	518	25.9	12.3
1976	Ingham	May 19-June 7		20	350	17.5	0.99
1976	Clinton	May 20-June 8		20	446	22.3	2.0
1976	Huron	May 21-June 9		20	385	19.2	0.23
1975	Ionia	June 20-June 29	remaining days of the growing season	10	347	34.7	3.3
1976	Ingham	June 8-June 29		22	675	30.7	4.4
1976	Clinton	June 9-June 29		21	677	32.2	5.2
1976	Huron	June 10-June 29		20	600	30.0	2.4

to affect the development of the wheat up to this stage of growth. The resumption of spring growth was sprayed on March 26 in 1975 and on March 25 in 1976.

The degree days continued to be higher in 1976 than in 1975 for the days following the herbicide applications at the resumption of spring growth up to the fully tillered stage.

The increase in degree days in 1976 caused greater physiological activity and accelerated morphological development. In 1976 it took from 15 to 27 days, depending on location, to advance from the resumption of spring growth to the fully tillered stage. For the 1975 wheat 38 days were required for the same morphological development.

From the date of spraying the fully tillered stage until the date of spraying early jointing, environmental conditions reversed for the two years studied. Degree days were higher in 1975 than in 1976. The 1975 wheat advanced from fully tillered to early jointing in 6 days. In 1976 the same process took from 7 to 20 days, depending on the location. Higher rainfall accompanied the lower degree days in 1976. Slower plant processes were apparent in the 1976 wheat.

For 20 days following herbicide applications at early jointing, environmental differences between 1975 and 1976 increased. The 1976 daily average of degree days ranged from 9 to 13. In 1975 the daily average degree days was 32. Moisture was not limiting for either year.

For 21 to 40 days following the last herbicide application, degree days remained lower in 1976 than in 1975. Seventeen to 22 compared with 26 daily average degree days in 1976 and 1975 respectively. Moisture became limiting during this period in 1976; 0.23 to 2.0 cm of

rain had fallen in twenty days. The 1975 crop received 12.3 cm of rain in the corresponding time period. For the remaining days in June degree days and rainfall were similar for both years.

The environmental conditions that follow the post application of herbicides are important for the activity of the herbicide that will follow. In 1975 degree days gradually increased throughout the growing season. Environmental conditions favorable for plant growth existed after each spray application, and water was not limiting throughout the growing season. It is suggested that due to the favorable environmental conditions, increased penetration and translocation of the herbicides occurred in 1975. This resulted in a higher degree of visual injury in 1975.

In 1976 degree days were higher in the early spring preceding herbicide applications at fully tillered than in 1975. Following herbicide applications at fully tillered, degree days were lower in 1976 than in 1975. This difference in degree days continued for 40 days. When degree days were adequate for growth, rainfall was limiting. It is possible that unfavorable growing conditions in 1976 decreased the activity of the plant and the herbicides. As a result, a lower degree of visual injury was observed in 1976.

Although the degree of visual injury differed in 1975 and 1976, similarities do exist (Table 1). For both years studied, the highest average of percent visual injury occurred to the Tecumseh variety for all spring stages of growth treated. The lowest average of visual injury occurred to the Ionia and Yorkstar varieties. Average visual injury for the Arthur variety was similar to visual injury for

the Tecumseh variety in 1975 and for the Ionia and Yorkstar varieties in 1976.

In 1975 and 1976 the least visual injury from herbicide applications at the spring stages of growth for all varieties occurred at the resumption of spring growth. In 1975 the highest average percent visual injury occurred at the fully tillered and early jointing stages. In 1976 the highest visual injury occurred at early jointing. Intermediate visual injury occurred at fully tillered in 1976.

Tables 3 through 7 list the percent visual injury for wheat varieties from applications of dicamba and 2,4-D amine and ester formulation at different stages of growth.

Two fall applications were made in 1974 at location 1 (Table 3). Of the five stages treated in 1975, preemergence received the least visual injury. Ionia and Yorkstar were not significantly visually injured from any preemergence treatment. Significant visual injury did occur from dicamba (0.56 kg/ha) for Tecumseh and Arthur. Significant injury for Arthur also occurred from dicamba plus 2,4-D amine at 0.28 + 0.28 kg/ha. Although significant, the visual injury at this stage of growth was comparatively low (10 percent to 12 percent) for the same treatments at other stages.

The second fall application was the fall tiller. Dicamba (0.28 kg/ha) caused significant visual injury to the Arthur variety only. Significant visual injury occurred to all varieties from dicamba (0.56 kg/ha) and dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha). Ionia and Yorkstar received significantly less visual injury than Tecumseh and Arthur. Tecumseh rated significantly higher visual injury than

Table 3. Visual injury for four winter wheat varieties from herbicide applications made at five stages of growth, Ionia County, Michigan, 1974-75. Location 1.

Variety	Herbicide	Rate (kg/ha)	Stages of Growth				
			Pre-emergence ¹	Fall Tiller	Resumption		
					of Spring Growth	Fully Tillered	Early Jointing
			% Injury	% Injury	% Injury	% Injury	% Injury
Ionia	No treatment		0 a	0 a	0 a	0 a	0 a
"	Dicamba	0.28	0 a	2 a	2 a	17 de	20 e
"	Dicamba	0.56	2 a	7 b	0 a	20 e	17 de
"	Dicamba + 2,4-D Amine	0.28 + 0.28	0 a	12 c	0 a	12 bc	15 cd
"	Dicamba + 2,4-D Amine	0.28 + 0.56					10 b
Yorkstar	No treatment		0 a	0 a	0 a	0 a	0 a
"	Dicamba	0.28	0 a	5 ab	2 a	15 cd	15 cd
"	Dicamba	0.56	2 a	12 c	0 a	20 e	12 bc
"	Dicamba + 2,4-D Amine	0.28 + 0.28	0 a	12 c	2 a	10 b	12 bc
"	Dicamba + 2,4-D Amine	0.28 + 0.56					12 bc
Tecumseh	No treatment		2 a	0 a	0 a	2 a	0 a
"	Dicamba	0.28	0 a	5 ab	12 b	35 g	37 f
"	Dicamba	0.56	12 b	27 d	30 c	45 h	37 f
"	Dicamba + 2,4-D Amine	0.28 + 0.28	5 a	45 e	17 c	35 g	35 f
"	Dicamba + 2,4-D Amine	0.28 + 0.56					37 f
Arthur	No treatment		2 a	2 a	0 a	2 a	0 a
"	Dicamba	0.28	5 a	15 c	12 b	35 g	32 f
"	Dicamba	0.56	10 b	12 c	25 d	35 g	35 f
"	Dicamba + 2,4-D Amine	0.28 + 0.28	10 b	27 d	20 c	27 f	35 f
"	Dicamba + 2,4-D Amine	0.28 + 0.56					32 f

¹ Within a stage of growth, means followed by different letters are significantly different at the 5 per-cent level by Duncan's Multiple Range Test.

Table 4. Visual injury for four winter wheat varieties from herbicide applications made at three stages of growth, Ingham County, Michigan, 1976. Location 2.

Variety	Herbicide	Rate (kg/ha)	Stages of Growth		
			Resumption of Spring Growth	Fully Tillered	Early Jointing
			% Injury	% Injury	% Injury
Ionia	No Treatment		0 a	0 a	0 a
"	Dicamba	0.28	0 a	0 a	10 bc
"	2,4-D Ester	0.84	0 a	0 a	5 ab
"	Dicamba + 2,4-D Amine	0.28 + 0.56	0 a	0 a	20 de
"	Dicamba + 2,4-D Ester	0.14 + 0.42	0 a	0 a	20 de
"	Dicamba + 2,4-D Ester	0.28 + 0.56	0 a	0 a	20 de
Yorkstar	No treatment		0 a	0 a	0 a
"	Dicamba	0.28	5 ab	0 a	10 bc
"	2,4-D Ester	0.84	5 ab	10 bc	5 ab
"	Dicamba + 2,4-D Amine	0.28 + 0.56	5 ab	5 ab	15 cd
"	Dicamba + 2,4-D Ester	0.14 + 0.42	0 a	0 a	15 cd
"	Dicamba + 2,4-D Ester	0.28 + 0.56	10 b	10 bc	25 e

Tecumseh	No Treatment				
"	Dicamba		0 a	0 a	0 a
"	2,4-D Ester	0.28	0 a	10 bc	20 de
"	Dicamba + 2,4-D Amine	0.84	5 ab	0 a	10 bc
"	Dicamba + 2,4-D Ester	0.28 + 0.56	0 a	0 a	10 bc
"	Dicamba + 2,4-D Ester	0.14 + 0.42	5 ab	15 cd	20 de
"	Dicamba + 2,4-D Ester	0.28 + 0.56	0 a	15 cd	20 de
Arthur	No Treatment				
"	Dicamba		0 a	0 a	0 a
"	2,4-D Ester	0.28	0 a	20 d	5 ab
"	Dicamba + 2,4-D Amine	0.84	0 a	5 ab	15 cd
"	Dicamba + 2,4-D Ester	0.28 + 0.56	0 a	0 a	20 de
"	Dicamba + 2,4-D Ester	0.14 + 0.42	0 a	5 ab	15 cd
"	Dicamba + 2,4-D Ester	0.28 + 0.56	0 a	5 ab	20 de

¹Within a stage of growth, means followed by different letters are significantly different at the 5 percent level by Duncan's Multiple Range Test.

Table 5. Visual injury for Ionia winter wheat from herbicide applications made at two stages of growth, at two locations in Michigan, 1976.

