ISOXAFLUTOLE (BALANCE) HERBICIDE INJURY TO CORN IN NEBRASKA

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ABSTRACT. Isoxaflutole (proposed common name for RPA 201772 and for Balance\textsuperscript{R}) Herbicide) caused injury to about 15% of the corn treated preplant or preemergence in Nebraska. Isoxaflutole was applied to soils from sandy loams to clay loams with organic matter contents ranging from 0.9 to 4% and pH from 5.6 to 8.1. Injury was associated with application errors, soil type and associations, seed bed preparation, soil compaction, planting depth, rainfall pattern, soil pH, and cation exchange capacity (CEC). Employing better mixing and application techniques and crop management practices would have greatly reduced the isoxaflutole complaints.

Why Nebraska farmers used isoxaflutole. Weed control with isoxaflutole has been excellent in University trials at Clay Center, Lincoln, North Platte, and Scottsbluff since 1995. Although some crop injury occurred at Scottsbluff, lowering the rate reduced the corn bleaching symptoms. Farmers used isoxaflutole in 1999 because it controlled kochia and velvetleaf and was an economical herbicide treatment. Crop response was expected to be nil on most soils; however, that was not the case.

Weed control in 1999. Isoxaflutole-treated fields were noticeably free of weeds in comparison with fields treated with other herbicides. This indicates that rates may have been too high in some fields for the weather conditions this year; thus, causing more crop response. Occasionally, isoxaflutole alone or in combination with other herbicides did not control all weeds, for instance, high densities of kochia, longspine sandbur, and yellow foxtail. This may be the case of too many plants competing for the isoxaflutole, but not enough herbicide to kill them. This has happened with volunteer wheat growing from fallen heads or grain spills during winter wheat harvesting when atrazine was applied after harvest.

Acres and location of crop response. Of 8.5 million corn acres in Nebraska, isoxaflutole was applied to about 850,000 acres in 1999 with the most acres treated in southwest Nebraska (Figure 1). Fifteen percent of the fields exhibited crop response from isoxaflutole. This included sprayer overlaps and field ends where rates were excessive. Crop loss occurred on about 5 to 6% of the acres. Isoxaflutole plus flufenacet (sold as Epic\textsuperscript{TM}) was also used in Nebraska. Figure 1 shows the areas in the state where most of the isoxaflutole injury

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complaints occurred. This includes all injury symptoms. The Panhandle also had corn injury, but not as many acres were treated.

White corn plants in fields treated with isoxaflutole began to appear in fields during the last week in May and the first 10 days of June in western, southwest, west-central, and northeastern Nebraska. Most isoxaflutole injury was in southwestern Nebraska. Soils in this area and in the Panhandle are lower in organic matter and higher in pH than eastern Nebraska. Injury was most noticeable on center pivot fields on hilly ground where the hill tops were eroded exposing the clay subsoils containing low organic matter and high pH. Fields with variable soil types often exhibited extreme differences in isoxaflutole response. Injury varied from none on finer textured soils to slight on medium-textured soils to severe on coarse-textured soils. Largely this was because one rate was used across the entire field. Injury was also visible in other fields, especially on the ends of fields and overlaps. Injury was also found on silt loams with 4% organic matter and high pH. Most corn injured by isoxaflutole recovered quickly. By June 25, most corn recovered in color, but severely injured fields lost plants and/or corn height was variable until corn tasseled. In some fields, tasseling was delayed 1 to 3 weeks. Injury in some fields was severe enough that the corn was replanted.

**Conditions favoring corn injury.** Rainfall was above normal (April 1 - June 13) for much of the area where isoxaflutole was applied. Most of this was received after May 5. Many areas received 4 inches above normal and some received 12 inches in a month after planting. The growing degree days (GDD) were below normal during the rainy period and soil temperatures were cool.

Moles and root feeding insects may also increase damage to corn seedlings. Seedlings that were partially damaged by moles were bleached by isoxaflutole while plants not damaged were green. This same phenomenon could also occur with root feeding insects. When atrazine was first introduced in southwest Nebraska, injury to corn was observed in fields that had low organic matter, high soil pH, and contained rootworms. Growers applied atrazine preemergence, but no insecticide. They waited for corn to grow big enough to cultivate to apply the insecticide in the row and cover the insecticide with soil. The rootworms pruned the roots leaving the remaining roots in the treated soil; resulting in corn plants damaged by atrazine.

