I. Literature Review

I-1 Crop Weed Control

Fresh market cucumber (*Cucumis sativus* L.), pumpkin (*Cucurbita maxima* Duch. ex Lam.), and summer squash (*Cucurbita pepo* L.) are economically important crops in Virginia. Based on cash receipts, cucumbers were ranked thirteenth among Virginia's top agricultural commodities in 2000 (Anonymous 2000). Together cucumber, pumpkin, and summer squash are planted on 2,834 hectares in Virginia (Anonymous 1997). Weed management systems for these crops are limited and inefficient. No-tillage, conventional tillage, early cultivation, stale seedbed, mulching, and herbicides are options currently utilized for weed control.

No-till systems, in which the previous crop and weeds are killed by a non-selective herbicide and not plowed under, have been utilized in some cucurbit plantings. In this system, seeds are planted directly into soil and a preemergence (PRE) herbicide program is often used. No-till culture provides the advantages of reduced disease inoculum and minimized fertilizer usage. In Maryland, about 60% of pumpkins are planted no-till (Rouse et al. 2000). However, the use of no-till practices in combinations with a PRE herbicide program does not always provide sufficient weed control, and may affect the opportunity to obtain higher early market prices in summer squash (NeSmith et al. 1994).

Conventional tillage is the predominate cultural system in Virginia with respect to cucurbit production. With this system, seeds are planted directly into well-tilled soil, a PRE herbicide is applied, and the farmer has the option of early season cultivation. Early cultivation can be combined with herbicide applications but can only be utilized within the first few weeks of planting (Locascio and Stall 1982) because the growing season of cucurbits such as summer squash and cucumber is short. These plants grow rapidly and in just a few weeks cultivation may not be possible without crop damage. The interval from seeding to fruiting in these crops may be as little as two months (Robinson 1997). Although pumpkin requires a longer growing season, plants rapidly attain a large size, so cultivation is practical for only a few weeks after planting. Late cultivation may have the potential to damage crop root systems as well as crop vegetation, which can be a significant problem in cucurbits due to their shallow rooting habit (Robinson 1997).

The stale seedbed production technique has been used for cucurbit production in some areas of the United States. This cultural practice involves tilling the soil several weeks prior to seeding the crop to stimulate weed seed germination. Weeds are then killed with a non-selective herbicide and the crop is planted. In previous studies, the stale seedbed technique controlled weeds without the use of potentially injurious herbicides (Johnson and Mullinix 1998). This method of controlling weeds may not be consistently effective due to the varying germination periods of different weeds and the perennial nature of some weed species.

In recent years, the use of black polyethylene as a method of weed control has gained popularity. In this system, the soil is prepared conventionally and formed into raised beds. A drip or trickle irrigation system is often placed on or in the formed bed and then plastic is laid over the bed. Plants are seeded or transplanted into openings in the plastic. The black plastic provides season-long control of most weed species, with the exception of some sedges and weeds that emerge around the hole used for planting. The disadvantages of using black plastic include high cost, irrigation, and removal and disposal of the plastic.

I-2 Herbicides for Cucumber, Pumpkin, Zucchini, and Yellow Summer Squash.

Few herbicides are registered with the United States Environmental Protection Agency (US EPA) for weed control in cucumber, pumpkin, and summer squash. Summer squash has the fewest registered herbicides among the three crops. These herbicides include glyphosate, paraquat, bensulide, clomazone, and ethalfluralin. Sethoxydim is an additional herbicide registered for pumpkin. Naptalam and clethodim, in addition to the registered herbicides available for pumpkin and summer squash, are registered for use in cucumber.

Glyphosate and paraquat are nonselective herbicides registered for use in each of these vine crops. Applications are made before planting and postemergence (POST) between rows. Both of these herbicides lack residual control and have limitations when applied post-directed (POSD) (Anonymous 2002), including the failure to control weeds beneath or closes to the crop canopy. Therefore, additional POST herbicides that are non-toxic to the crop would be beneficial. Bensulide is an herbicide used preplant incorporated (PPI) and PRE in these crops and can be tank-mixed with naptalam. Bensulide primarily controls annual grasses, with suppression of only three broadleaf weeds (Derr and Monaco 1982). Bensulide may persist in the soil for months, which may result in potential injury to other crops (Menges 1974 and Grey 2000). Naptalam suppresses only broadleaf weeds when applied alone, and therefore provides a better spectrum of control when applied in combination with bensulide (Derr and Monaco 1982). However, naptalam and bensulide did not provide effective control of sedge species (Appleby 1978 and Anderson 1970). Both of these herbicides are highly dependent on moisture for activity. Without irrigation or rainfall after herbicide application, bensulide and naptalam are not activated and do not control weeds. To ensure the activity of these herbicides, they are often incorporated into the soil to a depth of 2 to 4 cm.

Clethodim and sethoxydim are both graminicides and, as such, control only grasses POST (Anonymous 2002). In Virginia, farmers often use a combination of clomazone and ethalfluralin for weed management in their cucurbit production. Clomazone applied alone suppresses several annual broadleaf weeds and grasses. Clomazone controls galinsoga species (*Galinsoga* spp.), common lambsquarters (*Chenopodium album* L.), spurred anoda (*Anoda cristata* L.), velvetleaf (*Abutilon theophrasti* Medicus.), and suppresses others including jimsonweed (*Datura stramonium* L.) (Anonymous 2002). Higher clomazone rates control additional weeds, but may injure cucurbits. Clomazone has the potential to injure cucurbit crops and adjacent vegetation as a result of volatilization and drift. Al-Khatib et al. (1995) found that clomazone caused chlorosis in cucumber plants, though recovery was rapid. In other studies, differential cultivar sensitivity to clomazone by pumpkin and summer squash has been documented and resulted in reduction of fruit quality (Barth et. al. 1995). Grey et al. (2000) found that clomazone caused significant bleaching in summer squash, although recovery was rapid and there was no effect on yield.

Like clomazone, ethalfluralin controls many broadleaf and grass weeds and may injure cucumber, pumpkin, and summer squash. Injury to cucurbit crops from ethalfluralin differs from that of clomazone in that stunting of plants and thinning of plant stand may occur. In several studies rainfall or irrigation has increased injury from ethalfluralin on cucurbit crops (Grey 2000, Escobar 1985, Locascio 1982, Precheur 1983, and Derr 1982). These authors also reported that increased seeding depth and incorporation of ethalfluralin may increase crop injury. Carpetweed (*Mollugo verticillata* L.), common lambsquarters, pigweed spp. (*Amaranthus* spp.), common purslane (*Portulaca oleracea* L.), and annual grasses are controlled by ethalfluralin. Locascio (1982) observed that ethalfluralin PRE was less effective than ethalfluralin incorporated. However, crop injury due to incorporated ethalfluralin was high. When clomazone and ethalfluralin were used in combination, annual grass control was excellent and control of broadleaf weeds improved. Al-Khatib (1995) found that applying clomazone and ethalfluralin together controlled redroot pigweed (*Amaranthus retroflexus* L.), hairy nightshade (*Solanum sarrachoides* Sendt.), and ladysthumb smartweed (*Polygonoum persicaria* L.), better than either herbicide alone.

Registration of a pre-package mix[1] herbicide for cucurbits containing 18.2% ethalfluralin and 5.6% clomazone has recently been approved by the US EPA. This herbicide combination, though effective against weeds listed as controlled by clomazone and ethalfluralin, has little to no activity on weed species such as smooth pigweed (*Amaranthus hybridus* L.), morningglory species (*Ipomoea* spp.), and yellow nutsedge (*Cyperus esculentus* L.). Growth of these weeds in cucurbits can interfere with harvesting and reduce the grade of fruit. Liebl and Norman (1991) found that smooth pigweed has

[1] Strategy. United Agri Products, Platte Chemical Co, Greeley, CO 80631.

intermediate sensitivity to clomazone. In previous studies, smooth pigweed was highly competitive and reduced yields in both horticultural and agronomic crops (Lugo et al.1995). Perhaps equally competitive in cucurbits, annual morningglory species have a prolonged vegetative life cycle and vine aggressively, using cucurbits for structural support.

Yellow nutsedge is a perennial weed found in every state of the U.S. and can reproduce sexually by seed and asexually by rhizomes (Gifford 1995). A single yellow nutsedge plant may produce over 400 tubers a year. Competition and allelopathic effects of yellow nutsedge at high densities may reduce cucumber yields as much as 83% (Johnson, III and Mullinix, Jr. 1999). Buker et al. found that yellow nutsedge at a density of twenty-five plants per square meter reduced cucurbit yields. An additional herbicide that would offer suppression of morningglory, smooth pigweed, and yellow nutsedge and have safety in cucurbits would be beneficial.

I-3 Halosulfuron

Halosulfuron is a sulfonylurea herbicide registered for use in field corn, grain sorghum, fallow ground, ornamentals, and turf. Halosulfuron inhibits the acetolactate synthase enzyme responsible for the production of the amino acids valine, leucine, and isoleucine (Hawkes et. al. 1989). Sensitive plant species exhibit symptoms of necrosis and reddening of plant tissue. Injury symptoms are most common in actively growing shoots of susceptible plants and gradually extend to older plant tissue. Older plant structures are less affected initially due to the reservoir of amino acids within the cells.

Tolerant plant species are capable of metabolizing halosulfuron by way of conjugation, hydrolysis, or hydroxylation (Hatzios 1997). Halosulfuron controls and suppresses several broadleaf weeds and sedge species at the rate registered for use in corn, 84 g ai/ha. Common cocklebur (*Xanthium strumarium* L.), common ragweed (*Ambrosia artemisiifolia* L.), redroot pigweed, common lambsquarters, morningglory species, and sedge species (*Cyperus* spp.) are among the weeds controlled by halosulfuron (Anonymous 2002).

The effects of halosulfuron on broadleaf weed control were investigated by Sprague et al. (1997), who found that halosulfuron applied PRE at 84 g/ha in corn (*Zea mays* L.) controlled greater than 90% of broadleaf weeds including velvetleaf, common lambsquarters, common cocklebur, and tall morningglory. In cucumber, halosulfuron controlled 99% of smooth pigweed when applied PRE, and 75% when applied POST (Mitchem and Monks 1997).

In other studies, the control of both purple nutsedge (*Cyperus rotundus* L.) and yellow nutsedge have been evaluated in the field. Webster and Czarnota (1997) found that POST applications of halosulfuron at 70-72 g/ha controlled purple nutsedge. Yellow nutsedge was controlled POST with only 35 g/ha (Ackley et al. 1996). Little research has been conducted with halosulfuron on other sedge species, or on yellow nutsedge at lower rates. However, Belcher et al. (1998) found that halosulfuron controlled greater than 87% of the non-tuberous sedge species annual kyllinga (*Cyperus sesquiflorus* Torr.), green kyllinga (*C. brevifolius* Rottb.), annual flatsedge (*C. compressus* L.), and globe sedge (*C. globulosus* Aubl.).