Herbicide	Rate (kg/ha)	Location 4 Stages of Growth			Location 5 Stages of Growth		
		Fully ¹ Tillered	Early Jointing	% Injury	Fully Tillered	Early Jointing	% Injury
No Treatment		0 a	0 a		0 a	0 a	
Dicamba	0.14				3 a	10 abcd	
"	0.28	0 a	13 bcd*		6 a	13 bcd	
"	0.42				6 a	10 abcd	
2,4-D Amine	0.56				5 a	10 abcd	
"	0.84	3 a	6 ab		3 a	3 ab	
2,4-D Ester	0.56				3 a	6 abc	
"	0.84	10 ab	10 abc		0 a	13 bcd*	
Dicamba + 2,4-D Amine	0.14 + 0.42	3 a	10 abc		3 a	10 abcd	
"	0.28 + 0.28	10 ab	16 bcde		10 a	10 abcd	
"	0.28 + 0.56	6 ab	20 cdef*		6 a	16 cd*	
"	0.28 + 0.84	6 ab	16 bcde*		10 a	16 cd	
Dicamba + 2,4-D Ester	0.14 + 0.42	6 ab	20 cdef*		6 a	16 cd*	
"	0.28 + 0.28	6 ab	26 ef*		0 a	13 bcd*	
"	0.28 + 0.56	10 ab	23 def*		3 a	16 cd*	
"	0.28 + 0.84	16 b	30 f*		3 a	20 d*	

¹Within a stage of growth and location, means followed by different letters are significantly different at the 5 percent level by Duncan's Multiple Range Test.

*Significance at the 5 percent level between stages of growth by Duncan's Multiple Range Test.

Table 6. Visual injury for two winter wheat varieties from herbicide applications made at two stages of growth, Clinton County, Michigan, 1976. Location 3.

Herbicide	Rate (kg/ha)	Yorkstar		Tecumseh	
		Fully Tillered	Early Jointing	Fully Tillered	Early Jointing
		% Injury	% Injury	% Injury	% Injury
No Treatment		0 a	0 a	0 a	0 a
Dicamba	0.28	0 a	3 ab	3 a	13 de*
2,4-D Amine	0.84	0 a	3 ab	3 a	10 cde
2,4-D Ester	0.84	0 a	3 ab	1 a	6 abc
Dicamba + 2,4-D Amine	0.14 + 0.42	3 a	6 abc	0 a	6 abc
" "	0.28 + 0.28	5 a	6 abc	6 a	15 e*
" "	0.28 + 0.56	1 a	6 abc	6 a	16 e*
" "	0.28 + 0.84	0 a	11 cde*	0 a	13 de*
Dicamba + 2,4-D Ester	0.14 + 0.42	3 a	13 de*	0 a	13 de*
" "	0.28 + 0.28	0 a	10 cde*	3 a	16 e*
" "	0.28 + 0.56	0 a	8 bcd	3 a	23 f*
" "	0.28 + 0.84	3 a	15 e*	6 a	16 e*

¹ Within a stage of growth, for Yorkstar and Tecumseh, means followed by different letters are significantly different at the 5 percent level by Duncan's Multiple Range Test.

* Significance at the 5 percent level between stages of growth by Duncan's Multiple Range Test.

Table 7. Visual injury for Tecumseh winter wheat from herbicide applications made at two stages of growth, at three locations in Michigan, 1976.

Herbicide	Rate (kg/ha)	Location 6			Location 7			Location 8		
		Stages of Growth			Stages of Growth			Stages of Growth		
		Resumption ¹ of Spring Growth	Early Jointing	Early Jointing	Fully Tillered	Early Jointing	Fully Tillered	Early Jointing	Fully Tillered	Early Jointing
		% Injury	% Injury	% Injury	% Injury	% Injury	% Injury	% Injury	% Injury	% Injury
No Treatment		0 a	6 a	6 a	0 a	6 a	3 a	0 a		
Dicamba	0.14						10 ab	10 abc		
"	0.28	10 abc	26 cde*	16 abc	26 bc		10 ab	20 cde*		
"	0.42						3 a	30 efg*		
2,4-D Amine	0.56						3 a	3 ab		
"	0.84	6 ab	10 ab	16 abc	13 ab		10 ab	13 abcd		
2,4-D Ester	0.56						6 ab	20 cde*		
"	0.84	16 bc	20 bcd	20 bc	20 abc		6 ab	16 bcde*		

Dicamba + 2,4-D Amine	0.14 + 0.42	3 ab	16 abc	6 ab	16 abc	6 ab	20 cde*
"	"	6 ab	23 cde*	16 abc	23 bc	10 ab	20 cde*
"	"	6 ab	26 cde*	16 abc	23 bc	6 ab	23 cdef*
"	"	10 abc	26 cde*	20 bc	23 bc	10 ab	26 def*
Dicamba + 2,4-D Ester	0.14 + 0.42	10 abc	30 de*	10 abc	23 bc	3 a	30 efg*
"	"	13 abc	26 cde	16 abc	26 bc	20 b	36 fg*
"	"	20 c	36 e*	23 c	30 c	13 ab	40 g*
"	"	16 bc	36 e*	26 c	30 c	10 ab	40 g*

¹ Within a stage of growth and location, means followed by different letters are significantly different at the 5 percent level by Duncan's Multiple Range Test.

* Significance at the 5 percent level between stages of growth by Duncan's Multiple Range Test.

Arthur. The dicamba plus 2,4-D amine combination caused significantly higher visual injury than the dicamba (0.56 kg/ha) for three of four varieties. The 2,4-D amine increased the susceptibility to visual injury for Ionia, Tecumseh and Arthur.

Arthur was the only variety to receive significant visual injury from dicamba (0.28 kg/ha) at fall tiller. Arthur was also the only variety that did not have a significant increase in visual injury from dicamba at 0.56 kg/ha. Based on the information from the other varieties, the data on Arthur are considered suspect.

The resumption of spring growth stage was treated at location 1 (Table 3) in 1975 and at locations 2 (Table 4) and 6 (Table 7) in 1976. Of the three spring stages studied, the least visual injury occurred at this stage.

Ionia and Yorkstar did not show visual injury at resumption of spring growth in both years. In 1976, at location 2, only dicamba plus 2,4-D ester (0.28 + 0.56 kg/ha) resulted in significant visual injury to Yorkstar (10 percent). In 1975 no visual injury occurred to Ionia or Yorkstar. The tolerance of these two varieties to visual injury is comparable at resumption of spring growth in 1975 and 1976 to preemergence in 1975.

At the resumption of spring growth no significant visual injury occurred to Tecumseh or Arthur at location 2 in 1976 (Table 4). Significant visual injury did occur to Tecumseh in 1976 at location 6 (Table 7) and to Tecumseh and Arthur in 1975 at location 1 (Table 3).

At location 1, significant visual injury occurred to Tecumseh and Arthur from all herbicide treatments. The degree of visual injury received was rate dependent. Dicamba at 0.56 kg/ha caused significantly higher visual injury than dicamba at 0.28 kg/ha. Intermediate visual injury occurred from dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha). Tecumseh was injured significantly higher from the high rate of dicamba (0.56 kg/ha) than was Arthur.

At location 6, visual injury was apparent to Tecumseh from all herbicide treatments. The highest percent visual injury resulted from the dicamba plus 2,4-D ester combinations and 2,4-D ester (0.84 kg/ha). Intermediate visual injury occurred from dicamba (0.28 kg/ha) and the high rate of dicamba plus 2,4-D amine. The low rates of dicamba plus 2,4-D amine and 2,4-D amine (0.84 kg/ha) resulted in the least visual injury. Significant visual injury occurred from dicamba plus 2,4-D ester (0.28 + 0.56 and 0.28 + 0.84 kg/ha) and 2,4-D ester (0.84 kg/ha).

The visual injury to Tecumseh was comparable at location 1, 1975 and location 6, 1976. The dicamba 0.28 kg/ha treatment caused similar injury. The dicamba plus 2,4-D amine combination in 1975 was comparable to the dicamba plus 2,4-D ester combination in 1976.

The fully tillered stage was treated at seven of the eight locations studied in 1975 and 1976. In 1976 at location 2 (Table 4), 1.5 cm of rain occurred one hour after herbicide application. This accounts for the erratic and decreased visual injury ratings. Location 2 will be disregarded in this discussion for the fully tillered stage.

In all locations treated Ionia and Yorkstar were injured less than Tecumseh and Arthur from herbicide applications at fully tillered. The degree of visual injury differed between 1975 and 1976, because of environmental conditions previously explained, and is particularly noticeable at fully tillered. Table 8 lists the average percent visual injury for varieties in 1975 and 1976 excluding location 2 (Table 4). Only the most susceptible variety Tecumseh reflects visual injury in 1976.

Table 8. Visual injury for four winter wheat varieties from applications of dicamba and 2,4-D at the fully tillered stage of growth in 1975 and 1976.

Variety	1975	1976
	<u>%</u>	<u>%</u>
Ionia	16	6
Yorkstar	15	1
Tecumseh	38	12
Arthur	32	-

At location 1 in 1975 (Table 3) Ionia and Yorkstar responded similarly to herbicide treatments at fully tillered. The amount of visual injury received was rate responsive for dicamba. Dicamba at 0.56 kg/ha resulted in higher visual injury than did 0.28 kg/ha. The dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) resulted in a significant decrease in visual injury from the dicamba treatments. The addition

of 2,4-D to dicamba increased the tolerance of Ionia and Yorkstar to visual injury.

Yorkstar was not significantly visually injured at location 3 in 1976 (Table 6). Six herbicide treatments rated 0 percent visual injury, and 5 percent visual injury was the highest rating recorded.

No significant visual injury occurred at location 5 (Table 5) for the Ionia variety. At location 4 (Table 5) only the high rate of dicamba plus 2,4-D ester ($0.28 + 0.84$ kg/ha) resulted in significant visual injury to Ionia, 16 percent.