In 1999, lots of yellow corn occurred due to iron chlorosis and insufficient nitrogen in fields treated and not treated with a herbicide. Chlorotic corn in fields in the creek and river valleys were especially bad under cold, cloudy, and wet conditions that existed. Usually these fields exhibit these symptoms every year. These symptoms are referred to as “Platte Valley Yellows”. Some hybrids do not tolerate high pH soils.

Some farmers reported different hybrids planted the same day in the same field responded differently to isoxaflutole. Even if isoxaflutole was applied correctly, corn was severely damaged on susceptible hybrids. Seedling vigor may have been a factor increasing injury as weak plants probably took up more isoxaflutole. Herbicides containing the seed safener dichlormid may reduce isoxaflutole injury.
Other herbicides may have injured the corn, but the injury symptoms were not as noticeable as bleached corn. The variability in corn height could also be detected in fields treated with s-metolachlor + atrazine. However, crop response was less noticeable with s-metolachlor + atrazine at 1.9 + 1 lb ai/A than isoxaflutole + s-metolachlor + atrazine at 1.3 oz + 0.6 + 1.2 lb ai/A applied preemergence because of the bleaching.

White corn can also be associated with the genetic make up of the corn. Occasional white corn plants were observed in fields this year and in past years. These white plants are likely genetically related. Hail can cause occasional plants to be a whitish yellow. Larger injured areas are likely caused by herbicides, misapplication, or drift. Glyphosate drift and clomazone carryover can also cause corn plants to be white and yellow.

**Soil types.** Nebraska is divided up into several soil groups that are related to the climate (Figure 2). Prairie grasses instead of forests dominated the natural vegetation across the state. Tall grasses flourished in the higher precipitation of eastern Nebraska (figure 3) and short grasses dominated the vegetation in western Nebraska. The soil groups consist of the udolls, uric ustolls, Typic ustolls, aridic ustolls, and psamments. The udolls are associate with the tall prairie grasses of eastern Nebraska and the aridic ustolls represent soils found in western Nebraska. The psamments are the sandhills soils. These areas are broken down into various soil associations. Some of the common associations for the udolls are: Crete-Hastings-Butler, Hastings-Fillmore, Sharpsburg, Wymore-Pawnee-Burchard, and Hastings-Holder. These are considered the safest soils for use of isoxaflutole. Examples of the uric ustolls are Nora-Crofton-Moody and Nora-Moody-Judson which have less organic matter and higher pH than the udolls. The Typic ustolls, Coly-Uly-Holdrege and Kuma-Keith-Coby, are found in southwest Nebraska. These soils are medium textured and some soil types may have less than 1.5% organic matter and above 7.2 pH. Alliance-Rosebud-Kuma and Keith-Alliance-Rosebud are representative of the aridic ustolls found in southwest Nebraska and the Panhandle. Only low rates of isoxaflutole could be used on these soils because of pH and organic matter limitations. Hersh-Valentine represents psamments soils. Isoxaflutole use is risky on these soils. Intertwined throughout Nebraska are the soils in the river and stream bottoms. Examples of soil associations that were formed from alluvium are Lawett-Gothenburg-Platte, and soil associations formed from alluvium or loess on stream terraces and bottomlands are Tripp-Mitchell-Alice, Hord-McCook-Inavale, Cozad-Hord, and Bridget-Tripp-McCook. These soils are variable in organic matter, pH, and soil texture and injury occurred on these soils in 1999. Gibbon and Wann silt loams may have high pH’s (>7.5) and relatively high organic matter content (2.6 to 4%). Severe corn injury and 33% stand losses have occurred on these soils using isoxaflutole at 1.5 oz/A.

The pattern of crop response from isoxaflutole followed Nebraska soil and long-term precipitation maps). The pattern also follows the growing degree days map (not shown). Crop response on fine-textured soils low in pH (<7.0) and high organic matter content (>2.5%) in much of southeastern and south-central Nebraska was virtually nil compared with soils with coarser-textured and lower organic matter in southwestern Nebraska and north of the Platte River. All of these soils have well defined “A” horizons, but differ in organic matter, pH,
CEC, and percent clay, silt, and sand. Many of these fields that showed crop response had different soil types, organic matter percentage, and pH within the same field. Soils in southeastern and south-central Nebraska have higher organic matter and lower pH because of higher precipitation. If injury occurred on these soils, it was from application errors, planting too shallow, not covering the seed with sufficient soil, or severely eroded slopes.