Many *Amaranthus* species have developed resistance to sulfonylurea herbicides. Poston et al. (2000) found that smooth pigweed biotypes with resistance to imidazolinone were cross-resistant to ALS-inhibiting herbicides. Cross-resistance to halosulfuron has also been found in a plant of the same genus, Palmer amaranth (*Amaranthus palmeri* L.) by Gaeddert et al. (1997). Control of ALS-inhibitor-resistant smooth pigweed populations with halosulfuron has not been reported and the efficacy of halosulfuron for control of these populations may be reduced.

Cucurbits are generally susceptible to injury from most herbicide applications, including registered herbicides. The effects of halosulfuron in these vine crops have been investigated previously. Garvey et al. (1997) found that cucumber tolerated PRE and POST applications of halosulfuron at 36 to 71 g/ha better than summer squash, and that summer squash showed varietal responses and was injured at higher rates and with sequential applications. Cucumber treated with halosulfuron produced yields similar to those by weed-free checks in both studies (Mitchem and Monks 1997).

Objectives

Managing the diversity of broadleaf weeds and sedges in cucumber, summer squash, and pumpkin fields is difficult. Halosulfuron may control some of these weeds without causing injury to thes crops. For these reasons, research was conducted to investigate halosulfuron for control of weeds in vine crops. Specific objectives were to: 1) investigate the effects of lower use rates of halosulfuron on control of smooth pigweed, yellow nutsedge, morningglory species, rice flatsedge (*Cyperus iria* L.) and common ragweed, 2) evaluate response of cucurbit cultivars to halosulfuron, 3) evaluate the effects of PRE and POST applications of halosulfuron on yields of four vine crops, and 4) evaluate halosulfuron for control of several ALS-inhibitor resistant smooth pigweed populations.

II. Materials and Methods.

General field procedures. Research was conducted in 1999, 2000, and 2001 at the Eastern Shore Agricultural Research and Extension Center near Painter, VA. Planting and herbicide application dates are presented in Table 1. The soil type of the study site was a Bojac sandy loam (Typic Hapladult) with less than 1% organic matter and a pH of 6.2. Cucumber, pumpkin, zucchini squash, and yellow summer squash were planted in a seedbed prepared by moldboard plowing and discing twice.

The cultivars used and fertility practices followed were according to Virginia recommendations (Alexander et al., 2001). Cucumber, zucchini squash, and yellow summer squash were planted using a commercial single row planter. The crops were seeded approximately 1.2 to 2.5 cm deep at a rate of 4 seeds per 0.9 m. Plots consisted of a single row, 2.7 m wide and 7.6 m long in the row. Pumpkin was planted by hand into the prepared bed at two seeds per hill, 2.5 cm deep, and approximately 1.2 m apart in the row; rows were 2.7 m apart. In 2001, the cucumber study was replanted due to poor emergence of the first planting.

Preemergence (PRE) treatments were applied after planting and prior to weed or crop emergence. Postermergence (POST) treatments were applied when the crop was at the three to four true leaf stage and weeds were actively growing. In all three years a nonionic surfactant was included in the spray solution at a rate of 0.25 % v/v when POST applications were made[2]. The combination of clomazone at 175 g ai/ha and ethalfluralin at 630 g ai/ha was applied PRE to all plots except the untreated checks. Halosulfuron was applied at 4, 9, 18, and 27 g ai/ha PRE and POST. Each year a weedy-check was

[2] Induce, a noninonic low-foam wetter/spreader adjuvant with 90% principal functioning agents as a blend of alkyl aryl polyoxylkane ether and free fatty acids. Setre Chemical Co., Memphis, TN 38137.

included, and in 2000 and 2001 a weed-free check was added for comparison. Weed-free plots were maintained by hand-weeding once a week. Herbicides were applied with a tractor-mounted sprayer for all field studies. The sprayer delivered 234 L/ha with a pressure of 206 kPa through extended range flat fan spray nozzles[3]. Plots were cultivated one week after POST applications in 1999, but they were not cultivated in the following years except for cucumber in 2001.

Pumpkin study near Mappsburg, VA. An additional study was conducted in 2001 in a grower field near Mappsburg, VA. The field was prepared conventionally and pumpkin (unknown cultivar) was seeded with a single row planter and spaced approximately 1.0 m apart. Plot sizes were 6.1 m long by 1.8 m wide in single rows. Clomazone was applied at 175 g/ha PRE and sethoxydim POST at 190 g/ha for weed control. Rice flatsedge (*Cyperus iria* L.) was present at approximately 350 plants per m^2. Halosulfuron was applied POST at 4, 9, 18, and 27 g/ha with a nonionic surfactant[2] at 0.25 % v/v on June 20, 2001, when pumpkin had three to four true leaves and flatsedge was 3 to 7 cm tall. Halosulfuron was applied with a backpack propane-pressurized sprayer. The sprayer delivered 190 L/ha with a pressure of 220 kPa through flat fan spray nozzles[3].

Established smooth pigweed study. In 2000 and 2001 the control of established smooth pigweed with halosulfuron was investigated in the field. Plots were 2.7 m wide by 7.6 m long. Smooth pigweed had a high population density, approximately 350 to 400 plants per m^2,and was sprayed with halosulfuron POST at 4, 9, 18, and 27 g/ha mixed with a nonionic surfactant at 0.25% v/v[2]. Applications were made using the same tractor mounted sprayer as utilized in the field crop studies. The smooth pigweed was sprayed when plants reached 3 to 13 cm tall in one study and 15 to 40 cm of in the second study.

[3] Teejet8003 flat fan spray tips. Spraying Systems Co., North Avenue, Wheaton, IL 60188.

Environment. Environmental factors varied between the 3 years of investigation. Seasonal rainfall patterns and temperatures were recorded and are shown in Tables 2 and 3. Rainfall accumulation for the period of 10 days after application of halosulfuron for cucumber, pumpkin, zucchini squash, and yellow summer squash in 1999, 2000, and 2001 is presented in Table 4. To ensure uniform stand establishment and growth, rainfall was supplemented with irrigation in seasons when moisture was not adequate prior to planting, and during prolonged dry periods throughout crop growth.

Weed Species and Data Collection. Percent crop injury was rated 10 d after treatment (DAT) for each crop. Percent weed control ratings were made 6 wk after treatment (WAT) for each weed species. The distribution of weed species differed by year, by crop, and in density (Table 5). Morningglory species were present in pumpkin in 2001, and in all four crops during the 1999 growing season. Common ragweed was present in cucumber, zucchini squash, and yellow summer squash in 1999, and then was present in pumpkin in 2000 and 2001. Smooth pigweed was present in all four crops in 2000 and 2001. In the last two years of these studies, yellow nutsedge was present in zucchini squash and yellow summer squash.

Crop fruit was hand-harvested and graded. Zucchini squash and yellow summer squash were harvested approximately every 3 d for approximately 3 wk. Cucumber was harvested two to four times during the growing period. Pumpkin was harvested twice. Because differences in fruit quality were not observed due to herbicide treatment, data presented represent total yields. In 2001, weed control ratings were collected from the initial cucumber site where cucumber stand was not adequate, and yields and crop injury were determined from the replanting. Weed populations were low where cucumber was replanted. Weed control and pumpkin injury were evaluated in the Mappsburg pumpkin study, but the crop was not harvested. In the pigweed timing studies, visual control ratings were made 21 DAT.

Experimental Design and Data Analysis. A randomized complete block design with three replications was used in all field experiments. Data were analyzed statistically by analysis of variance using single degree of freedom contrasts to test for pre-planned specific treatment comparisons at the 0.05 significance level. Means were then separated using Fisher's least significant difference (LSD).

Greenhouse Cultivar Study. Greenhouse studies were conducted to investigate the tolerance of crop cultivars to halosulfuron. Two cucumber cultivars, 'Dasher II' and 'Thunder' were compared. Three cultivars of pumpkin were evaluated and included 'Appalachian', 'Big Max', and 'Howden'. Zucchini squash cultivars selected, were 'Tigress', 'Senator', and 'Seneca'.Yellow summer squash cultivars studied in the greenhouse included 'Monet', 'Cougar', and 'General Patton'.

Crops were direct seeded into a peat-based soil-less media contained in 11.4 cm square pots[4]. The crops were planted at a density of three per pot and thinned to two plants following emergence. Crops were kept in the greenhouse until the first true leaf developed and then moved outside to ensure optimal light conditions. Adequate moisture was provided to the crops as well as weekly fertilization. At the 3 to 4 true-leaf stage, the crops were sprayed with halosulfuron at 0, 4, 9, 18, and 27 g/ha plus a nonionic surfactant at 0.25 % v/v[2]. The plants were sprayed in a greenhouse cabinet sprayer equipped with compressed air and a single 8001EVS moving nozzle[5] delivering 171 L/ha at 289 kPa.

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[4] Pro-Mix BX. Premier Horticulture, Inc., Red Hill, PA 18076.
[5] Teejet8001 flat fan spray tips. Spraying Systems Co., North Avenue, Wheaton, IL 60188.

Crops were visually rated 7 DAT for crop injury. Crops were harvested and dried to constant weight at 65 C for approximately 5 d and weighed for dry weight determination in 2000 and 2001. In 1999, crops were harvested and fresh weights determined. Treatments were arranged in a randomized complete block design and replicated four times. Data were analyzed using a 3 by 5 factorial analysis for all crops exept cucumber, where a 2 by 5 factorial analysis was utilized. The factorials represent the three or two cultivars compared at the five rates of halosulfuron. Main effects and interactions of cultivars with halosulfuron were considered significant at the 0.05 significance level. If interactions were significant, main effect means were not examined, as the effect of halosulfuron rate was dependent on cultivar.

Acetolactate Synthase (ALS) inhibitor resistant smooth pigweed. In 2000, six *A. hybridus* populations were chosen, on the basis of history of exposure to ALS –inhibiting herbicides (Table 6). The five ALS-inhibitor resistant smooth pigweed populations were designated R1, R2, R3, R4 and R5. The susceptible smooth pigweed population was designated S. Seed of ALS-inhibitor resistant smooth pigweed, and seed of the susceptible species were planted into separate 43- by 53-cm greenhouse flats filled with a commercial peat-based soil-less media[4]. These flats were kept on a bench with overhead mist irrigation until pigweed grew to 1 to 2 true-leaves. Seedlings were then transplanted by hand into 11.4 by 11.4 cm pots filled with commercial peat-based media[4]. Four seedlings of equal size were planted into each pot. Plants were kept in the greenhouse under overhead sprinkler irrigation and fertilized weekly.

When plants reached approximately 7 to 9 cm tall, they were sprayed with halosulfuron at 0, 0.27, 2.7, 27, 270 and 2700 g/ha with a nonionic surfactant at 0.25 %

v/v[2]. The same sprayer, application pressure, and volume were used as in the cultivar study. Percent control was rated 21 DAT. Plants were harvested and dried to constant weight at 65 C before determining weight.