Tecumseh and Arthur were significantly visually injured from all herbicide applications at fully tillered at location 1, 1975 (Table 3). Thirty-five percent visual injury was recorded from dicamba (0.28 kg/ha) for both varieties. Dicamba (0.56 kg/ha) resulted in a significant increase in visual injury for Tecumseh (45 percent). Visual injury for Arthur remained unchanged from the low to high rate of dicamba. Dicamba plus 2,4-D amine ($0.28 + 0.28$ kg/ha) resulted in visual injury equal to that obtained with dicamba (0.28 kg/ha) on Tecumseh. The combination treatment resulted in a significant decrease in visual injury compared to dicamba (0.28 kg/ha) on the Arthur variety. The addition of 2,4-D amine apparently increased the tolerance of Arthur but not Tecumseh.

Tecumseh was treated at the fully tillered stage at three locations in 1976. Visual injury occurred at locations 7 and 8 (Table 7). The dicamba plus 2,4-D amine ($0.28 + 0.28$ kg/ha) caused visual injury equal to dicamba (0.28 kg/ha) in both locations. This supports data from location 1, 1976. The dicamba plus 2,4-D ester combinations

caused higher visual injury than dicamba plus 2,4-D amine combination. Significant visual injury occurred from dicamba plus 2,4-D ester (0.28 + 0.28 kg/ha) at location 8 and from 2,4-D ester (0.84 kg/ha), dicamba plus 2,4-D amine (0.28 + 0.84 kg/ha), and dicamba plus 2,4-D ester (0.28 + 0.56 and 0.28 + 0.84 kg/ha) at location 7.

No significant visual injury occurred to Tecumseh at location 3 (Table 6). Three of eleven treatments recorded 0 percent visual injury and the highest visual injury rating was 6 percent.

Treatment of winter wheat varieties at early jointing resulted in significant visual injury at all locations. The highest degree of visual injury occurred at this stage in 1976. In 1975 visual injury at early jointing was equal to the visual injury at the fully tillered stage. Varietal differences existed at all locations except location 2, 1976.

Table 9 lists the average percent visual injury to winter wheat varieties from herbicide applications at early jointing. At

Table 9. Visual injury for four winter wheat varieties from applications of dicamba and 2,4-D at the early jointing stage of growth in 1975 and 1976.

Variety	Location 2 1976	Locations 3-8 1976	Location 1 1975
	<u>%</u>	<u>%</u>	<u>%</u>
Ionia	15	15	16
Yorkstar	14	8	13
Tecumseh	16	22	37
Arthur	15	-	34

location 2 in 1976 all varieties responded equally. At seven other locations in 1975 and 1976, varieties could be ranked as to the visual injury recorded: Yorkstar<Ionia<Arthur<Tecumseh.

At location 1, 1975 (Table 3) Ionia and Yorkstar were visually injured significantly less than Tecumseh and Arthur at early jointing. For Ionia the dicamba plus 2,4-D amine combination resulted in less visual injury than dicamba alone. This decrease in visual injury from the combination treatment was significant from dicamba (0.28 kg/ha). The higher rate of 2,4-D amine in combination with dicamba resulted in significantly less visual injury than the low rate of 2,4-D amine. The tolerance of Ionia to visual injury was increased by the addition of 2,4-D amine to dicamba, and this tolerance increased with the higher rate of 2,4-D amine.

Ionia was treated at early jointing at location 4 and 5 in 1976 (Table 5). Seven out of eleven treatments at location 4 and six out of fifteen treatments at location 5 resulted in significant visual injury. The 2,4-D amine resulted in less visual injury than the 2,4-D ester. Dicamba (0.28 kg/ha) resulted in higher visual injury than any 2,4-D formulation alone. The combination of dicamba plus 2,4-D amine caused greater visual injury than dicamba alone. The dicamba plus 2,4-D ester combination caused the greatest visual injury. At early jointing visual injury for Ionia from dicamba plus 2,4-D ester combinations at locations 4 and 5, 1976, was comparable to the dicamba plus 2,4-D amine combinations at location 1 in 1975.

Tecumseh was more susceptible to herbicides than Yorkstar at early jointing at location 3 (Table 6). Nine of eleven treatments

caused significant visual injury to Tecumseh while five out of eleven treatments resulted in significant visual injury to Yorkstar. Significantly higher visual injury occurred to Tecumseh for five treatments. The dicamba plus 2,4-D ester combinations caused greater visual injury than the dicamba plus 2,4-D amine combination.

The highest percent visual injury at location 1 (Table 3) occurred to Tecumseh and Arthur. All treatments caused significant and similar visual injury ranging from 32 percent to 37 percent. Visual injury at early jointing was rate and combination independent for Tecumseh, Arthur and also Yorkstar at location 1.

Tecumseh was treated at early jointing at locations 6, 7, and 8. Significant visual injury occurred in all but five of fifteen treatments. The dicamba (0.14 kg/ha), 2,4-D amine (0.84 and 0.56 kg/ha), 2,4-D ester (0.84 kg/ha) and dicamba plus 2,4-D amine (0.14 + 0.42 kg/ha) treatments did not cause significant visual injury. Of the treatments that did cause significant visual injury, less significant difference among treatments existed except at location 8. Increased if not significantly greater visual injury was present at locations 6 and 7 (Table 7). The dicamba plus 2,4-D ester (0.28 + 0.56 and 0.28 + 0.84 kg/ha) resulted in the highest percent visual injury. The dicamba plus 2,4-D ester combinations caused greater visual injury than the dicamba plus 2,4-D amine combinations. The high rate of dicamba (0.42 kg/ha) resulted in visual injury comparable to low rates of dicamba plus 2,4-D ester. Dicamba (0.28 kg/ha) and the 2,4-D ester treatments caused visual injury comparable to dicamba plus 2,4-D amine.

The degree of visual injury caused by the dicamba plus 2,4-D ester combinations at location 8 in 1976 was comparable to the visual injury from dicamba and dicamba plus 2,4-D amine at location 1, 1975.

Figures 1-3 display the effects of dicamba at three spring stages and dicamba plus 2,4-D amine at early jointing, May 9, to Tecumseh and Ionia in 1975. The resumption of spring growth corresponds with the March 26 date and fully tillered with May 3. Note the absence of visual injury for Ionia from the herbicide treatments compared with Tecumseh.

From the photographs (Figures 1-3), it is observed that in 1975 the wheat straw and spike length were dependent on the spring stage of wheat growth, wheat variety, and the herbicide rate that was applied. At resumption of spring growth, a greater reduction in plant height and spike length occurred at 0.56 kg/ha (1/2 lb/A) dicamba than at 0.28 kg/ha (1/4 lb/A) dicamba. At fully tillered, 0.28 kg/ha (1/4 lb/A) dicamba caused a greater reduction in plant height and spike length than did any treatment at the resumption of spring growth. Dicamba applied at 0.56 kg/ha (1/2 lb/A) at fully tillered caused a larger plant and spike length reduction than 0.28 kg/ha (1/4 lb/A) dicamba.

Spike twisting and standing thinning also occurred at the resumption of spring growth and fully tillered stages in 1975. The degree of severity for these abnormalities was not visually discernable between stages and rates of herbicide applications. A lower degree of spike and straw shortening and stand thinning but a higher degree of spike twisting occurred at early jointing than at the resumption of

Figure 1. Straw length and bundle size from herbicide applications¹ made at different stages of growth² to Tecumseh.

¹1/4 lb. Banvel = 0.28 kg/ha dicamba, 1/2 lb. Banvel = 0.56 kg/ha dicamba, 1/4 lb. 2,4-D = 0.28 kg/ha 2,4-D.

²March 26 = resumption of spring growth, May 3 = fully tillered, May 9 = early jointing.



Figure 2. Straw length and bundle size from herbicide applications¹ made at different stages of growth² to Ionia.

¹1/4 lb. Banvel = 0.28 kg/ha dicamba, 1/2 lb. Banvel = 0.56 kg/ha dicamba, 1/4 lb. 2,4-D = 0.28 kg/ha 2,4-D.

²March 26 = resumption of spring growth, May 3 = fully tillered, May 9 = early jointing.