Fifty-two soil samples were taken by University of Nebraska and Rhone Poulenc personnel from fields that showed differences in crop response to isoxaflutole as influenced by soil type. Four samples were taken in the injured and four in the uninjured areas. The sub-samples were combined and most of the samples were analyzed by Olsen’s Agricultural Laboratory, Inc. in McCook, NE for pH, organic matter, etc. The fields were planted the same day with the same hybrid. This eliminated some of the potential factors that may influence isoxaflutole injury, such as hybrid sensitivity, rate, rainfall, method of planting, etc.

The soil data were pooled into different ranges within each category. Crop response for soil analysis are shown in Figures 4, 5, 6, 7, 8, 9, and 10. High $r^2$ values indicate those soil factors that fit closely with isoxaflutole injury. These ranked from most to least important as follows: CEC, percent organic matter, pH, percent silt, percent clay, and percent sand. It was surprising that percent sand correlation was so low. However, the crop response of isoxaflutole from these soil characteristics is more complicated than one factor. Two or more of these factors also determine the extent of crop response. For example, corn on loamy sand had less crop response to isoxaflutole than corn growing on a sandy loam (Figure 10). Normally, greater crop response is expected to corn growing on loamy sand than the sandy loam. However, in the areas we sampled, seven of nine loamy sand soil samples had pH’s of 5.6 to 6.3 compared with 6.1 to 8.2 for the sandy loam soils. Four of the nine sandy loam samples had pH’s of 7.8 to 8.2.

**Seed bed preparation and planting method.** A relationship of isoxaflutole injury to corn and seedbed preparation existed. The injury complaints could be separated into two groups -- seedbeds prepared by tillage or no-till. Corn in the no-till fields were planted into corn, grain sorghum, soybean, sunflower or winter wheat residues. Fields that were tilled had the most injury. This was probably because they were planted when the surface soil was wet. Most of the no-till fields were planted when soil surfaces were dry and/or isoxaflute was applied preplant. Some no-till fields planted and treated with isoxaflutole after the rains began were injured because of poor soil closure over the row.

Ecofallow corn consistently had less injury than no-till planted in corn, grain sorghum, soybean, or sunflower residues. Ecofallow consists of applying herbicides after winter wheat harvest with herbicides and planting corn with a no-till planter the following spring. The spring of 1999 was dry and farmers planted the ecofallow fields before they planted the tilled ground because they could reach moisture without setting the furrow openers too deep. Herbicides were applied preplant or preemergence. Normally, more injury would have been expected in ecofallow because the soils are wetter and cooler than tilled ground. The wheat residues insulate the soil and reduce water evaporation. The wheat residues probably intercepted some of the isoxaflutole and slowed the release of the herbicide. In 1999, many
of the preplant fields were planted before the rain, thus avoiding poor coverage of soil over the seed row. Apparently, the extra time allowed for degradation and movement of isoxaflutole into the soil by rainfall and/or some soil containing chemical was removed from the row during planting. Only one severe injury report was received in ecofallow corn planted in areas of a field that had sandy loam. Injury was observed in eroded areas and where soil was removed to build terraces. Experienced ecofallow farmers know that corn cannot be planted shallow or the corn will lodge. Symptoms look like corn rootworm damage. Another big factor is that fields that have been in ecofallow for a few years have lower pH because of higher nitrogen use and reduced tillage operations. This would greatly reduce the chances of isoxaflutole injury.

**Soil compaction.** Increased corn injury was observed in small areas on the ends of some fields. This was caused by preplant tillage, by floaters spraying after planting when the soils were wet, or where vehicles parked when loading and unloading fertilizer, herbicides, insecticides, and grain. Sometimes the effects of compaction could be seen where the floater drove through the field. Also, compaction by center pivot sprinkler wheels caused white plants growing in the tracks. However, in some fields the greenest and taller corn was found along the wheel track. Plants were injured more when floater tracks passed over the pivot wheel tracks. Compaction increased corn injury as roots may not have been able to penetrate into deeper soil and therefore remained in soils with a higher concentration of isoxaflutole.