Pots were arranged in a randomized complete block design with four replications, and the test was repeated. The data collected from the two tests were pooled because no interaction of treatement by test was present. A nonlinear model was used to analyze the populations and predict the values for dose-response curves, which were used to compare the effects of halosulfuron on populations of smooth pigweed (Schabenberger and Pierre, 2002). Based upon the non-linear model, estimates were used to predict the concentration of halosulfuron required to reduce the shoot growth of smooth pigweed by 50% (GR_{50}). The estimates from the nonlinear model were used to make pairwise comparisons between populations as in Poston et al. (2000). Visual ratings were not used in the determination of the GR_{50} or in the pairwise comparisons, but rather percent dry weight.

Yellow nutsedge. In 1999 and 2000, greenhouse studies were conducted to evaluate halosulfuron control of yellow nutsedge grown from tubers. Four tubers of yellow nutsedge were planted in 11.4 by 11.4 cm pots filled with commercial peat-based media[4]. When the yellow nutsedge was 10 cm high, plants were sprayed with halosulfuron at 4, 9, 18, and 27 g/ha and a non-ionic surfactant[2] at 0.25 % v/v with the greenhouse cabinet sprayer. Yellow nutsedge was visually rated for percent control 21 DAT. Plants were harvested and placed in a dryer at 65 C to constant weight for dry weight determination. Plants were arranged in a randomized complete block design with four replications. Data were analyzed using analysis of variance and means were compared at the 0.05 significance level using Fisher's LSD.

III. Results and Discussion

Cucumber field response. Visual estimates of percent cucumber injury from PRE and POST halosulfuron applications varied among years but did not exceed 13 % in any year (Table 7). Injury appeared as stunting and foliar chlorosis. Cucumber treated POST with halosulfuron developed injury symptoms within 7 d following herbicide application. Cucumber recovery from symptoms of halosulfuron was rapid in all years and was complete within 2 wk following development of symptoms. According to the method of contrast analysis, injury from PRE and POST applications of halosulfuron was similar in all three years. Also, injury from the PRE application of clomazone plus ethalfluralin did not exceed 6 % in any year and recovery was complete within 7 d.

Cucumber yields are presented as the sum of all grades for the first harvest and the total of all harvests (Table 8). Yields differed among years. This is likely a result of rainfall differences (Table 2). In 2000, rainfall during the growing season was approximately 15 cm higher than in 1999 and 2001, and cucumber yields were higher in 2000 than in 1999 and 2001 (Table 8). Cucumber treated with halosulfuron produced initial yields comparable to or higher than those produced by cucumber treated only with clomazone plus ethalfluralin, the weeded or untreated check. Initial injury was not reflected in cucumber yield. In all three years, total yields from cucumber treated with halosulfuron were similar to or higher than those from clomazone plus ethalfluralin treatments and the untreated checks.

Cucumber greenhouse response. Two cultivars of cucumber were grown in the greenhouse and treated with halosulfuron POST in the summers of 1999, 2000, and 2001

(Table 9). Injury symptoms of chlorosis and plant stunting developed on treated cucumber 2 to 3 DAT and persisted less than 2 wk.

Injury to cucumber from halosulfuron in 1999 was averaged over the two cultivars because the cultivars responded similarly. In 1999, injury to cucumber increased with the rate of halosulfuron applied. In 2000 and 2001, the two cultivars responded differently to halosulfuron treatments with respect to injury. In 2000, ‘Thunder’ was injured more from higher applications of halosulfuron than was ‘Dasher II’. Where ‘Thunder’ was injured 8 and 15 % by halosulfuron at 18 and 27 g/ha, respectively, POST, ‘Dasher II’ was injured only 3 and 0 %, respectively. In 2001, cucumber cultivars responded similarly to halosulfuron applied POST.

In 1999 and 2000, no interaction of cultivar and halosulfuron treatment on weight was found, and fresh weights in 1999 and dry weights in 2000 were averaged over the two cultivars. Halosulfuron did not affect fresh weight in 1999 or dry weight in 2000. In 2001, dry weight differences from halosulfuron on the two cultivars were likely due to variability in data. Halosulfuron applied at 27 g/ha resulted in a higher weight in ‘Thunder’ than in ‘Dasher II’.

Pumpkin field response. Halosulfuron injury symptoms in pumpkin were similar to those of cucumber. Visual injury included stunting of plant growth, marginal leaf cupping, and chlorosis of treated foliage. Halosulfuron injury was higher in pumpkin than in cucumber in the three years of evaluation (Table 10). Halosulfuron injury does not appear to be closely correlated with precipitation. In 2001, 6.9 cm of rainfall occurred within 10 days after PRE applications (Table 4), which is more than in the previous two years. However, injury in 2001 was the least of the three years, so injury may not have been enhanced by moisture. Injury symptoms developed 2 d after herbicide application in POST treated pumpkin. Injury was as high as 43 % on pumpkin treated with halosulfuron PRE at 27 g/ha. Pumpkin recovery from herbicide injury was rapid, with symptoms usually disappearing 2 to 3 wk after development. Clomazone plus ethalfluralin alone did not injure pumpkin in all three years.

According to contrast analysis, PRE applications in 1999 resulted in higher injury to pumpkin than POST. When applied PRE at 18 g/ha, halosulfuron injured pumpkin 26 % compared to POST applications at the same rate resulting in 13 % injury. In 2000 and 2001, pumpkin injury from halosulfuron did not differ by application method when analyzed by contrasts. There was a linear effect of halosulfuron rate on pumpkin injury for both methods of herbicide application, where injury increased with herbicide rate in all three years.

Pumpkin yields (Table 11) are the sum of all harvests and grades. Yields in the 1999 growing season were almost double that of the following two years. In 2000, a high infestation of powdery mildew occurred and applications of fungicide did not effectively suppress the disease. As a result, pumpkins were harvested only once. The lower yields of 2001 may partially be attributed to the lower precipitation during that growing season (Table 2).

Yields from pumpkin treated with halosulfuron differed among treatments in 1999, 2000, or 2001. In 1999, halosulfuron applied POST at 27 g/ha was the only treatment in the study that produced higher yields than the untreated check. All pumpkin treated with halosulfuron in 2000 produced yields similar to the hand-weeded check.

Halosulfuron applied postemergence at 9 g/ha was the only treatement to differ from the hand-weeded check in 2001.

Pumpkin off-station response. Pumpkin in the two tests conducted near Mappsburg, VA in 2001 had injury symptoms of chlorosis and plant stunting from halosulfuron (Table 12). Pumpkin injury did not exceed 15 %. All halosulfuron rates resulted in similar pumpkin injury in the first test. Halosulfuron applied at 27 g/ha injured pumpkin more than when applied at 4 g/ha in the second test, but did not exceed 14 %.

Pumpkin greenhouse response. Three cultivars of pumpkin were evaluated, and included 'Appalachian', 'Howden', and 'Big Max'. Pumpkin injury and weight from halosulfuron applied POST in the greenhouse for the years 1999, 2000, and 2001 are contained in Table 13. Injury symptoms of treated pumpkin included chlorosis of treated leaves and general plant stunting, which generally persisted for 2 WAT.

In 1999, halosulfuron injury did not differ among the three cultivars and therefore injury was averaged over the three cultivars. With an increase in halosulfuron rate, injury increased in the three cultivars in 1999. In 2000 and 2001, the three cultivars of pumpkin differed in their response to halosulfuron with respect to injury. 'Howden', in 2000, was injured more by halosulfuron applications at rates of 18 and 27 g/ha than was 'Appalachian' or 'Big Max'. In 2001, 'Big Max' was injured more by halosulfuron at rates of 18 and 27 g/ha than the other two cultivars. There is no apparent explanation for these differences.

Because there was no interaction between halosulfuron and cultivar with respect to weight, the weight of pumpkin was averaged over the three cultivars in all three years. In 1999 and 2000, there were a few inconsistent differences in the weight of pumpkin from halosulfuron applications. In both years however, halosulfuron applied at the highest rate, 27 g/ha, resulted in similar weights to those of the untreated check.

Zucchini field response. Zucchini squash was injured each year by PRE and POST halosulfuron although the magnitude varied with year and application method (Table 14) Injury symptoms included overall stunting of plant growth and chlorosis.

Development of injury symptoms was evident within 3 to 4 d following emergence from PRE halosulfuron applications or 3 to 4 d following POST applications. Zucchini squash recovery from halosulfuron occurred within 2 to 3 WAT with all treatments.

Injury to zucchini squash was 12 to 17% and 24 to 47% from PRE and POST applications of halosulfuron respectively in 1999 (Table 14). According to contrast analysis, injury from POST halosulfuron in 1999 was higher than from PRE applications and POST injury was linear with halosulfuron rate.

In 2000, zucchini squash injury to halosulfuron at 4 to 27 g/ha was 6 to 24%, respectively, from PRE applications, 6 to 20%, respectively, from POST applications, and did not differ between application method according to contrast analysis. The effect of halosulfuron rate on zucchini squash injury was a quadratic response for PRE and POST applications according to contrast analysis.

In 2001, rainfall following PRE applications was 6.9 cm and likely caused injury from PRE treatments including ethalfluralin plus clomazone. According to contrast analysis, injury from PRE halosulfuron treatments was higher than from POST halosulfuron treatments. The effect of halosulfuron treatment on zucchini squash injury was a quadratic response again in 2001.

Yields of zucchini squash are presented as the initial harvest and the total from multiple harvests (Table 15). Initial harvest in 1999 was reduced by PRE halosulfuron at 18 g/ha and from all POST applications compared with ethalfluralin plus clomazone. In 2000 and 2001, most halosulfuron treatments did not reduce first harvest compared with ethalfluralin plus clomazone, although 27 g/ha halosulfuron PRE and all POST halosulfuron applications reduced initial harvest compared to the hand weeded check in 2000.

Total yields in 1999 and 2000 were not affected by treatment. As a result it is concluded that where initial yields were reduced, this amounted only to delays in crop development rather than overall reductions in total crop yield. In 2001, total yields from all halosulfuron treated zucchini squash were higher than from squash treated with ethalfluralin plus clomazone except zucchini squash treated with halosulfuron POST at 27 g/ha. Yields were below those from the weeded check, however. The effect of halosulfuron on total yield in 2000 may relate to the high rainfall following applications and subsequent injury. Zucchini squash may not have recovered from halosulfuron or clomazone plus ethalfluralin injury in 2001.

According to contrast analysis, initial and total yields of halosulfuron treated squash were not affected by application timing.

Zucchini greenhouse response. The cultivars of zucchini squash evaluated in the greenhouse were ‘Tigress’, ‘Senator’, and ‘Seneca’. Zucchini squash injury developed 2 to 3 DAT and included necrotic lesions on leaf edges, plant stunting, and chlorosis which persisted for less than 2 wk. Injury and weights from halosulfuron treated zucchini squash in the greenhouse in 1999, 2000, and 2001 are presented in Table 16.