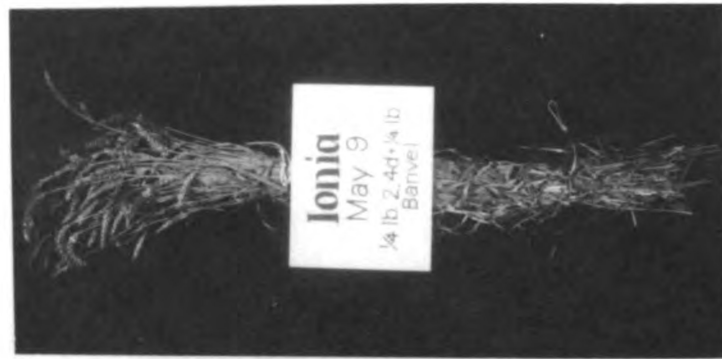
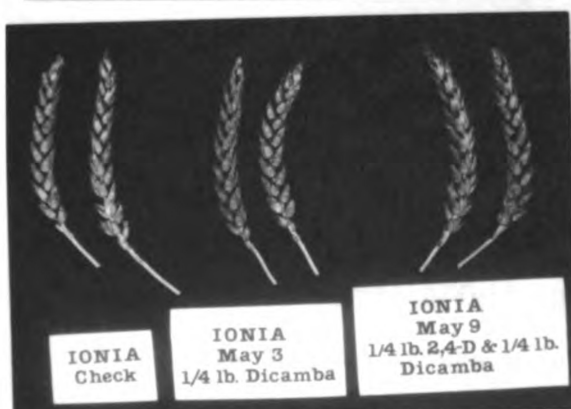
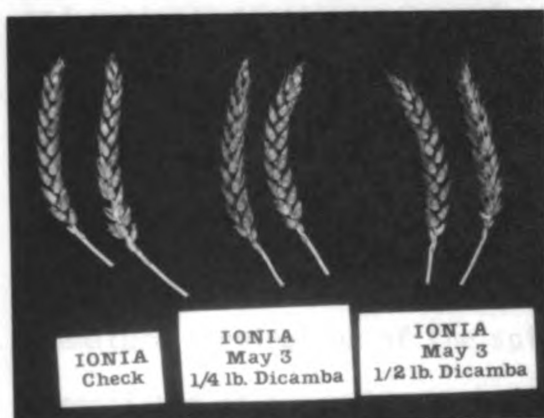
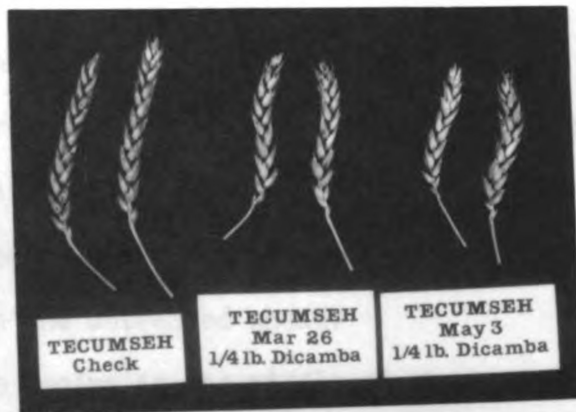
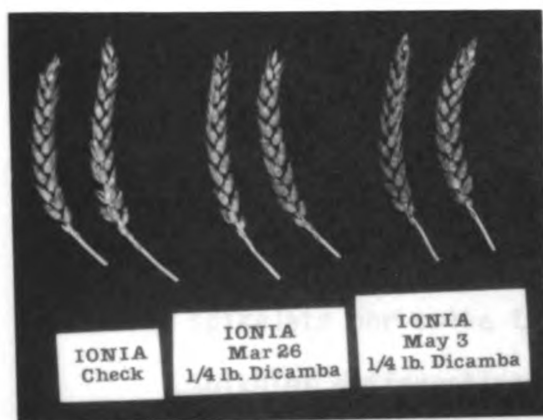


Figure 3. Spike shortening and twisting from herbicide applications¹ made at different stages of growth² to Tecumseh and Ionia.

¹1/4 lb. Banvel = 0.28 kg/ha dicamba,
1/2 lb. Banvel = 0.56 kg/ha dicamba,
1/4 lb. 2,4-D = 0.28 kg/ha 2,4-D.

²March 26 = resumption of spring growth,
May 3 = fully tillered,
May 9 = early jointing.



spring growth or fully tillered stages. The degree of injury was not visually discernible between herbicide rates at early jointing.

Measurements of straw and spike length were not taken. It is evident from the photographs presented that the straw and spike size were reduced by the herbicide treatments in 1975. From the photographs of the wheat spikes, it is apparent that the herbicide treated wheat had fewer spikelets per spike than the untreated wheat.

Spikelet differentiation begins in the middle of the spike and proceeds to the top and the base of the spike (8). The wheat spike is a determinate inflorescence which terminates in an apical spikelet. When the spikelets differentiate, the number of spikelets that will appear on the spike is fixed (8). Dicamba and dicamba plus 2,4-D amine applied before all of the spikelets had differentiated may have caused premature termination of the spike. Because fewer spikelets had differentiated at an early stage of growth, a greater reduction in spike size occurred.

The reduction of straw length paralleled that of spike length from herbicide applications at different stages of growth. The stage of stem primordia development at the time of herbicide application may also be critical to the effect observed.

The bundles of wheat in Figures 1 and 2 represent a three-foot section of row that was collected from field plots adjacent to the rows harvested for yield. The size of the bundles is representative of yield.

The type of visual abnormality that appeared in 1976 was dependent on the stage of wheat growth treated and the herbicide used.

This was discernible in 1976 because the dicamba, 2,4-D amine, and 2,4-D ester formulations were applied separately and in combination. In 1975 dicamba was applied separately or in combination with 2,4-D amine. The morphological abnormalities caused by the herbicide applications occurred to all of the winter wheat varieties studied.

In 1976 spike twisting, reduction in wheat straw length, and stand thinning were prominent visual abnormalities. Reduction in spike size was slight when present. All treatments of dicamba at 0.14 and 0.28 kg/ha caused spike twisting with very little effect to plant height or spike length. This was true for treatment at the resumption of spring growth, fully tillered and early jointing stages. Dicamba applied at 0.42 kg/ha at early jointing caused stand thinning, delayed maturity, and caused reduction of straw and spike length as well as spike twisting.

Applications of 2,4-D amine and ester formulations separately at the resumption of spring growth and fully tillered stages caused a reduction in straw length. Slight spike twisting was observed but was not prominent. At early jointing the amine and ester formulations of 2,4-D did not reduce straw length but caused spike twisting.

The combination treatments resulted in characteristic visual abnormalities. Application of dicamba plus 2,4-D amine at resumption of spring growth and fully tillered caused spike twisting. Reduction in straw length did not occur as when 2,4-D amine was applied alone at the corresponding stages. The dicamba injury was dominant to the 2,4-D amine injury. Application of dicamba plus 2,4-D ester at the same stages caused a reduction in straw length, spike twisting, and stand

thinning. The dicamba plus 2,4-D ester combination resulted in an additive response. The effects of dicamba and 2,4-D ester applied separately at the corresponding stages were present, plus the effect of stand thinning.

Dicamba plus 2,4-D amine treated at early jointing caused a reduction in straw length and spike twisting. Dicamba plus 2,4-D ester applied at the same stage resulted in a reduction in straw length, spike twisting, stand thinning and a reduction in spike length. When applied separately at this stage, dicamba and 2,4-D amine and ester formulations resulted in spike twisting only. Combination of the herbicides increased the types of abnormalities present. The abnormalities observed at this stage are similar to the abnormalities recorded from the high rate of dicamba applied separately. The combination of herbicides may increase the activity of dicamba.

Early visual injury was observed in 1976. Depending on the location, early visual injury was observed thirteen to thirty-one days after spraying the resumption of spring growth or fully tillered stage. Forty to 60 percent visual injury occurred for all varieties from the application of dicamba separately or dicamba plus 2,4-D amine or ester. No visual injury occurred from the separate application of 2,4-D amine or ester. The leaf tips were chlorotic to 7 to 10 cm from the base of the plant. Leaves were 20 to 30 cm long. The plants were also prostrate in appearance. Dicamba in combination with 2,4-D, amine or ester, resulted in greater visual injury than dicamba alone. The dicamba plus 2,4-D ester caused a higher degree of visual injury than the dicamba plus 2,4-D amine. The dicamba plus 2,4-D ester (0.28 + 0.84 kg/ha)

caused the greatest degree of visual injury and was easily picked out from all other treatments at all locations. Injury from this treatment was in the range of 60 percent to 75 percent.

The early visual injury was noticed when the application was made at early jointing. An attempt to formally rate the early visual injury for all stages of growth was made two weeks after spraying at early jointing. At this time no visual injury was apparent, as previously observed. All wheat varieties had recovered, no chlorosis or differences in plant heights were noticeable.

No early visual injury was noted in 1975. In the spring of 1975 it was thirty-nine days between application at the resumption of spring growth and the fully tillered stage. The 1975 location had not been monitored between spraying dates. Based on the 1976 results, the early visual injury may have already passed by the time the fully tillered stage was sprayed.

Yield

In 1975 application of dicamba and dicamba plus 2,4-D amine to winter wheat varieties resulted in significant yield reductions. Yield losses were dependent on stage of growth, wheat variety and herbicide rate.

There was an inherent yield difference among wheat varieties in 1975. The average yield for the no-treatment plots was highest for the Ionia variety, 3691 kg/ha. The Yorkstar variety yields averaged 3335 kg/ha, 90 percent of Ionia. The corresponding no-treatment yields and percent of Ionia for Tecumseh and Arthur are 3257 kg/ha, 88 percent

and 3096 kg/ha, 84 percent, respectively. Because of these differences in yields among varieties, it is unfair to compare the effect of the herbicide treatments on the basis of actual weights per hectare.

For example, at location 1 (Appendix A) dicamba (0.56 kg/ha) at fully tillered resulted in a yield of 3122 kg/ha for the Ionia variety. This was a 20 percent yield reduction from the no treatment. Dicamba at 0.28 kg/ha at the same stage resulted in a yield of 2640 kg/ha for the Arthur variety. This was a 13 percent yield reduction from the no treatment. Because the split-split-plot design used for this analysis compares the yields of all varieties at the same stage of growth, the 20 percent yield reduction for the Ionia variety was significantly less than the 13 percent yield reduction for the Arthur variety. For this reason all yields are reported as percent of no treatment for each variety. No statistically significant statements may be made among varieties; however, varietal differences from comparison of the yields as percent of no treatment are evident.

Table 10 lists the 1975 yields as a percent of no treatment for each variety at each stage of growth treated. Appendix A lists the corresponding yields for Table 10 in kg/ha. Appendix B lists the yield loss in kg/ha for a corresponding yield loss as a percent of no treatment. For example, a 10 percent yield loss as compared with the no treatment for the Ionia variety represents a yield reduction of 360 kg/ha.

Weed pressure was a factor in 1975. Herbicide applications resulted in effective weed control for the treated plots. The control

Table 10. Yield as a percent of no treatment for four winter wheat varieties from herbicide applications made at five stages of growth, Ionia County, Michigan, 1974-75. Location 1.