**Planting depth, covering depth, and seed furrow closure.** Surface soil conditions varied at planting time because of rain in 1999. In many fields that had corn injury, corn seeds were covered with less than 1.5 inches of soil. Some was as shallow as 0.5 inches. In one field, plants were dead when seeds were covered with only 0.5 inches of soil. However, planting too deep was also a problem. In one field corn planted deeper than 1.5 inches was damaged more. Plants that came from seeds 1.25 inches deep were yellow, at 2.0 inches they were white and yellow stripped, and seedlings at 2.5 inches were white and almost dead. In another field, the plants from seeds planted at 2.5 inches deep were either not damaged or were injured severely. Measurement of three adjacent plants found one plant 13-inches tall, one 4 inches, and the other was dead. All seeds were covered with 2.5-inches of soil. This may have been due to poor seedling vigor in cold wet soils or presents of a few self-pollinated seeds. Also in one field, it appeared that corn plants that were close together had less injury. Since the field was planted with the same planter, density should be the same in different rows. We couldn’t find any seeds which may have rotted in the injured rows. Why seed distribution was uneven is speculation.

Planters’ furrow openers also may be a contributing factor as in some instances’ one or more rows had more injury than others. Depth of corn seeds varied as much as a half an inch in these rows. In some fields more corn injury was from deeper planting depths. Planting corn into a depression created by the furrow openers could also contribute to increased injury if a heavy rain occurred after planting. It appeared that the ridges next to the row were flattened out and the additional soil containing isoxaflutole was silted over the row by intense rain. On a Platte loam containing 3.7 % organic matter with 7.3 pH, corn injury occurred on one row when a corn stalk prevented the planter unit from lowering, thus reduced planting depth from
2 inches to 1 inch.

**Planting into wet soil.** In a previous no-till sunflower field, corn seedlings were damaged when planted with a slot-planter that left a groove in the soil after planting. The surface soil was wet when the corn was planted 1 day after 0.4 inches of rain occurred over 3 days. It rained 1.3 inches 8 to 12 days later and water may have moved isoxaflutole (applied broadcast) into the depression caused by the slot-shoe opener. In one area of the field the planter was lifted out of the ground, backed up 15 feet and planting continued. Severe injury was observed in six rows and not the other six. The two sets of rows were only 6 inches apart, but corn seeds in six row planted first were covered with 0.5 to 1 inches more soil than the six adjacent rows planted last. Some of the soil from the second planting covered the adjacent rows that were planted first. The corn plants whose seeds were covered with more soil were 6 inches taller than the corn in the row planted last. Isoxaflutole at 1.5 oz/A was applied broadcast one day after planting. Corn planted a week earlier with the same planter in adjacent no-till soybean or ecofallow fields was not injured.

In one field of continuous corn treated with a broadcast application of isoxaflutole following planting, the first two planter rounds were not injured but the remaining rows had various degrees of injury. The first two rounds were planted when surface soil was dry, but a shower delayed planting until the next day. As a result, the corn residues and soil surface were damp and prevented the covering discs from moving sufficient soil to cover the seed row uniformly the next day. Corn was injured where seeds were not covered deep enough. Sporadic injured rows occurred in small areas throughout the field. But corn planted the same day on the pivot corners was not injured because no corn residues were present and seeds were covered uniformly. Another farmer had tandem-disk harrowed an extra time around the edge of a field. Corn was not injured in the extra disked portion, but was damaged by isoxaflutole where not disked an extra time before planting. Apparently the disking dried out the soil sufficiently and destroyed sufficient crop residues which allowed good soil flow for covering the corn seeds. The same farmer had another field that was tandem-disk harrowed the day before planting and had no isoxaflutole injury.