In 1999 and 2000, the three cultivars of zucchini squash responded differently to halosulfuron with respect to injury. In 1999, ‘Senator’ was injured more by halosulfuron at all rates applied than either ‘Tigress’or ‘Seneca’. At 27 g/ha halosulfuron injured ‘Senator’ 28 % compared to 17 and 16 % injury of ‘Tigress’ and ‘Seneca’ respectively. In 2000, ‘Senator’ and ‘Seneca’ were both injured more by halosulfuron applied at 18 and 27 g/ha, than was ‘Tigress’. All three cultivars of zucchini squash responded similarly to halosulfuron applications in the greenhouse in 2001, therefore, injury was averaged over the three cultivars. With an increase in rate of halosulfuron applied, injury increased in the three cultivars.

No interaction between cultivar and halosulfuron with respect to weight existed. Therefore, weights were averaged over the three cultivars in all three years. In 1999 and 2000, halosulfuron applied at 4 g/ha resulted in a higher zucchini squash weight than when it was applied at 18 and 27 g/ha. In 2001, halosulfuron applied at 27 g/ha resulted in zucchini squash with lower weights than the untreated check.

Yellow summer squash field response. Yellow summer squash sustained the highest levels of injury from halosulfuron among the four crops (Table 17). Symptoms of halosulfuron injury were consistent with those of the other crops including stunting and chlorosis of treated leaves. Injury symptoms were slow to develop in PRE treatments, usually developing within a week after emergence, POST injury was visible within 3 days of application. Yellow summer squash recovered rapidly from injury in most years, except for 2001, where visible stunting persisted for 4 wk. Highest injury from halosulfuron was in 2001, when approximately 6.9 cm of rain followed PRE applications

In 1999, injury of yellow squash was greater than or equal to 10 % for all halosulfuron treatments. Halosulfuron applied PRE at 27 g/ha resulted in 25 % injury, which was higher than all other PRE treatments. Halosufuron applied POST injured yellow summer squash from16 % at 4 g/ha to 35 % at 27 g/ha. POST applications of halosulfuron in 1999 caused higher injury than PRE according to contrast analysis. Injury increased linearly with halosulfuron rate for both application methods in 1999.

In 2000, halosulfuron applied PRE at 27 g/ha resulted in more injury than any other treatment with 27 %. Halosulfuron applied at 4 and 9 g/ha PRE and POST resulted in the same amount of injury to yellow summer squash as the squash in the clomazone plus ethalfluralin treatment and the checks. PRE halosulfuron applications injured yellow summer squash more than POST according to contrast analysis. A linear effect of rate on yellow summer squash injury for both application methods was present.

Some of the injury of yellow summer squash in 2001 may be attributed to moisture. High moisture conditions could have induced the squash to take up more herbicide, and thus increase crop injury. Halosulfuron applied PRE at 27 and 18 g/ha resulted in 52 and 38 % injury respectively. These applications were more injurious than all other treatments. Halosulfuron at 4 g/ha injured yellow summer squash similar to the clomazone plus ethalfluralin treatment and the checks. PRE applications of halosulfuron resulted in higher yellow summer squash injury than POST according to contrasts. The rate of halosulfuron increased yellow summer squash injury linearly for both methods of application.

Yellow summer squash yields are presented as the initial harvest and sum of all harvests in Table 18. Yields from the 1999 growing season are higher than in the following years. The significantly lower yields of 2001 may be attributed to moisture and a high weed pressure of eastern black nightshade (*Solanum ptycanthum* Dun.). In 2001, the study site experienced a weed population shift to eastern black nightshade with approximately 150 plants per m^2. Neither clomazone plus ethalfluralin, nor halosulfuron controlled this weed species. In 1999, halosulfuron applied POST at 27 g/ha yielded lower in the first harvest than some of the other treatments. This may be attributed to the high injury sustained earlier. In 2000, halosulfuron applied at 27 g/ha PRE had lower first harvest yields than the rest of the treatments and may reflect squash injury. In 2001, yellow summer squash treated with herbicides had lower first harvest yields than those in the weeded check.

Total yields of yellow summer squash treated with halosulfuron in 1999 did not differ. All herbicide treated yellow summer squash produced yields higher than squash in the untreated check. Lower yields of the first harvest were compensated for by sequential harvests later in the season. In 2000, halosulfuron treated squash produced total yields equal to or higher than squash treated with clomazone plus ethalfluralin, hand-weeded squash, or untreated squash.

The effect of the eastern black nightshade on yellow squash yields may be reflected in total yields in 2001. The weeded check had significantly higher yields than any other treatment. The weeded squash had twice the yields of the halosulfuron treated squash, and four times that of the clomazone plus ethalfluralin check. Squash in the untreated check produced only 526 Kg/ha. Some reduction of yield could also be attributed to herbicide injury that persisted into the season. All halosulfuron treated squash produced similar yields.

Yellow summer squash greenhouse response. ‘Monet’, ‘Cougar’, and ‘General Patton’ were the three cultivars of yellow summer squash in the greenhouse study. Percent injury and fresh or dry weights of yellow summer squash treated POST with halosulfuron in the greenhouse is presented in Table 19. Symptoms of yellow summer squash injury were consistent with that of zucchini squash in the greenhouse. Crop injury developed within 2 to 3 days, and persisted for 2 wk.

In 1999 and 2000, yellow summer squash cultivars responded differently to halosulfuron applications with respect to injury. ‘General Patton’ and ‘Monet’ were both injured more than ‘Cougar’ in 1999, when halosulfuron was applied at 18 and 27 g/ha. In 2000, ‘General Patton’ was injured more than ‘Monet’, at 20 and 9 % respectively, when treated with halosulfuron at 27 g/ha. The three cultivars responded similarly to halosulfuron applications in 2001, and injury was averaged over the three cultivars.

The three cultivars of yellow summer squash did not differ in weight due to halosulfuron application and therefore weights were averaged over the three cultivars for all three years. In 1999, halosulfuron applied at 27 g/ha resulted in lower fresh weights of yellow summer squash than when applied at 4 and 9 g/ha. In 2000, halosulfuron applied at 27 g/ha resulted in a lower dry weight than when applied at 18 g/ha only. Halosulfuron did not reduce cultivar dry weights at any application rate in 2001.

Morningglory response. Control of morningglory in cucurbits with halosulfuron never exceeded 83 % (Table 20). Rainfall after PRE applications was correlated with increased control of morningglory. PRE applications of halosulfuron in 1999 controlled morningglory only 43 % after 1.3 cm of precipitation; in 2001 that control was increased to 67 % after 6.9 cm of precipitation (Table 4).

Control of morningglory from PRE applications was relatively low across all four crops and in both years. The best control from PRE applications was in 2001 after a significant amount of rainfall was received following application. In cucumber and yellow squash in 1999 and pumpkin in 2001, the highest rate of halosulfuron PRE controlled morningglory better than the clomazone plus ethalfluralin check.

In all crops and both years, POST halosulfuron applications controlled morningglory better than the clomazone plus ethalfluralin check. POST halosulfuron control of morningglory was higher than PRE according to contrast analysis. The greatest control of morningglory POST occurred in zucchini squash in 1999 with halosulfuron at 18 g/ha with 83%.

Common ragweed response. Control of common ragweed in cucumber, pumpkin, zucchini squash and yellow summer squash in 1999, 2000, and 2001 is presented in Table 21. Halosulfuron POST controlled common ragweed equal to or greater than 90 % in all crops and years, except pumpkin in 2001.

Control of common ragweed from PRE applications of clomazone plus ethalfluralin never exceeded 45 %. In cucumber and yellow summer squash in 1999, and pumpkin in 2000, halosulfuron applications provided higher common ragweed control than the clomazone plus ethalfluralin check. PRE control by halosulfuron was highest in 2000 in pumpkin, resulting in 98 % control of common ragweed when applied at 27 g/ha. The efficacy of halosulfuron PRE treatments on common ragweed control may not correlate with precipitation in these studies. This is evident when comparing the control of common ragweed in 2000 and 2001, where the control was greater in 2000 receiving only 3.9 cm of rainfall as apposed to 2001 receiving 6.8 cm.

POST halosulfuron applications were similar in amount of common ragweed control for all crops and in all years. POST applications of halosulfuron in 1999 provided significantly better control of common ragweed than PRE according to contrast analysis. Control of common ragweed was not affected by application method in 2000. In 2001, the control of common ragweed was variable, but was higher from POST applications according to contrast analysis. In 2001, all halosulfuron treatements except 18 g/ha PRE provided higher common ragweed control than the clomazone plus ethalfluralin check.

Smooth pigweed response. In 2000 and 2001, smooth pigweed populations were present at high densities in all crops. Control of smooth pigweed in 2000 and 2001 in all four cucurbit crops is presented in Tables 22-23. In 2000, PRE and POST halsosulfuron controlled smooth pigweed season long (Table 22). Halosulfuron provided higher control of smooth pigweed than the clomozone plus ethalfluralin check independent of application method in 2000. Control of smooth pigweed in 2000 was highest from PRE halosulfuron applications across all four crops. POST applications of halosulfuron at 4 to 27 g/ha controlled smooth pigweed 82 to 98 % in the four crops evaluated. These high levels of control during the 2000 growing season greatly facilitated fruit havest.

Smooth pigweed control in 2001 was less than that of the previous year, but PRE halosulfuron treatments at 27 g/ha controlled smooth pigweed equal to or greater than 97 % in each crop (Table 23). The cucumber crop of 2001 was infested with a pathogen and did not compete with weeds. Thus, the control of smooth pigweed in 2001 from halosulfuron was reduced in cucumber. POST applications of halosulfuron provided better control of smooth pigweed than the clomazone plus ethalfluralin check for all crops except pumpkin.

Control of smooth pigweed at later growth stages with POST halosulfuron was lower than from early applications (Table 24). Smooth pigweed varying in height from 3 to13 cm, was sprayed with halosulfuron POST in 2000. Smooth pigweed control from halosulfuron in this study was 47 to 83 % at 4 to 27 g/ha, respectively. These levels of control are lower than the control of smooth pigweed in the field studies (Tables 22-23). Application to smooth pigweed 15 to 40 cm in height in 2001 resulted in only 58 % control from 27 g/ha halosulfuron. Taken together, these studies reflect the decrease in smooth pigweed control from delayed applications of halosulfuron.

Smooth pigweed greenhouse response. Smooth pigweed grown in the greenhouse and treated with halosulfuron in 2000 was affected within 24 hours after application. Smooth pigweed displayed symptoms of chlorosis, epinasty, and overall stunting. Lower application rates of halosulfuron, which at first induced some visible injury to smooth pigweed, were not effective. Visual control ratings of the five sulfonylurea-resistant and one sulfonylurea-susceptible smooth pigweed population are presented in Table 25.

Halosulfuron applied at 27 g/ha, which was effective in controlling smooth pigweed in the field, controlled the sulfonylurea-susceptible population at a rating of only 67 %. The effectiveness of control may have been compromised in the greenhouse due to optimal growing conditions and lack of competition. At 270 g/ha halosulfuron controlled the R2 population only 59 %, while all other populations were controlled 78% or greater. Even at the highest rate of halosulfuron, the R2 population was controlled only 94 %. Other populations such as R1 and R5, did not reach optimal control even at the highest herbicide application. When a nonlinear model was used to calculate the concentration of halosulfuron required to reduce the shoot growth of each smooth pigweed population by

50 % (GR_{50}), the R2 population stood out from the rest (Table 26). Approximately 8 g/ha halosulfuron was required to reduce the shoot dry weight 50 % in the S population compared to more than 17 g/ha in all R populations. R2 and R4 populations were statistically different from the S population, requiring 97 and 27 g/ha halosulfuron to reduce shoot dry weight 50 %.