Variety	Herbicide	Rate (hg/ha)	Stages of Growth ¹				
			Pre-emergence	Fall Tiller	Resumption of Spring Growth	Fully Tillered	Early Jointing
			% Yield	% Yield	% Yield	% Yield	% Yield
Ionia	No Treatment		100	100	100	100	100
"	Dicamba	0.28	90 b	73*c	109 a	98 a	99 a
"	Dicamba	0.56	79*b	73*c	106 a	80*b	93 a
"	Dicamba + 2,4-D Amine	0.28 + 0.28	83*b	76*c	98 b	93 a	101 a
"	Dicamba + 2,4-D Amine	0.28 + 0.56					84*
		Treatment $\bar{X}$ = 84		74	104	90	94
Yorkstar	No Treatment		100	100	100	100	100
"	Dicamba	0.28	90 b	64*c	98 ab	99 ab	100 a
"	Dicamba	0.56	74*b	62*c	97 a	79*b	92 a
"	Dicamba + 2,4-D Amine	0.28 + 0.28	79*c	66*d	75*d	91 b	99 a
"	Dicamba + 2,4-D Amine	0.28 + 0.56					79*
		Treatment $\bar{X}$ = 81		64	90	89	92

Tecumseh	No Treatment		100	100	100	100
"	Dicamba	0.28	92 a	94 ab	86 b	89 ab
"	Dicamba	0.56	72*a	83*a	66**b	82*a
"	Dicamba + 2,4-D Amine	0.28 + 0.28	75*b	73*c	84*b	94 a
"	Dicamba + 2,4-D Amine	0.28 + 0.56				78*
		Treatment $\bar{X}$ = 79	60	83	78	85
Arthur	No Treatment		100	100	100	100
"	Dicamba	0.28	84*b	90 b	87 b	99 a
"	Dicamba	0.56	64**bc	83*a	61*c	83*a
"	Dicamba + 2,4-D Amine	0.28 + 0.28	67**c	68**c	88 b	95 a
"	Dicamba + 2,4-D Amine	0.28 + 0.56				77*
		Treatment $\bar{X}$ = 71	62	80	78	88

¹ Within a herbicide level for one variety, means followed by different letters are significantly different at the 5 percent level by Duncan's Multiple Range Test.

* Within a stage of growth for one variety, significant at the 5 percent level; **Significantly greater than * at the 5 percent level by Duncan's Multiple Range Test.

plots that did not receive herbicide treatments were not hand weeded. Larger differences in yields would have been obtained had the no-treatment plots been weed free.

At the preemergence stage dicamba (0.56 kg/ha) and dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) significantly reduced yields for all varieties. Significant yield loss occurred from dicamba (0.28 kg/ha) for Arthur. This yield loss was significantly less than the yield loss from the high rate of dicamba and the combination dicamba plus 2,4-D amine treatments. The degree of yield loss from preemergence treatment was varietal. The average yield for all treatments as a percent of no treatment was Ionia 84 percent, Yorkstar 81 percent, Tecumseh 80 percent and Arthur 72 percent.

The highest average yield reductions occurred at fall tiller. All treatments significantly reduced yields. The yield reduction was independent of herbicide rate. Reduced yield loss occurred from the combination treatment for all varieties, but this was not significant. The average yields for all treatments were Ionia 74 percent, Yorkstar 64 percent, Tecumseh 60 percent and Arthur 62 percent.

At the resumption of spring growth, no significant yield loss occurred to Ionia. From Table 10 there appears to be an increase in yields for Ionia due to herbicide treatments at this stage, in that yield as a percent of no treatment is greater than 100 percent. This reflects a low yield for the no-treatment plots at this stage of growth.

Significant yield loss occurred to Yorkstar from dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) at the resumption of spring growth. Dicamba (0.56 kg/ha) and dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha)

resulted in significant yield losses for Tecumseh and Arthur. The dicamba plus 2,4-D amine combination resulted in the highest yield reductions for all varieties. This yield reduction was significantly greater than the yield reduction from dicamba (0.56 kg/ha) for the Yorkstar and Arthur varieties.

The average yields from all treatments were Ionia 104 percent, Yorkstar 90 percent, Tecumseh 83 percent and Arthur 80 percent.

At fully tillered dicamba (0.56 kg/ha) significantly reduced yields for all varieties. The dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) caused a significant yield reduction to Tecumseh. This yield loss was significantly less than the yield loss from dicamba at 0.56 kg/ha. The average yield for all treatments were Ionia and Yorkstar 90 percent, and Tecumseh and Arthur 79 percent.

At early jointing, significant yield reductions occurred to all varieties from the high rate of dicamba plus 2,4-D amine combinations (0.28 + 0.56 kg/ha). The high rate of dicamba (0.56 kg/ha) significantly reduced yields for Tecumseh and Arthur. The average yields for all treatments were Ionia 94 percent, Yorkstar 93 percent, Tecumseh 86 percent and Arthur 88 percent.

Tolerance to dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) from spring applications increased at later stages of growth. The order of decreasing yield reductions from dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) was resumption of spring growth, fully tillered, and early jointing.

At the resumption of spring growth dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) caused a significant yield loss for all varieties

except Ionia. This yield loss was the greatest for all treatments and significantly greater than dicamba (0.56 kg/ha) for Yorkstar and Arthur. The addition of 2,4-D amine to dicamba at the earliest spring stage resulted in greater injury than from the high rate of dicamba. The winter wheat was susceptible to the 2,4-D amine at this stage of growth.

At fully tillered and early jointing no significant yield reduction occurred from dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha), except for the Tecumseh variety at the fully tillered stage. Yield reductions were similar from dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) and dicamba (0.28 kg/ha). The wheat was tolerant to the 2,4-D amine (0.28 kg/ha) in combination with dicamba at the later spring stages.

At early jointing dicamba plus 2,4-D amine (0.28 + 0.56 kg/ha) resulted in significant yield loss for all varieties. This yield reduction was greater than from dicamba (0.56 kg/ha) for all varieties and significantly greater for Ionia and Yorkstar. Wheat was susceptible to the 0.56 kg/ha rate but not the 0.28 kg/ha rate of 2,4-D amine when applied in combination with dicamba (0.28 kg/ha). The dicamba plus 2,4-D amine (0.28 + 0.56 kg/ha) was applied at early jointing only.

The effect that 2,4-D amine has on wheat when applied in combination with dicamba appears to be dependent upon the stage of wheat growth and the rate of 2,4-D amine.

By examining each stage of growth separately, varieties may be ranked in the order of increasing yield loss from applications of dicamba and dicamba plus 2,4-D amine in 1975 as Ionia, Yorkstar, Tecumseh, and Arthur. However, for each variety there is a stage of growth

and herbicide rate that may be used to avoid significant yield reductions.

In terms of yield, Ionia and Yorkstar are more tolerant to applications of dicamba and dicamba plus 2,4-D amine at all stages of growth studied than were Tecumseh and Arthur. Because of this tolerance a wider range of stages of growth and herbicide rates may be applied to Ionia and Yorkstar without significant yield reductions.

All fall treatments significantly reduced yields for Ionia and Yorkstar excluding the preemergence application of dicamba (0.28 kg/ha). Yields from the application of dicamba (0.28 kg/ha) were significantly higher at early jointing for Yorkstar and at all spring stages for Ionia.

For the spring stages of growth, two treatments for Ionia and three treatments for Yorkstar significantly reduced yields. The high rate of dicamba (0.56 kg/ha) at fully tillered and dicamba plus 2,4-D amine combination (0.28 + 0.56 kg/ha) at early jointing significantly reduced yields for Ionia and Yorkstar. The dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) at the resumption of spring growth significantly reduced yields for Yorkstar. All other herbicide rates and spring stages did not result in significant yield loss.

Although dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) did not significantly reduce yields at more than one stage of growth for Ionia or Yorkstar, yields from the application of this combination was stage of growth dependent.

For Ionia, no significant yield reduction resulted from the treatment of dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) at any spring

stage. Significantly lower yields did occur from application of dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) at the resumption of spring growth (98 percent) when compared with fully tillered (93 percent) and early jointing (101 percent). The yields in actual weight represented by 98 percent, 93 percent, and 101 percent were 3390 kg/ha, 3861 kg/ha and 3691 kg/ha, respectively.

For Yorkstar the dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) treatment resulted in the highest yield when applied at early jointing and a significantly lower yield occurred at the fully tillered stage.

No significant yield loss for Tecumseh occurred from dicamba (0.28 kg/ha) at the fall preemergence or any spring stage of growth and dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) at early jointing. Dicamba (0.28 kg/ha) applied preemergence resulted in a significantly greater yield than at fully tillered. Significant yield loss to Tecumseh occurred from all other herbicide rates and stages of growth.

Arthur yields were not significantly reduced from the application of dicamba (0.28 kg/ha) at the spring stages of growth. Yields were significantly higher from the application of dicamba (0.28 kg/ha) at early jointing than at resumption of spring growth or fully tillered. No significant yield loss for Arthur occurred from the application of dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) at fully tillered and early jointing. Yields were significantly higher from the application of dicamba plus 2,4-D amine (0.28 + 0.28 kg/ha) at early jointing than at fully tillered. All other herbicide rates and stages of application resulted in significant yield loss.

At one location in 1976 yields were both significantly decreased and increased from herbicide applications, depending on variety and stage of growth. Yields from location 2, 1976 are presented as a percent of no treatment in Table 11 and in kg/ha in Appendix C.

The significant yield increases occurred in Ionia and Yorkstar at the fully tillered and early jointing stages, respectively. The apparent increase in yields is attributed to field variability resulting in low no-treatment yields.