In one field, rain delayed planting with a 12-row planter three days. The corn height was uniform in the area planted before the rain, but was variable in the portion of the field that was planted after the rain. One could find areas where six rows on one side of the planter had more injury than the six rows on the other side for short distances. However, this was not consistent through the field as injury could occur on either side of the planter. Lack of uniform coverage of the seed with soil was obvious. Plants from seeds that were covered with 0.75 inches of soil were 6 inches tall, while healthy ones were knee high where seeds were covered with 1.5 to 1.75 inches of soil. Also, seedlings from seeds covered with more than 2 inches of soil were stunted. These plants probably were covered with isoxaflutole-treated soil from the areas that were covered at the shallow depth. Soil movement by water was obvious in the field.

Deep ripping with chisels between rows in fields that had been in no-till corn in 1998 reduced corn injury caused by isoxaflutole. The ripping occurred in early spring when soil was dry.
Injury was less where the fields had been deep chiseled or a light rain occurred after planting in areas that were not chiseled to seal the soil over the row. Soils were probably drier where ground was chiseled and water infiltration was greater.

**Lasting effects of isoxaflutole injury.** By July 15, the severely injured plants still were shorter, giving the fields an uneven appearance. Crop consultants reported more western bean cutworm eggs were found on plants that were delayed in maturity by isoxaflutole. The threshold levels were high enough that the damaged areas had to be treated with an insecticide. Some injured areas also showed more damage from second and third generation corn borers. These insects prefer to lay their eggs on less mature corn plants. Isoxaflutole injury delayed silking and made the silking plants more attractive to the corn rootworm beetles which clipped off the silks. These ears were not filled out as well as corn that was not injured. One farmer that had a tank agitation problem and banded isoxaflutole reported that yields were 10 to 20 bu/A less that the areas of the field that had no herbicide injury. In some years, an early frost before corn maturity may also reduce corn yields in fields where injury delayed maturity.

**Summary.** The cold wet weather in the spring of 1999 increased corn injury with isoxaflutole, but better crop management practices would have greatly reduced the injury. Corn was planted from about April 10 to mid June. The worst injury was in corn planted between May 5 and May 25 when most of the rain occurred. In addition, the numerous cloudy days during this period may have reduced the corn’s ability to metabolize isoxaflutole. Wet soils introduced another factor. When soils are too wet to prevent good soil flow with the covering discs, planters should be adjusted to meet the soil conditions. The planter should be checked for covering depth of seeds in each field. Injury was greater on soils with high pH, low organic matter, and eroded areas, and especially in fields with variable soil characteristics.

Isoxaflutole should only be applied in combination with other herbicides in marginal soils. Reduction of rates would reduce injury, but then weed control on some weed species, especially grasses, may be poorer in more normal rainfall years. Combinations with other herbicides will be needed to control the entire weed spectrum in many fields. Other contributing factors were surface soil condition at time of planting, seed depth and soil coverage, depression of seed furrow, time and amount of rain and/or irrigation after planting, and possibly corn seedling vigor. Many of these problems can be solved by better management, but environmental factors will still be a factor that affects injury from isoxaflutole. One of the challenges in 2000 will be using the proper rate in fields with variable organic matter, pH, and soil types.

Sharper delineation of soils on the isoxaflutole label may help reduce crop injury, but will not eliminate injury from preemergence applications. A guideline would be to apply isoxaflutole preemergence only on soils that have a pH less than 7.2 and an organic matter content greater than 1.5% in the top 6 inches. Preplant restrictions would be less stringent as these fields had less injury especially in ecofallow. Also, isoxaflutole should not be applied too early on fine-textured soils or poor weed control may occur before the canopy closes. These fields should be in a planned herbicide program where an additional herbicide is applied preemergence or
early postemergence to control weeds that isoxaflutole is weak on.

Some corn hybrids are more susceptible to isoxaflutole than others. This information needs to be obtained from the seed corn companies. Planting tolerant hybrids and combining isoxaflutole with herbicides that contain suitable safeners appear to be promising areas to research. Possibly a safener could be added to isoxaflutole.

Lastly, some fields treated with isoxaflutole had severe late-season weed problems because of corn stand losses from isoxaflutole or corn was severely injured and recover was delayed. Weeds took advantage of the lack of competition from the corn. Sufficient weed seeds were produced in these fields to hinder crop production in 2000. One approach is planting a glyphosate-resistant crop. This would enable the grower to get on top of the weed potential problem. One would have to check the herbicide plant-back intervals for soybean if soybean is a viable option.