Pairwise comparisons of nonlinear estimates of smooth pigweed populations are presented in Table 27. These comparisons show if there is a significant difference in the response of two populations to halosulfuron. There was a significant interaction between the S and R2 populations as well as the S and R4. The interaction between the S and R4 population is not as defined. Visual control of the R4 population did not differ greatly from that of the S (Table 25). Dry weight analysis and percent dry weight of the control plants reveal the S and R4 interaction. Other interactions are found between R1 and R2 as well as R2 and R3 populations.

Regression curves of percent dry weight and halosulfuron rate are presented in Figures 1-6. The regression for each population shows that the nonlinear model used to predict estimates was accurate for the test and that there were significant differences among the populations. The regression curve for the S population (Figure 1) decreases rapidly with herbicide rate and has a higher slope than the R curves. In comparison, the regression of R2 population is significantly different, never reaching 20 % (Figure 3). The R4 population has a similar curve to that of the S, yet the level at which 50 % of shoot dry weight is reduced is at a higher rate of halosulfuron (Figure 5).

Yellow nutsedge field response. Yellow nutsedge was evaluated for control in zucchini and yellow squash in 2000, and in yellow squash in 2001 (Table 28). Control of yellow nutsedge was 70 % or less for all PRE treatments in both years and crops. The clomazone plus ethalfluralin check did not control yellow nutsedge, and was similar to the untreated checks. POST halosulfuron applications controlled yellow nutsedge equal to or greater than 94 % in all three studies. Control of yellow nutsedge increased linearly by rate of halosulfuron for both methods of application when analyzed by contrasts.

Yellow nutsedge greenhouse response. In 1999 and 2000, halosulfuron applied POST controlled yellow nutsedge greater than 73 % irrespective of rate (Table 29). Yellow nutsedge dry weights were reduced by halosulfuron at 4 g/ha. Biomass was not further reduced by higher halosulfuron rates.

Rice flatsedge response. In 2001, the off-station pumpkin study was populated with a high density of rice flatsedge, approximately 350 plants per m^2. The study, comprised of two tests, was treated with halosulfuron POST and evaluated for control (Table 30). Halosulfuron provided greater than 93 % control in both tests when applied at 27 g/ha. The lowest rate of halosulfuron at 4 g/ha controlled rice flatsedge at least 68 % .

Conclusion

Halosulfuron is one of few POST herbicides with selectivity for use in cucurbit crops. Control of many weed species was increased with the addition of halosulfuron to an existing PRE program. Tolerance of cucurbits to halosulfuron was relatively high, though a few of the crops may require further investigation. Interactions of cucurbit cultivars and halosulfuron application were minimal.

Cucumber tolerance to halosulfuron, as observed in these studies, and in agreement with the results of Mitchem and Monks (1997), may be considered high. Applications of halosulfuron in cucumber increased yields and caused only minimal injury in studies conducted by Mitchem and Monks (1997) and Garvey et al. (1997). The tolerance of pumpkin to halosulfuron is also high. The prolonged growing season of pumpkin allows for sufficient recovery time from herbicide damage. Pumpkin yields were generally higher with halosulfuron applications than with clomazone and ethalfluralin alone. Zucchini squash has a lower tolerance to halosulfuron than either cucumber or pumpkin. Zucchini plants were injured by PRE applications of halosulfuron, especially following rainfall. Addition of halosulfuron generally did not increase the yields of zucchini over that of clomazone and ethalfluralin applied alone. Yellow squash has the least amount of tolerance to halosulfuron of the four crops. Moist conditions enhanced halosulfuron injury in yellow squash and in some years caused delayed fruiting. Though yields from halosulfuron treated squash were higher than the clomazone plus ethalfluralin check in some years, herbicide damage to the crop was significant.

Cultivar studies conducted in the greenhouse showed there was some variation in response of cultivars to halosulfuron. These differences existed mainly with the visual injury assessment. Weights taken from halosulfuron treated plants showed there were no significant interactions among cultivars and halosulfuron rates. Therefore any injury sustained initially by the crop, dissipated within the three weeks after herbicide application.

The application of halosulfuron PRE and POST resulted in different weed responses. When applied POST and in combination with clomazone and ethalfluralin, halosulfuron controlled morningglory species, common ragweed, smooth pigweed, yellow nutsedge, and rice flatsedge. The control of yellow nutsedge POST was achieved at much lower halosulfuron rates than those reported by Ackley et al. (1996). Rice flatsedge control with halosulfuron was consistent with the findings of Belcher et al. (1998), who found halosulfuron provided control of several non-tuberous sedges. Application of halosulfuron PRE in combination with clomazone and ethalfluralin controlled common ragweed and smooth pigweed only.

When applying halosulfuron to control smooth pigweed, the history of herbicidal use for a particular site is necessary. ALS-tolerant smooth pigweed populations such as those studied herein may have cross-resistance from other herbicides or an increased tolerance to the herbicide. This may be exemplified with the R2 and R4 populations studied in the greenhouse, which showed a degree of resistance to halosulfuron. These two populations are consistent with populations discussed by Poston et al. (2000) and Gaeddert et al. (1997), with respect to pigweed resistance and cross-resistance.

It is important to consider the need for crop rotation with respect to cucurbits. Without crop rotation, the potential for soil born pathogen outbreak is increased. The possibility of a weed species shift is also increased when crop rotation is not practiced.

Both of these problems were encountered during the progress of this research, due to a lack of crop rotation.

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Table 1. Planting dates of cucumber, pumpkin, zucchini and yellow squash and herbicide application dates in 1999, 2000, and 2001.

Crop	Cultivar	Year	Planting date	Application date	Application date
				——— PRE ———	—— POST ——
Cucumber	Dasher II	1999	June 25	June 25	July 15
		2000	June 12	June 12	June 30
		2001	June 13	June 13	July 9
		2001	July 13	July 13	August 2
Pumpkin	Appalachian	1999	June 25	June 25	July 15
		2000	June 12	June 12	June 30
		2001	June 13	June 13	July 9
Zucchini squash	Tigress	1999	June 25	June 25	July 15
		2000	June 2	June 2	June 20
		2001	May 25	May 25	June 13
Yellow squash	Monet	1999	June 25	June 25	July 15
		2000	June 2	June 2	June 20
		2001	May 25	May 25	June 13

Table 2. Monthly precipitation from April through August near Painter, VA, in 1999, 2000, and 2001.

Month	1999	2000	2001	61-yr avg
	cm			
April	7	10	6	8
May	3	11	10	9
June	10	9	13	9
July	7	21	24	11
August	12	17	5	11
Totals	65	80	64	56

Table 3. Average maximum and minimum monthly temperatures for April through August near Painter, VA, for 1999, 2000, and 2001.

Month	1999		2000		2001	
	Max.	Min.	Max.	Min.	Max.	Min.
	Celsius					
April	21	7	18	8	20	8
May	23	13	26	14	24	13
June	27	18	29	19	28	19
July	32	22	28	19	28	18
August	30	20	28	19	29	21

Table 4. Rainfall accumulation for the period of 10 days after application of halosulfuron for cucumber, pumpkin, zucchini and yellow squash in 1999, 2000, and 2001.

Crop	Cultivar	Year	Application date	Rainfall	Application date	Rainfall
			PRE	cm	POST	cm
Cucumber	Dasher II	1999	June 25	1.3	July 15	3.3
		2000	June 12	3.9	June 30	1.3
		2001	June 13	6.8	July 9	0.7
		2001	July 13	0.3	August 2	0.9
Pumpkin	Appalachian	1999	June 25	1.3	July 15	3.3
		2000	June 12	3.9	June 30	1.3
		2001	June 13	6.8	July 9	0.7
Zucchini squash	Tigress	1999	June 25	1.3	July 15	3.3
		2000	June 2	1.3	June 20	3.8
		2001	May 25	6.9	June 13	6.8
Yellow squash	Monet	1999	June 25	1.3	July 15	3.3
		2000	June 2	1.3	June 20	3.8
		2001	May 25	6.9	June 13	6.8

Table 5. Weed species density and height at herbicide application.

Weed	Weed Density	Height at Application
	—Plants per m^2—	—cm—
Morningglory species	20 to 25	11 to 18
Common Ragweed	10 to 12	5 to 8
Smooth Pigweed	350 to 400	8 to 10
Yellow Nutsedge	5 to 10	5 to 15
Rice Flatsedge	350 to 375	10 to 20

Table 6. Designation and origin of six smooth pigweed populations selected on the basis of history of exposure to ALS –inhibiting herbicides.

Designation	Location	Population Name	Herbicide Resistance
S	Painter, VA	Painter	None
R1	Pocomoke City, MD	J. Ring	Imazethapyr
R2	Ridgley, MD	Ridgley	Imazethapyr
R3	Pocomoke City, MD	Brittingham	Imazethapyr
R4	Marion, MD	Marion	Imazethapyr, Imazaquin, Rimsulfuron, Chlorimuron
R5	Oak Hall, VA	Oak Hall	CGA 362622

Table 7. Injury to cucumber from halosulfuron applied preemergence and postemergence in 1999, 2000, and 2001.[a]

Halosulfuron rate	Application method	Injury 1999	Injury 2000	Injury 2001
g ai/ha		%		
0	NONE	4 a[d]	6 cd	0 c
4	PRE	8 a	8 abcd	2 bc
9	PRE	13 a	7 bcd	3 bc
18	PRE	12 a	11 ab	5 b
27	PRE	9 a	10 abc	10 a
4	POST[b]	11 a	5 d	3 bc
9	POST	4 a	6 bcd	4 b
18	POST	6 a	8 abcd	5 b
27	POST	10 a	12 a	4 b
0	Weeded	-[c]	0 e	0 c
0	Untreated	0 b	0 e	0 c
LSD		10	5	4

[a]All treatments except the checks included clomazone at 175 g ai ha^{-1} and ethalfluralin at 630 g ai ha^{-1} applied PRE.
[b]All POST treatments contained 0.25% v/v non-ionic surfactant.
[c]1999 study did not include a hand-weeded check.
[d]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 8. Yield from cucumber treated with halosulfuron preemergence and postemergence in 1999, 2000, and 2001.[a]

Halosulfuron rate	Application method	Yield 1999 Harvest 1	1999 Total	2000 Harvest 1	2000 Total	2001 Harvest 1	2001 Total
g ai/ha		Kg/ha					
0	NONE	3467 b[d]	9263 c	3192 a	28713 f	8085 a	16470 ab
4	PRE	7051 ab	15396 ab	3475 a	41832 abc	8697 a	14686 ab
9	PRE	5153 ab	11247 abc	3977 a	38479 bcd	8541 a	17538 ab
18	PRE	5686 ab	14714 abc	4392 a	44118 ab	9452 a	18384 a
27	PRE	5239 ab	15467 ab	4330 a	46377 a	7721 a	20285 a
4	POST[b]	8251 a	16957 a	4737 a	33020 def	6770 a	14257 ab
9	POST	4314 ab	10706 cb	2565 a	30565 ef	7317 a	12864 b
18	POST	6753 ab	13436 abc	3733 a	35648 cde	8528 a	16262 ab
27	POST	8392 a	17138 a	3137 a	42385 abc	6588 a	14400 ab
0	Weeded	-[c]	-	4204 a	34338 def	6809 a	13137 ab
0	Untreated	4055 ab	8792 c	0[e]	188[e]	1068 b	3073 c
LSD		4466	6111	2763	7014	4444	6096

[a]All treatments except the checks included clomazone at 175 g ai ha^{-1} and ethalfluralin at 630 g ai ha^{-1} applied PRE.
[b]All POST treatments contained 0.25% v/v non-ionic surfactant.
[c]1999 study did not include a hand-weeded check.
[d]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.
[e]Means were not included in statistical analysis because the low yields interfered with means separation.