In 1976 significant yield losses occurred at one of the six locations harvested. A reason for a decrease in yield losses in 1976 is that only the more tolerant spring stages of growth were studied. Because of the high yield loss at preemergence and fall tiller in 1975 and the impracticality of effective weed control from fall-applied herbicides in winter wheat in Michigan, these stages were eliminated from the study.

Yield losses from location 2 (Table 11) show that at the resumption of spring growth significant yield loss occurred to Ionia and Yorkstar from dicamba plus 2,4-D ester ($0.28 + 0.56$ kg/ha). This correlates with yield loss in 1975 from the dicamba plus 2,4-D amine combination. The 2,4-D ester has increased activity over the amine formulation. Due to environmental conditions unfavorable for growth after herbicide applications in 1976, the ester of 2,4-D was required for results similar to the amine of 2,4-D in 1975. Significant yield reductions also occurred at the resumption of spring growth from

Table 11. Yield as a percent of no treatment for four winter wheat varieties from herbicide applications made at three stages of growth, Ingham County, Michigan, 1976. Location 2.

Variety	Herbicide	Rate (kg/ha)	Stages of Growth		
			Resumption of Spring Growth	Fully Tillered	Early Jointing
			% Yield	% Yield	% Yield
Ionla	No Treatment		100 ab	100 d	100 a
"	Dicamba	0.28	102 a	134 b	99 a
"	2,4-D Ester	0.84	89 bc	134 b	85 b
"	Dicamba + 2,4-D Amine	0.28 + 0.56	89 bc	151 a	98 a
"	Dicamba + 2,4-D Ester	0.14 + 0.42	86 c	129 bc	89 ab
"	Dicamba + 2,4-D Ester	0.28 + 0.56	87 c	118 c	100 a
Yorkstar	No Treatment		100 a	100 a	100 d
"	Dicamba	0.28	94 ab	95 a	115 ab
"	2,4-D Ester	0.84	83 c	91 a	121 a
"	Dicamba + 2,4-D Amine	0.28 + 0.56	97 ab	91 a	108 b
"	Dicamba + 2,4-D Ester	0.14 + 0.42	94 ab	94 a	102 cd
"	Dicamba + 2,4-D Ester	0.28 + 0.56	89 bc	96 a	113 abc

Tecumseh	No Treatment		100 a	100 a	100 a
"	Dicamba	0.28	109 a	92 ab	99 a
"	2,4-D Ester	0.84	105 a	96 ab	103 a
"	Dicamba + 2,4-D Amine	0.28 + 0.56	110 a	107 a	105 a
"	Dicamba + 2,4-D Ester	0.14 + 0.42	103 a	87 b	105 a
"	Dicamba + 2,4-D Ester	0.28 + 0.56	106 a	101 a	112 a
Arthur	No Treatment		100 a	100 a	100 a
"	Dicamba	0.28	107 a	86 bc	85 b
"	2,4-D Ester	0.84	94 ab	88 bc	71 c
"	Dicamba + 2,4-D Amine	0.28 + 0.56	92 ab	91 ab	73 c
"	Dicamba + 2,4-D Ester	0.14 + 0.42	88 b	90 b	72 c
"	Dicamba + 2,4-D Ester	0.28 + 0.56	91 ab	79 c	76 bc

¹Within a stage of growth for one variety, means followed by different letters are significantly different at the 5 percent level by Duncan's Multiple Range Test.

dicamba plus 2,4-D ester (0.14 + 0.42 kg/ha) for Ionia and from 2,4-D ester (0.84 kg/ha) for Yorkstar.

No yield reduction occurred at the resumption of spring growth for Tecumseh in 1976. Only one treatment, dicamba plus 2,4-D ester (0.14 + 0.42 kg/ha), significantly reduced yield for Arthur at the same stage of growth. This contradicts 1975 data where only dicamba (0.28 kg/ha) did not decrease yields for Tecumseh and Arthur at the resumption of spring growth.

The fully tillered stage received 1.5 cm of rain one hour after herbicide application in 1976. This stage was excluded from the visual injury ratings because of inconsistent data. Significant yield differences do exist at this stage of growth and are discussed.

No significant yield loss occurred to Ionia or Yorkstar at the fully tillered stage. This corresponds with 1975 data. In 1975 significant yield loss occurred only from dicamba (0.56 kg/ha). This rate was not used in 1976.

Significant yield loss occurred to Tecumseh at fully tillered from dicamba plus 2,4-D ester (0.14 + 0.42 kg/ha). This does not correlate with 1975; significant yield losses occurred from all treatments excluding dicamba (0.28 kg/ha).

Arthur yields were significantly reduced from all treatments except dicamba plus 2,4-D amine (0.28 + 0.56 kg/ha) at fully tillered in 1976. In 1975 only the dicamba (0.56 kg/ha) significantly reduced yields. The increased susceptibility of Arthur in 1976 may be due to the use of 2,4-D ester instead of the 2,4-D amine, and may explain yield losses at the fully tillered stage despite the 1.5 cm of rain

received one hour after application. Also, the percent of yield in 1975 for herbicide treatments which did not cause a significant yield reduction is similar to the percent of yield that did result in significant yield reductions for Arthur in 1976, excluding the dicamba plus 2,4-D ester ($0.28 + 0.56$ kg/ha) treatment in 1976.

At early jointing in 1976, significant yield loss occurred to Ionia from one treatment, 2,4-D ester (0.84 kg/ha), and no yield loss occurred to Yorkstar or Tecumseh. This correlates with the 1975 data except for one treatment. In 1975 the dicamba plus 2,4-D amine ($0.28 + 0.56$ kg/ha) significantly reduced yields.

Increased susceptibility for Arthur also occurred at early jointing in 1976. All treatments resulted in significant yield loss in 1976. This correlates with 1975 data except with dicamba (0.28 kg/ha) where no significant yield loss occurred.

The stages of growth to apply herbicides correlate for 1975 and 1976 for the Ionia and Yorkstar varieties. The spring stages resulted in the least yield loss. The order of decreasing yield loss for stages of growth from the dicamba plus 2,4-D amine or ester combinations for both years were resumption of spring growth, fully tillered, and early jointing.

The 1975 and 1976 data do not correlate for Tecumseh. Only one treatment resulted in significant yield loss from herbicide application at a spring stage in 1976. The order of decreasing yield losses from the combination of dicamba and 2,4-D ester or amine remained the same for both years. This order is the same as for Ionia and Yorkstar listed above.

Significant yield losses occurred to Arthur in 1975 and 1976. In 1975 the stages of growth in decreasing order of susceptibility to yield loss from herbicide treatments were resumption of spring growth, fully tillered, and early jointing. In 1976 the above order of stages of growth represented an increase in susceptibility to yield loss from herbicide treatments.

In 1976 no significant yield reductions occurred in five out of six locations. At all locations in 1976 herbicide treatments often increased yields over the no-treatment plots. Weed pressure was not a factor in these fields. During harvest it was visually observable that the herbicide-treated wheat plants had tillered more than the no-treatment plots. Although the treated wheat plants had shortened straw and spikes were twisted, more tillering had occurred. The main culm was stunted in the treated plants and not dominant as in the untreated plants. For this reason treated wheat plots appeared to have a thinner stand than the untreated wheat plots. Thinning of wheat stand was a morphological abnormality recorded for the visual injury ratings.

The unfavorable growing conditions that existed after herbicide applications and the effect of the herbicide treatments on the wheat plants are responsible for the increased yields of the treated wheat.

In 1976, cool weather followed the application of herbicides at the fully tillered stage. This cool weather continued for twenty days after the herbicide applications at early jointing. Warmer temperatures favorable for the wheat growth existed for the twenty-one

to forty days after early jointing application. However, water was limiting for plant growth during this time span. The remainder of the growing season, from the first week in June until harvest, was favorable for wheat growth.

Although herbicidal activity was decreased due to unfavorable environmental conditions, the decrease in growth that did occur due to the herbicidal treatments resulted in a decrease in plant processes when environmental conditions were unfavorable for growth and increased plant processes when environmental conditions were favorable for growth. This reduction in plant processes due to the herbicide treatments was visually observed for wheat treated at resumption of spring growth and fully tillered. Early visual injury was rated between 40 percent and 60 percent. Leaves were chlorotic to 7-10 cm from the base and the plants were prostrate. The net effect was an increase in yield for the herbicide-treated wheat plants over the untreated wheat plants, because the untreated wheat plants suffered environmental stress while the treated wheat plants were suppressed due to the effect of the herbicide. This suppressed state aided in soil moisture conservation that was limiting later in the season when temperatures were favorable for growth but rainfall was limiting.

The herbicide treatments also appeared to increase tillering of the wheat plants. The herbicide-induced tillers developed later than the tillers of the untreated plants. More favorable growing conditions existed for these late-developing tillers.

Yields from location 8 (Table 12) support the environmental herbicide interaction hypothesis stated above.

Table 12. Tecumseh winter wheat yields from herbicide applications made at two stages of growth, Huron County, Michigan, 1976. Location 8.

Herbicide	Rate (kg/ha)	Stage of Growth	
		Fully Tillered ¹ (kg/ha)	Early Jointing (kg/ha)
No Treatment		3920 a-h	3190 abc
Dicamba + 2,4-D Amine	.14 + .42	5158 fgh	3060 ab
" "	.28 + .28	4253 a-h	3959 a-h
" "	.28 + .56	4194 a-h	3584 abcde
" "	.28 + .84	4590 c-h	3553 abcd
Dicamba + 2,4-D Ester	.14 + .42	4114 a-h	5418 h
" "	.28 + .28	4124 a-h	4684 c-h
" "	.28 + .56	4588 c-h	5207 gh
" "	.28 + .84	4080 a-h	5081 efgh

¹Within a stage of growth, means followed by different letters are significantly different at the 5 percent level by Duncan's Multiple Range Test.