Table 9. Injury (%) and dry or fresh weight (g) of cucumber treated with halosulfuron postemergence in the greenhouse in 1999, 2000, and 2001.[a]

		Injury			Weight		
	Halosulfuron	Cultivar		Mean[c]	Cultivar		Mean
Year	rate	Dasher II	Thunder		Dasher II	Thunder	
	g ai/ha			LSD = 3			LSD = 3.3
1999 [b]	0	0	0	0 d[d]	27.3	22.8	25.0 a
	4	1	2	2 d	28.2	28.3	28.2 a
	9	13	8	10 c	26.2	24.9	25.5 a
	18	17	11	14 b	30.7	26.0	28.3 a
	27	19	17	18 a	29.8	23.0	26.4 a
							LSD = 0.6
2000	0	0 c	0 c		4.9	4.7	4.8 a
	4	1 c	2 c		4.4	5.3	4.9 a
	9	1 c	2 c		5.0	5.3	5.1 a
	18	3 c	8 b		4.6	5.2	4.9 a
	27	0 c	15 a		4.0	5.3	4.7 a
		LSD = 5					
2001	0	0 d	0 d		2.9 b	3.6 ab	
	4	3 bcd	3 bcd		3.3 b	3.6 ab	
	9	1 cd	6 ab		3.5 ab	3.4 b	
	18	8 a	6 ab		2.9 b	3.3 b	
	27	8 a	5 abc		3.1 b	4.3 a	
		LSD = 4			LSD 0.8		

[a] All treatments contained 0.25% v/v non-ionic surfactant.
[b] Fresh weights were taken in 1999.
[c] Main effects and interactions considered statistically significant when $p < 0.05$.
[d] Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 10. Injury to pumpkin from halosulfuron applied preemergence and postemergence in 1999, 2000, and 2001.[a]

Halosulfuron rate	Application method	Injury 1999	Injury 2000	Injury 2001
——— g ai/ha ———		——— % ———		
0	NONE	0 e[d]	0 e	0 e
4	PRE	9 de	7 de	2 de
9	PRE	14 cd	8 d	6 cd
18	PRE	26 b	23 bc	10 bc
27	PRE	43 a	31 a	16 a
4	POST[b]	5 de	10 d	1 de
9	POST	13 cd	18 c	6 cd
18	POST	13 cd	25 abc	10 bc
27	POST	20 bc	27 ab	14 ab
0	Weeded	-[c]	0 e	0 e
0	Untreated	0 e	0 e	0 e
LSD		10	7	5

[a]All treatments except the checks included clomazone at 175 g ai ha^{-1} and ethalfluralin at 630 g ai ha^{-1} applied PRE.
[b]All POST treatments contained 0.25% v/v non-ionic surfactant.
[c]1999 study did not include a hand-weeded check.
[d]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 11. Yield from pumpkin treated with halosulfuron preemergence and postemergence in 1999, 2000, and 2001.[a]

Halosulfuron rate	Application method	Yield 1999 Total	Yield 2000 Total	Yield 2001 Total
g ai/ha		Kg/ha		
0	NONE	40016 ab[d]	18345 c	20197 ab
4	PRE	37987 ab	20228 bc	19898 ab
9	PRE	43726 ab	26644 abc	17334 abc
18	PRE	45729 ab	26024 abc	12855 abc
27	PRE	43433 ab	35609 a	23295 a
4	POST[b]	46413 ab	34079 a	20471 ab
9	POST	44934 ab	28769 abc	10502 bc
18	POST	42755 ab	27459 abc	19271 ab
27	POST	52199 a	25687 abc	15694 abc
0	Weeded	-[c]	31742 ab	25240 a
0	Untreated	31466 b	3239 d	5922 c
LSD		17995	12135	12670

[a]All treatments except the checks included clomazone at 175 g ai ha^{-1} and ethalfluralin at 630 g ai ha^{-1} applied PRE.
[b]All POST treatments contained 0.25% v/v non-ionic surfactant.
[c]1999 study did not include a hand-weeded check.
[d]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 12. Injury to pumpkin from halosulfuron applied postemergence in two tests near Mappsburg, VA in 2001.[a]

Halosulfuron rate	Injury	
	Test 1	Test 2
––––– g ai/ha –––––	––––––––––––––– % –––––––––––––––	
0	0 b[b]	0 c
4	12 a	10 b
9	14 a	13 ab
18	15 a	13 ab
27	15 a	14 a
LSD	4	4

[a]All POST treatments contained 0.25% v/v non-ionic surfactant.
[b]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 13. Injury (%) and fresh or dry weight (g) from pumpkin treated with halosulfuron postemergence in the greenhouse in 1999, 2000, and 2001.[a]

		Injury				Weight			
	Halosulfuron	Cultivar			Mean[c]	Cultivar			Mean
Year	rate	Appalachian	Howden	Big Max		Appalachian	Howden	Big Max	
	g ai/ha				LSD = 3				LSD = 3.2
1999 [b]	0	0	0	0	0 d[d]	28.1	34.1	32.4	31.5 abc
	4	6	6	2	5 c	28.9	35.5	37.0	33.8 a
	9	10	5	8	8 b	26.4	32.2	26.6	28.4 c
	18	21	13	16	16 a	26.6	30.1	31.7	29.5 bc
	27	22	17	18	18 a	26.4	33.8	34.1	31.6 ab
									LSD = 0.6
2000	0	0 e	0 e	0 e		6.8	6.9	7.0	6.9 ab
	4	3 cde	9 b	5 bcde		7.5	6.5	7.3	7.1 a
	9	2 de	8 bc	3 cde		6.5	7.7	7.6	7.3 a
	18	8 bc	23 a	7 bcd		7.2	6.8	6.5	6.8 ab
	27	9 b	25 a	9 b		5.7	6.4	6.8	6.3 b
			LSD = 6						
									LSD = 0.5
2001	0	0 d	0 d	0 d		5.8	5.8	6.1	5.9 a
	4	5 cd	5 cd	7 c		6.3	5.8	6.0	6.0 a
	9	5 cd	8 bc	8 bc		6.4	5.1	5.6	5.7 a
	18	6 c	6 c	12 ab		6.0	5.4	6.4	5.9 a
	27	6 c	9 bc	17 a		6.3	5.7	5.5	5.8 a
			LSD = 5						

[a] All treatments contained 0.25% v/v non-ionic surfactant.

[b] Fresh weights were taken in 1999.

[c] Main effects and interactions considered statistically significant when $p < 0.05$.

[d] Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 14. Injury to zucchini squash from halosulfuron applied preemergence and postemergence in 1999, 2000, and 2001.[a]

Halosulfuron rate	Application method	Injury 1999	Injury 2000	Injury 2001
—— g ai/ha ——		—— % ——		
0	NONE	0 e[d]	2 fg	11 ef
4	PRE	12 d	6 efg	10 ef
9	PRE	15 cd	10 cde	20 bcd
18	PRE	17 cd	15 bc	23 abc
27	PRE	17 cd	24 a	27 a
4	POST[b]	25 bc	6 ef	6 f
9	POST	31 b	9 de	15 de
18	POST	46 a	13 cd	18 cd
27	POST	47 a	20 ab	25 ab
0	Weeded	-[c]	0 g	0 g
0	Untreated	0 e	0 g	0 g
LSD		11	6	5

[a]All treatments except the checks included clomazone at 175 g ai ha^{-1} and ethalfluralin at 630 g ai ha^{-1} applied PRE.
[b]All POST treatments contained 0.25% v/v non-ionic surfactant.
[c]1999 study did not include a hand-weeded check.
[d]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 15. Yield from zucchini squash treated with halosulfuron preemergence and postemergence in 1999, 2000, and 2001.[a]

Halosulfuron rate	Application method	Yield 1999 Harvest 1	1999 Total	2000 Harvest 1	2000 Total	2001 Harvest 1	2001 Total
g ai/ha		Kg/ha					
0	NONE	5785 a[d]	20020 a	878 ab	17138 a	619 b	4494 c
4	PRE	4617 ab	20932 a	949 ab	20228 a	1364 ab	9937 b
9	PRE	4098 abc	19647 a	784 abc	18934 a	972 ab	10369 b
18	PRE	3161 bcd	17133 a	792 abc	18291 a	1411 ab	9553 b
27	PRE	4402 ab	18157 a	400 cd	19247 a	1129 ab	10683 b
4	POST[b]	2764 bcd	17236 a	447 cd	18800 a	1819 ab	12047 b
9	POST	3563 bcd	18456 a	565 bcd	16126 a	1741 ab	11396 b
18	POST	2353 cd	19216 a	580 bc	15632 a	1388 ab	9608 b
27	POST	2205 cd	16657 a	604 bc	14871 a	1152 ab	7961 bc
0	Weeded	-	-	1090 a	17946 a	1858 a	17977 a
0	Untreated	1794 d	8990 b	157 e	5333 b	7[e]	533[e]
LSD		1999	4944	411	5359	1218	4302

[a]All treatments except the checks included clomazone at 175 g ai ha^{-1} and ethalfluralin at 630 g ai ha^{-1} applied PRE.
[b]All POST treatments contained 0.25% v/v non-ionic surfactant.
[c]1999 study did not include a hand-weeded check.
[d]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.
[e]Means were not included in statistical analysis because the low yields interfered with means separation.