LSD at the 5 percent level = 828.

Coefficient of variation = 21.9 percent.

At location 8 the application of the dicamba plus 2,4-D amine and the dicamba plus 2,4-D ester combinations at fully tillered resulted in similar wheat yields for the Tecumseh variety. These wheat yields were higher than the untreated wheat yields. Due to the susceptibility of Tecumseh wheat at this stage of growth, all herbicide treatments increased the wheat yields over the untreated wheat. The treated wheat plants did not experience the environmental stresses that the untreated wheat plants did because of a herbicidal-induced suppressed state.

At early jointing, application of the dicamba plus 2,4-D amine combinations resulted in wheat yields comparable to the untreated wheat. The dicamba plus 2,4-D ester combinations at the same stage resulted in an increase in wheat yields from the untreated wheat.

The Tecumseh wheat was more tolerant to herbicide applications at this stage of growth. The dicamba plus 2,4-D amine combinations did not cause a herbicidal suppressed state at this stage. For this reason the environmental stresses for the treated and untreated wheat were the same. Therefore the yields were similar.

Although the Tecumseh wheat was more tolerant to herbicide applications at early jointing, the dicamba plus 2,4-D ester combinations did result in a herbicidal suppressed state in the wheat. The increased activity of the dicamba plus 2,4-D ester combination compared with the dicamba plus 2,4-D amine combination is attributed to the physical properties of the 2,4-D ester formulation. The 2,4-D ester formulation has a higher spray retention time and increased foliar penetration. Due to this the dicamba plus 2,4-D ester

combination induced a temporary suppressed state in the treated wheat plants. Because of this suppressed state the treated wheat plants did not experience the environmental stresses that the untreated wheat plants did, and therefore yielded higher.

There is no correlation between visual injury and yield. Comparisons of visual rating and yield at location 1 (Tables 3 and 10, respectively) illustrate this point. Visual injury was highest at early jointing. Yields were highest at this stage. Visual injury ratings were lowest at preemergence and yields were also low. Visual injury for Ionia was low at the resumption of spring growth and yields were not significantly reduced. At the same stage, visual injury was high for Tecumseh and yield was significantly reduced.

It is not surprising that visual injury ratings do not correlate with yield losses. The parameters used as a criteria for visual injury ratings do not necessarily have an influence on yields. Parameters that may have no effect on yields are shortening of the wheat stem and twisted spikes. Other parameters such as stand thinning and shortening of spike may result in a decrease in yield. The visual observation of stand thinning may not be accurate. As noted in 1976, wheat stands appeared thinner because the main culm was stunted and not dominant. At harvest the same wheat stands were actually thicker because of an increased number of tillers. A decrease in spike length would appear to decrease yields because of less spikelets per spike. However, the spikelets may be smaller or an increase in grains per spikelet may compensate for what was apparent yield loss.

Grains per spike were measured in 1975 and 1976. No significant differences occurred in 1976 and slight but inconsistent differences occurred in 1975 (Appendix D). Of the differences that did occur in 1975, an increase in grains per spike resulted in the treated wheat. The fact that few differences occurred in 1975, and that of the differences that did occur there was an increase in grains per spike, is of interest. In 1975 the size of the wheat spikes were visually reduced by the dicamba and dicamba plus 2,4-D amine treatments. This reduction in spike size was attributed to less spikelets per spike.

Each wheat spikelet has six or more florets; usually only the two basal florets of each spikelet are fertile. The decrease in the number of spikelets per spike may have resulted in less competition among spikelets present. Because of the improved growing conditions or possibly a growth regulator effect of the dicamba and 2,4-D amine, the number of grains per spikelet was increased in 1975. No correlation between visual injury and grains per spike was observed.

Test weights in kilograms per hectoliter were measured at four locations in 1976. No significant differences in test weights occurred for the Yorkstar, Ionia, and Tecumseh varieties at locations 3, 5, and 8, respectively. Significant differences in test weights did occur at location 2 for the Ionia, Yorkstar, Tecumseh, and Arthur varieties (Appendix E). Test weights were increased or decreased depending on the stage of growth and the variety of wheat. The differences were small and did not account for yield losses. Dicamba plus 2,4-D ester ($0.28 + 0.56$ kg/ha) at early jointing resulted in a

1354 kg/ha yield loss for the Arthur variety. The corresponding decrease in test weight accounted for only 3 percent of this yield loss.

A significant decrease in test weight did correspond with significant visual injury at location 2 in 1976 (Table 4). At the fully tillered stage of growth visual injury of 15 percent for Tecumseh and 20 percent for Arthur correlated with a significant decrease in test weight.

At early jointing a decrease in test weight correlated with the following visual injury: Ionia 5 percent to 20 percent; Yorkstar 25 percent; Tecumseh 20 percent; and Arthur 5 percent to 20 percent.

The factors that determine yield are spikes per hectare, number of grains per spike and test weight of the grain (19). The decrease in winter wheat yields from applications of dicamba and 2,4-D amine and ester formulations have not been accounted for by measurements of grains per spike in 1975 and 1976 or test weight in 1976. A decrease in the number of spikes or tillering per hectare from herbicide applications is attributed for yield losses in 1975. The increase in yields in 1976 attributed to a herbicidal-suppressed state X environmental interaction, and an increase in spikes or tillering per hectare caused by the herbicide applications.

The fact that Tecumseh has Arthur parentage in its pedigree and that the two varieties respond similarly to applications of dicamba and 2,4-D may have genetic implications.

SUMMARY

Dicamba and 2,4-D were applied to four winter wheat varieties in Michigan at two fall stages of growth in 1974 and three spring stages of growth in 1975 and 1976. The 2,4-D amine formulation was used in 1975 and the 2,4-D amine and ester formulations were used in 1976. Visual injury, yield, grains per head and test weight were measured.

The types of visual abnormalities that appeared were a function of the herbicides used and stages of wheat growth at the time of herbicide applications in 1976. The types of visual abnormalities described occurred to all winter wheat varieties studied.

The degree of visual injury that occurred was dependent on the stage of wheat growth, wheat variety, the herbicides used and the rate of herbicide in 1974-75 and 1976. Due to environmental conditions less visual injury occurred in 1976 than in 1975.

Early visual injury was observed for all varieties in 1976 from the application of dicamba, separately or in combination with 2,4-D, at the resumption of spring growth and fully tillered stages. The 2,4-D amine or ester formulations applied separately did not result in early visual injury.

In 1975, yield losses occurred to all varieties from applications of dicamba and dicamba plus 2,4-D amine. The degree of yield

loss was dependent on the stage of wheat growth, wheat variety, and herbicide combination and rate.

There was an inherent yield difference among the untreated wheat varieties in 1975. Yield losses were reported as percent of no treatment for each variety. The degree of yield loss from the herbicide treatments was varietal.

Ionia and Yorkstar were more tolerant to herbicide applications than Tecumseh or Arthur. A wider range of herbicide rates and stages of growth may be used for the Ionia and Yorkstar varieties than for the Tecumseh and Arthur varieties without significant yield loss.

In 1976, no significant differences in wheat yields occurred at five out of six locations. The yields of Ionia, Yorkstar, and Tecumseh were increased from herbicide treatments. The increase in yields were explained by a herbicidal-suppressed state x environmental interaction. Significant yield loss did occur to Arthur at location 2 in 1976.

There was no correlation between percent visual injury and yield in 1975 and 1976.

No significant differences in grains per spike occurred in 1976. Significant increases in grains per spike occurred in 1975. No correlation between visual injury and grains per spike were observed.

Significant differences in test weight were observed at location 2 in 1976. A decrease in test weight accounted for only 3 percent of yield loss for the Arthur variety. A correlation between visual injury and decreases in test weight was observed.

The plant factor responsible for yield loss in 1975 is attributed to a reduction in spikes or tillering per hectare. Yield increases in 1976 are due to an increase in spikes or tillering per hectare caused by a herbicide x environmental interaction.

Tecumseh has Arthur parentage in its pedigree. Both varieties responded similarly to herbicide applications. This may have genetic implications.

The results of this study indicate that significant yield reductions may occur to winter wheat varieties from the applications of dicamba and 2,4-D. Environmental conditions are an important factor in the results obtained from herbicide applications. Conclusions from herbicide applications to winter wheat are better founded on 1975 rather than 1976 yield data because environmental conditions in 1975 more typically represented growing conditions for winter wheat in Michigan.

Dicamba and dicamba plus 2,4-D amine may be safely used for weed control in winter wheat. The flexibility of a spray program is limited by the winter wheat variety planted. A wider range of treatment rates and stages of wheat growth may be used for the Ionia and Yorkstar varieties than for the Tecumseh and Arthur varieties. Visual injury may occur from herbicide treatments to all varieties but is no indication of yield.

Herbicide applications for Ionia and Yorkstar are as follows: dicamba 0.28 kg/ha at resumption of spring growth, fully tillered, and early jointing stages; dicamba 0.56 kg/ha at resumption of spring growth and early jointing; and dicamba plus 2,4-D amine

0.28 + 0.28 kg/ha at early jointing. Treatment of dicamba plus 2,4-D amine 0.28 + 0.28 kg/ha may also be made to Ionia at fully tillered.

Herbicide applications for Tecumseh are dicamba 0.28 kg/ha at preemergence, resumption of spring growth, fully tillered and early jointing stages; and dicamba plus 2,4-D amine 0.28 + 0.28 kg/ha at early jointing.

Herbicide applications for Arthur are dicamba 0.28 kg/ha and dicamba plus 2,4-D amine 0.28 + 0.28 kg/ha at early jointing.

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APPENDICES

APPENDIX A

Table A-1. Yield in kg/ha for four winter wheat varieties from herbicide applications made at five stages of growth, Ionia County, Michigan, 1974-75. Location 1.

Variety	Herbicide	Rate (kg/ha)	Stages of Growth ¹				
			Pre-emergence	Fall Tiller	Resumption of Spring Growth	Fully Tillered	Early Jointing
Ionia	No Treatment		3792 g	3722 f	3390 efg	3861 g	3691 gh
"	Dicamba	0.28	3414 fg	2728 c	3701 g	3791 g	3685 gh
"	Dicamba	0.56	3020 def	2749 c	3594 fg	3122 cde	3444 fgh
"	Dicamba + 2,4-D Amine	0.28 + 0.28	3162 ef	2856 cd	3325 defg	3595 fg	3744 h
"	Dicamba + 2,4-D Amine	0.28 + 0.56					3188 def
Yorkstar	No Treatment		3412 fg	3401 ef	3236 def	3289 ef	3335 efg
"	Dicamba	0.28	3085 def	2205 ab	3174 def	3259 def	3363 efg
"	Dicamba	0.56	2546 bc	2117 ab	3149 de	2608 b	3070 cdef
"	Dicamba + 2,4-D Amine	0.28 + 0.28	2711 cd	2272 b	2431 b	2993 bcde	3312 efg
"	Dicamba + 2,4-D Amine	0.28 + 0.56					2634 abc

APPENDIX B

Table B-1. Yield loss in kg/ha represented by percent yield loss of no treatment in Table 10.

Variety	Average No. Treatment Yield kg/ha	Yield Loss			
		10% kg/ha	15% kg/ha	20% kg/ha	30% kg/ha
Ionla	3691	369	554	738	1107
Yorkstar	3335	334	500	667	1000
Tecumseh	3257	326	489	651	977
Arthur	3096	310	464	619	929

APPENDIX C

Table C-1. Yield in kg/ha for four winter wheat varieties from herbicide applications made at three stages of growth, Ingham County, Michigan, 1976. Location 2.

Variety	Herbicide	Rate (kg/ha)	Stages of Growth		
			Resumption of Spring Growth	Fully Tillered	Early Jointing
Ionia	No Treatment		4979 ab	3479 d	4364 a
"	Dicamba	0.28	5092 a	4697 b	4358 a
"	2,4-D Ester	0.84	4438 bc	4699 b	3715 b
"	Dicamba + 2,4-D Amine	0.28 + 0.56	4452 bc	5304 a	4298 a
"	Dicamba + 2,4-D Ester	0.14 + 0.42	4289 c	4516 bc	3893 ab
"	Dicamba + 2,4-D Ester	0.28 + 0.56	4357 c	4149 c	4366 a
Yorkstar	No Treatment		6147 a	5958 a	4615 d
"	Dicamba	0.28	5780 ab	5706 a	5314 ab
"	2,4-D Ester	0.84	5143 c	5441 a	5603 a
"	Dicamba + 2,4-D Amine	0.28 + 0.56	6010 ab	5469 a	4999 b
"	Dicamba + 2,4-D Ester	0.14 + 0.42	5777 ab	5654 a	4739 cd
"	Dicamba + 2,4-D Ester	0.28 + 0.56	5494 bc	5746 a	5221 abc

Tecumseh	No Treatment	4978 a	4939 a	4330 a
"	Dicamba	5473 a	4585 ab	4318 a
"	2,4-D Ester	5245 a	4758 ab	4499 a
"	Dicamba + 2,4-D Amine	5512 a	5318 a	4589 a
"	Dicamba + 2,4-D Ester	5138 a	4328 b	4558 a
"	Dicamba + 2,4-D Ester	5317 a	5032 a	4857 a
Arthur	No Treatment	5182 a	5532 a	5622 a
"	Dicamba	5591 a	4783 bc	4797 b
"	2,4-D Ester	4867 ab	4892 bc	4018 c
"	Dicamba + 2,4-D Amine	4798 ab	5060 ab	4132 c
"	Dicamba + 2,4-D Ester	4602 b	4990 b	4056 c
"	Dicamba + 2,4-D Ester	4720 ab	4371 c	4268 bc

¹Within a stage of growth for one variety, means followed by different letters are significantly different at the 5 percent level by Duncan's Multiple Range Test.

LSD at the 5 percent level = 338.

Coefficient of Variation = 13.3 percent.

APPENDIX D

Table D-1. Grains per spike for four winter wheat varieties from herbicide applications made at five stages of growth, Ionia County, Michigan, 1974-75. Location 1.

Stages of Growth							
Variety	Herbicide	Rate (kg/ha)	Pre- emergence ¹	Fall Tiller	Resumption of Spring Growth	Fully Tillered	Early Jointing
Ionia	No Treatment		33.7 ab	34.4 a	36.9 ab	37.9 c	35.7 a
"	Dicamba	0.28	32.6 a	34.0 a	36.4 ab	33.3 a	35.1 a
"	Dicamba	0.56	34.5 ab	38.3 b	35.0 a	36.5 bc	36.2 a
"	Dicamba + 2,4-D Amine	0.28 + 0.28	35.9 b	36.8 ab	38.8 b	34.5 ab	35.1 a
"	Dicamba + 2,4-D Amine	0.28 + 0.56					35.9 a
Yorkstar	No Treatment		35.2 b	35.7 a	39.4 a	41.5 b	37.9 a
"	Dicamba	0.28	35.4 b	44.3 b	40.0 a	40.7 ab	38.0 a
"	Dicamba	0.56	29.5 a	38.1 a	38.2 a	40.0 ab	40.6 ab
"	Dicamba + 2,4-D Amine	0.28 + 0.28	37.5 b	36.3 a	38.8 a	38.0 a	38.2 a
"	Dicamba + 2,4-D Amine	0.28 + 0.56					42.1 b
Tecumseh	No Treatment		26.2 a	27.3 a	27.9 a	26.9 a	27.0 a
"	Dicamba	0.28	27.4 a	30.9 b	31.7 b	29.9 b	29.7 a
"	Dicamba	0.56	25.9 a	29.8 ab	32.6 b	29.7 b	28.9 a
"	Dicamba + 2,4-D Amine	0.28 + 0.28	25.9 a	28.1 ab	27.4 a	26.2 a	27.8 a
"	Dicamba + 2,4-D Amine	0.28 + 0.56					26.9 a
Arthur	No Treatment		28.6 a	32.2 a	26.8 a	28.7 a	29.6 a
"	Dicamba	0.28	31.0 ab	35.7 b	33.2 c	28.3 a	27.4 a
"	Dicamba	0.56	32.7 b	32.5 a	29.9 b	30.1 a	28.1 a
"	Dicamba + 2,4-D Amine	0.28 + 0.28	30.7 ab	29.8 a	29.9 b	27.9 a	28.8 a
"	Dicamba + 2,4-D Amine	0.28 + 0.56					33.3 b

¹Within a stage of growth at one variety, means followed by different letters are significantly different at the 5 percent level by Duncan's Multiple Range Test.

APPENDIX E

Table E-1. Test weight (kilograms/hectoliter) for four winter wheat varieties from herbicide applications made at three stages of growth, Ingham County, Michigan, 1976. Location 2.

Variety	Herbicide	Rate (kg/ha)	Stages of Growth		
			Resumption of Spring Growth	Fully Tillered	Early Jointing
			(kg/hl)	(kg/hl)	(kg/hl)
Ionla	No Treatment		72.7 a	73.2 a	74.4 c
"	Dicamba	0.28	74.0 bc	74.7 b	72.7 b
"	2,4-D Ester	0.84	73.5 ab	74.5 b	73.0 b
"	Dicamba + 2,4-D Amine	0.28 + 0.56	74.7 c	74.4 b	72.7 b
"	Dicamba + 2,4-D Ester	0.14 + 0.42	74.3 bc	74.3 b	71.7 a
"	Dicamba + 2,4-D Ester	0.28 + 0.56	73.6 ab	72.7 a	72.6 b
Yorkstar	No Treatment		70.2 b	71.1 b	70.4 bc
"	Dicamba	0.28	71.5 c	70.3 ab	69.5 ab
"	2,4-D Ester	0.84	68.7 a	70.2 ab	70.5 c
"	Dicamba + 2,4-D Amine	0.28 + 0.56	70.2 b	69.5 a	70.3 bc
"	Dicamba + 2,4-D Ester	0.14 + 0.42	70.2 b	69.8 a	69.5 ab
"	Dicamba + 2,4-D Ester	0.28 + 0.56	70.2 b	70.8 b	69.1 a

Tecumseh	No Treatment					
"	Dicamba			77.2 b	77.2 bc	76.9 b
"	2,4-D Ester	0.28		77.1 b	76.5 ab	75.7 a
"	Dicamba + 2,4-D Amine	0.84		76.3 ab	76.2 a	77.0 b
"	Dicamba + 2,4-D Ester	0.28 + 0.56		77.0 b	77.5 c	76.6 ab
"	Dicamba + 2,4-D Ester	0.14 + 0.42		75.8 a	76.1 a	76.1 ab
		0.28 + 0.56		76.0 a	76.0 a	76.6 ab
Arthur	No Treatment					
"	Dicamba	0.28		76.6 b	76.2 b	76.2 c
"	2,4-D Ester	0.84		76.6 b	74.8 a	75.2 b
"	Dicamba + 2,4-D Amine	0.28 + 0.56		75.7 ab	76.5 b	74.8 ab
"	Dicamba + 2,4-D Ester	0.14 + 0.42		75.8 ab	75.8 b	74.9 b
"	Dicamba + 2,4-D Ester	0.28 + 0.56		75.6 a	76.0 b	74.4 ab
				74.9 a	74.9 a	73.9 a

¹Within a stage of growth at one variety, means followed by different letters are significantly different at the 5 percent level by Duncan's Multiple Range Test.



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