Table 16. Injury (%) and fresh or dry weight (g) of zucchini squash treated with halosulfuron postemergence in the greenhouse in 1999, 2000, and 2001.[a]

		Injury				Weight			
	Halosulfuron		Cultivar		Mean[c]		Cultivar		Mean
Year	rate	Tigress	Senator	Seneca		Tigress	Senator	Seneca	
	g ai/ha								LSD = 3.6
1999[b]	0	0 i[d]	0 i	0 i		32.7	31.0	34.0	32.5 ab
	4	2 hi	13 cdef	4 ghi		38.8	30.8	34.5	34.7 a
	9	8 efgh	17 bc	10 defg		33.6	28.6	30.9	31.0 b
	18	14 cde	23 ab	10 defg		32.0	27.6	31.1	30.2 b
	27	17 bc	28 a	16 cd		32.4	29.8	30.9	31.0 b
			LSD = 6						
									LSD = 0.7
2000	0	0 d	0 d	0 d		5.7	7.4	5.9	6.3 c
	4	0 d	0 d	4 cd		8.0	7.6	6.8	7.5 a
	9	4 cd	3 cd	7 bcd		6.8	7.7	6.7	7.1 ab
	18	4 cd	15 ab	11 abc		6.4	7.3	5.8	6.5 bc
	27	7 bcd	19 a	19 a		6.5	7.0	5.6	6.4 c
			LSD = 8						
					LSD = 3				LSD = 0.8
2001	0	0	0	0	0 d	5.5	7.0	6.3	6.3 a
	4	11	11	8	10 c	5.3	6.5	5.4	5.7 ab
	9	9	13	9	10 bc	5.8	5.8	6.0	5.9 ab
	18	12	17	11	13 ab	5.7	5.6	5.3	5.5 ab
	27	17	14	16	15 a	5.1	5.9	5.1	5.4 b

[a] All treatments contained 0.25% v/v non-ionic surfactant.
[b] Fresh weights were taken in 1999.
[c] Main effects and interactions considered statistically significant when $p< 0.05$.
[d] Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 17. Injury to yellow summer squash from halosulfuron applied preemergence and postemergence in 1999, 2000, and 2001.[a]

Halosulfuron rate	Application method	Injury 1999	Injury 2000	Injury 2001
——— g ai/ha ———		——— % ———		
0	NONE	0 e[d]	4 ef	5 ef
4	PRE	10 de	6 efd	13 de
9	PRE	10 de	11 bcd	27 c
18	PRE	12 d	16 b	38 b
27	PRE	25 abc	27 a	52 a
4	POST[b]	16 cd	4 ef	7 def
9	POST	21 bcd	9 cde	13 de
18	POST	28 ab	8 cde	15 d
27	POST	35 a	12 bc	24 c
0	Weeded	-[c]	0 e	0 f
0	Untreated	0 a	0 e	0 f
LSD		11	6	8

[a]All treatments except the checks included clomazone at 175 g ai ha^{-1} and ethalfluralin at 630 g ai ha^{-1} applied PRE.
[b]All POST treatments contained 0.25% v/v non-ionic surfactant.
[c]1999 study did not include a hand-weeded check.
[d]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 18. Yield from yellow summer squash treated with halosulfuron preemergence and postemergence in 1999, 2000, and 2001.[a]

Halosulfuron rate	Application method	Yield 1999 Harvest 1	Yield 1999 Total	Yield 2000 Harvest 1	Yield 2000 Total	Yield 2001 Harvest 1	Yield 2001 Total
g ai/ha		Kg/ha					
0	NONE	2441 abcd[d]	19853 a	1216 ab	14126 bcd	196 b	2847 cd
4	PRE	2931 abc	25648 a	510 cde	15271 abcd	321 b	6290 b
9	PRE	3142 abc	26966 a	635 cd	17687 a	313 b	6000 b
18	PRE	3294 abc	25050 a	431 de	11969 d	164 b	4965 bc
27	PRE	2524 abcd	27045 a	227 e	12463 cd	102 b	3835 bc
4	POST[b]	3539 ab	23442 a	620 cd	15624 abc	274 b	4675 bc
9	POST	3902 a	27255 a	510 cde	14416 abcd	321 b	5875 b
18	POST	2343 bcd	25814 a	847 bc	16502 ab	415 b	5577 b
27	POST	1279 d	21829 a	431 de	16502 ab	407 b	4910 bc
0	Weeded	-[c]	-	1271 a	14510 abcd	1207 a	11906 a
0	Untreated	1862 cd	10941 b	243 e	3255 e	0 b	526 d
LSD		1948	8808	371	3487	449	2541

[a]All treatments except the checks included clomazone at 175 g ai ha^{-1} and ethalfluralin at 630 g ai ha^{-1} applied PRE.
[b]All POST treatments contained 0.25% v/v non-ionic surfactant.
[c]1999 study did not include a hand-weeded check.
[d]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 19. Injury (%) and fresh or dry weight (g) of yellow summer squash treated with halosulfuron postemergence in the greenhouse in 1999, 2000, and 2001.[a]

		Injury				Weight			
	Halosulfuron	Cultivar			Mean[c]	Cultivar			Mean
Year	rate	Monet	Cougar	General Patton		Monet	Cougar	General Patton	
	g ai/ha								LSD = 4.0
1999[b]	0	0 h[d]	0 h	0 h		37.6	30.1	38.4	35.4 ab
	4	5 gh	2 h	13 cdef		35.6	36.7	36.9	36.4 a
	9	11 cdefg	5 gh	11 cdefg		35.8	31.7	41.0	36.2 a
	18	21 bc	6 fgh	16 bcd		31.0	29.3	41.6	33.9 ab
	27	23 ab	15 cde	30 a		30.8	31.6	32.8	31.7 b
			LSD = 7						
									LSD = 0.5
2000	0	0 f	0 f	0 f		5.0	6.4	5.5	5.6 ab
	4	0 f	3 def	1 f		6.1	6.2	5.3	5.9 ab
	9	6 cdef	3 def	10 bcd		5.7	6.4	4.8	5.7 ab
	18	7 cdef	11 bc	11 bc		5.7	6.8	5.6	6.0 a
	27	9 bcde	15 ab	20 a		5.8	5.8	4.6	5.4 b
			LSD = 7						
					LSD = 3				LSD = 0.7
2001	0	0	0	0	0 c	5.3	5.9	3.7	5.0 a
	4	6	7	10	8 b	5.7	5.0	3.5	4.7 a
	9	8	8	11	9 b	5.9	5.3	4.0	5.1 a
	18	13	14	18	13 a	4.9	5.2	3.9	4.6 a
	27	11	15	13	15 a	5.5	4.9	3.7	4.7 a

[a] All treatments contained 0.25% v/v non-ionic surfactant.
[b] Fresh weights were taken in 1999.
[c] Main effects and interactions considered statistically significant when $p < 0.05$.
[d] Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 20. Control of morningglory species in cucumber, pumpkin, zucchini and yellow summer squash with halosulfuron preemergence and postemergence.[a]

		Morningglory control				
Halosulfuron rate	Application method	Cucumber 1999	Pumpkin 1999	Zucchini squash 1999	Yellow squash 1999	Pumpkin 2001
——— g ai/ha ———		——— % ———				
0	NONE	24 cd[d]	18 cd	28 b	2 d	26 b
4	PRE	31 bcd	18 cd	38 b	44 c	43 ab
9	PRE	35 bcd	23 bcd	40 b	48 bc	43 ab
18	PRE	52 abc	25 bcd	22 bc	47 c	50 ab
27	PRE	59 ab	43 abc	33 b	53 bc	67 a
4	POST[b]	74 a	51 abc	73 a	67 ab	63 a
9	POST	77 a	52 ab	71 a	74 a	51 ab
18	POST	77 a	54 ab	83 a	74 a	58 a
27	POST	76 a	62 a	81 a	75 a	58 a
0	Weeded	-[c]	-	-	-	0 c
0	Untreated	0 d	0 e	0 c	0 d	0 c
LSD		35	33	26	19	26

[a]All treatments except the checks included clomazone at 175 g ai ha^{-1} and ethalfluralin at 630 g ai ha^{-1} applied PRE.
[b]All POST treatments contained 0.25% v/v non-ionic surfactant.
[c]1999 study did not include a hand-weeded check.
[d]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 21. Control of common ragweed in cucumber, pumpkin, zucchini and yellow summer squash with halosulfuron preemergence and postemergence.[a]

Halosulfuron rate	Application method	Common ragweed control Cucumber 1999	Zucchini squash 1999	Yellow squash 1999	Pumpkin 2000	Pumpkin 2001
g ai/ha		%				
0	NONE	15 e[d]	45 c	24 c	40 d	32 e
4	PRE	55 d	71 abc	68 b	88 c	57 cd
9	PRE	68 d	76 abc	74 ab	90 bc	60 bcd
18	PRE	73 bc	79 ab	67 b	97 ab	48 de
27	PRE	84 abc	55 bc	81 ab	98 ab	78 abc
4	POST[b]	87 ab	90 a	94 ab	96 ab	73 abc
9	POST	89 a	94 a	95 a	97 ab	81 ab
18	POST	90 a	94 a	96 a	98 a	88 a
27	POST	90 a	95 a	96 a	96 ab	73 abc
0	Weeded	-[c]	-	-	0 e	0 f
0	Untreated	0 e	0 d	0 c	0 e	0 f
LSD		16	33	27	7	25

[a]All treatments except the checks included clomazone at 175 g ai ha^{-1} and ethalfluralin at 630 g ai ha^{-1} applied PRE.
[b]All POST treatments contained 0.25% v/v non-ionic surfactant.
[c]1999 study did not include a hand-weeded check.
[d]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 22. Control of smooth pigweed in cucumber, pumpkin, zucchini and yellow summer squash with halosulfuron preemergence and postemergence in 2000.[a]

Halosulfuron rate	Application method	Smooth pigweed control			
		Cucumber	Pumpkin	Zucchini squash	Yellow squash
——— g ai/ha ———		———	——— %	———	———
0	NONE	76 c[c]	89 d	60 d	52 e
4	PRE	95 a	98 b	89 c	95 abc
9	PRE	98 a	99 ab	95 b	98 abc
18	PRE	99 a	99 a	99 a	99 ab
27	PRE	99 a	99 a	99 a	99 a
4	POST[b]	82 bc	95 c	90 c	87 d
9	POST	84 b	98 ab	91 c	95 ab
18	POST	95 a	98 ab	95 b	94 c
27	POST	97 a	98 ab	95 b	97 abc
0	Weeded	0 d	0 e	0 e	0 f
0	Untreated	0 d	0 e	0 e	0 f
LSD		8	1	3	4

[a]All treatments except the checks included clomazone at 175 g ai ha^{-1} and ethalfluralin at 630 g ai ha^{-1} applied PRE.
[b]All POST treatments contained 0.25% v/v non-ionic surfactant.
[c]Means followed by the same letter do not differ at the 0.05 significance level by Fisher’s protected least significant difference within a column.

Table 23. Control of smooth pigweed in cucumber, pumpkin, zucchini and yellow summer squash with halosulfuron preemergence and postemergence in 2001.[a]

Halosulfuron rate	Application method	Smooth pigweed control			
		Cucumber	Pumpkin	Zucchini squash	Yellow squash
g ai/ha		%			
0	NONE	42 e[c]	60 b	30 e	37 e
4	PRE	60 d	75 ab	94 ab	89 b
9	PRE	68 cd	81 ab	96 ab	93 ab
18	PRE	65 cd	83 a	97 ab	96 a
27	PRE	91 a	91 a	98 a	97 a
4	POST[b]	72 bcd	74 ab	77 d	73 d
9	POST	67 cd	80 ab	83 c	80 c
18	POST	82 abc	90 a	94 ab	89 b
27	POST	88 ab	81 ab	93 b	93 ab
0	Weeded	0 f	0 c	0 f	0 f
0	Untreated	0 f	0 c	0 f	0 f
LSD		18	22	4	5

[a]All treatments except the checks included clomazone at 175 g ai ha^{-1} and ethalfluralin at 630 g ai ha^{-1} applied PRE.

[b]All POST treatments contained 0.25% v/v non-ionic surfactant.

[c]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 24. Control of established smooth pigweed in 2000 and 2001 with halosulfuron applied postemergence.[a]

Halosulfuron rate	2000 3-13 cm	2001 15-40 cm
g ai/ ha	%	
0	0 c[b]	0 c
4	47 b	39 b
9	56 b	44 b
18	73 a	56 a
27	83 a	58 a
LSD	11	10

[a]All POST treatments contained 0.25% v/v non-ionic surfactant.

[b]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 25. Visual control ratings of five sulfonylurea resistant and one susceptible smooth pigweed populations, grown in the greenhouse and treated with halosulfurom postemergence[a] in 2000.

Halosulfuron rate	Control					
	S	R1	R2	R3	R4	R5
g ai/ha	%					
0	0	0	0	0	0	0
0.27	0	0	0	2	0	5
2.7	25	24	10	22	19	22
27	67	55	33	59	62	64
270	98	94	59	78	98	78
2700	99	96	94	99	99	97

[a]All POST treatments contained 0.25% v/v non-ionic surfactant.

Table 26. The concentration of halosulfuron required to reduce the growth of one sulfonylurea-susceptible (S) and five sulfonylurea-resistant (R1, R2, R3, R4, and R5) smooth pigweed populations by 50% as determined by dry weights from the greenhouse.

S	R1	R2	R3	R4	R5
Halosulfuron (GR_{50})[a] g ai/ha					
8	17	97	18	27	22

[a]GR_{50} values were calculated using a nonlinear model.

Table 27. Pairwise comparisons of nonlinear estimates of one sulfonylurea-susceptible (S) and five sulfonylurea-resistant (R1, R2, R3, R4, and R5) smooth pigweed populations treated with halosulfuron.[ab]

Population	Halosulfuron
S X R1	ns
S X R2	*
S X R3	ns
S X R4	*
S X R5	ns
R1 X R2	*
R1 X R3	ns
R1 X R4	ns
R1 X R5	ns
R2 X R3	*
R2 X R4	ns
R2 X R5	ns
R3 X R4	ns
R3 X R5	ns
R4 X R5	ns

[a]A nonlinear model was used to test the interaction between populations.

[b]An asterisk denotes a significant difference in nonlinear estimates between populations.

Figure 1. Non-linear regression of sulfonylurea-susceptible (S) smooth pigweed population treated with halosulfuron postemergence in the greenhouse.

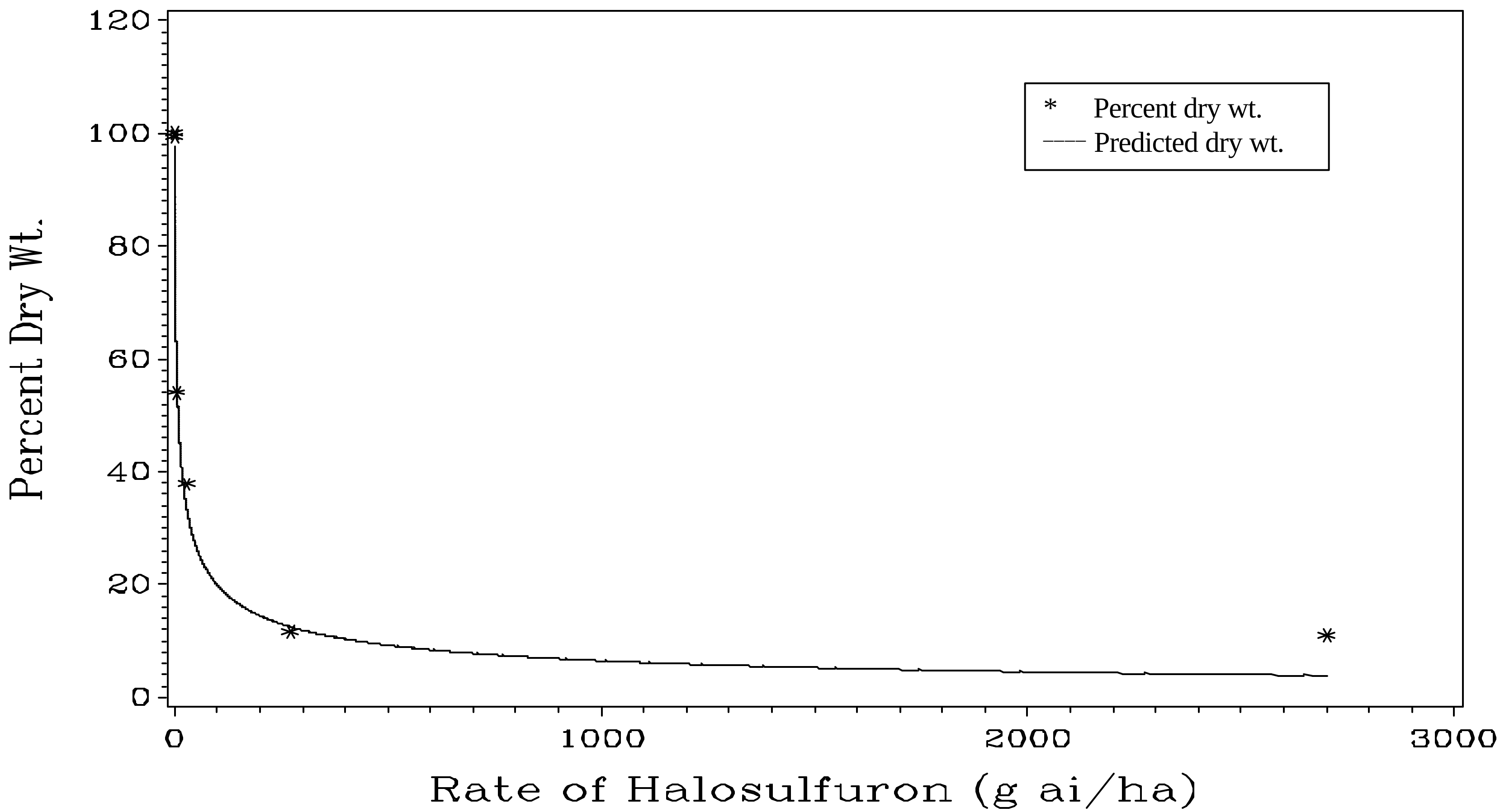

Figure 2. Non-linear regression of sulfonylurea-resistant (R1) smooth pigweed population treated with halosulfuron postemergence in the greenhouse.

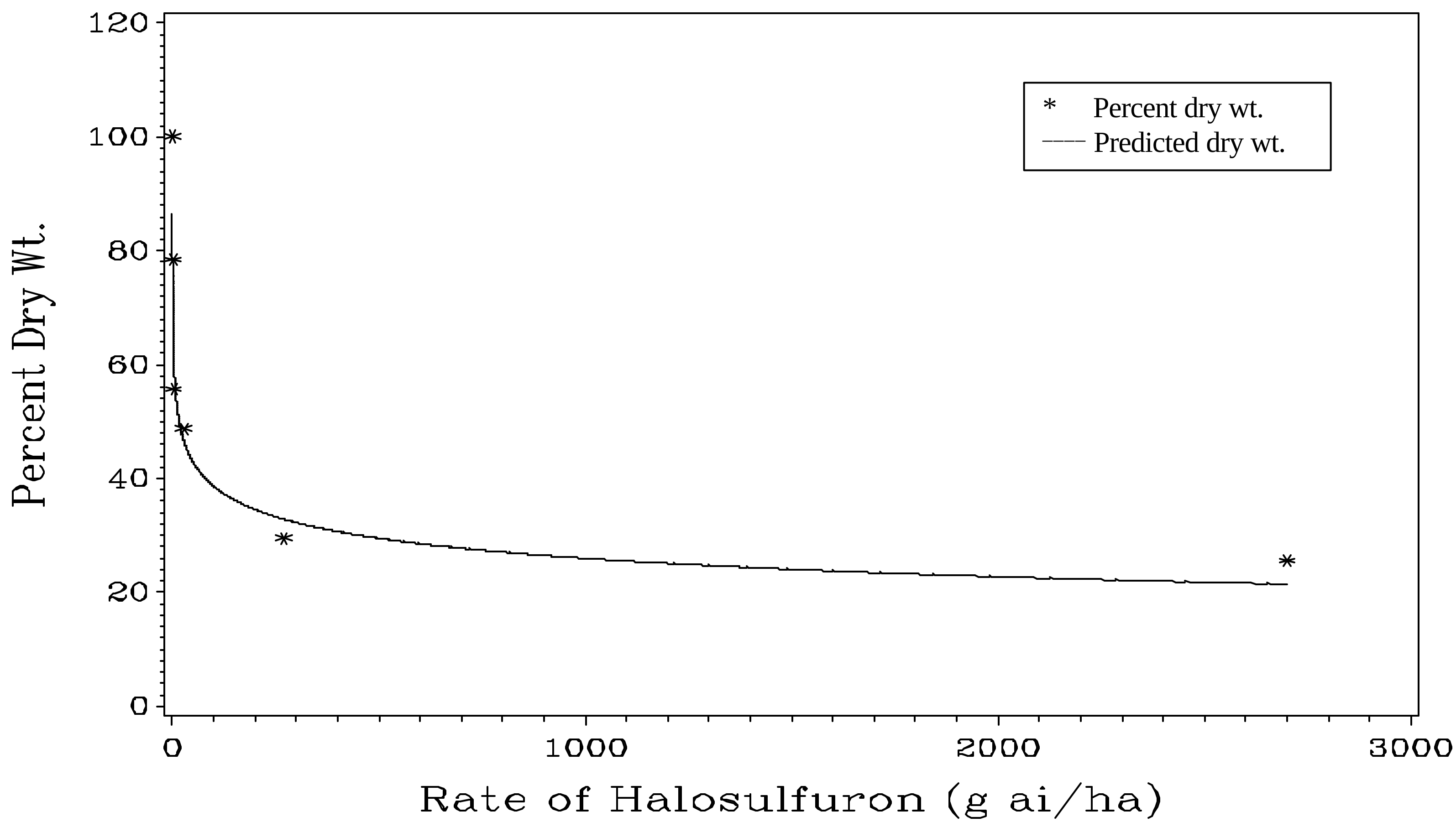

Figure 3. Non-linear regression of sulfonylurea-resistant (R2) smooth pigweed population treated with halosulfuron postemergence in the greenhouse.

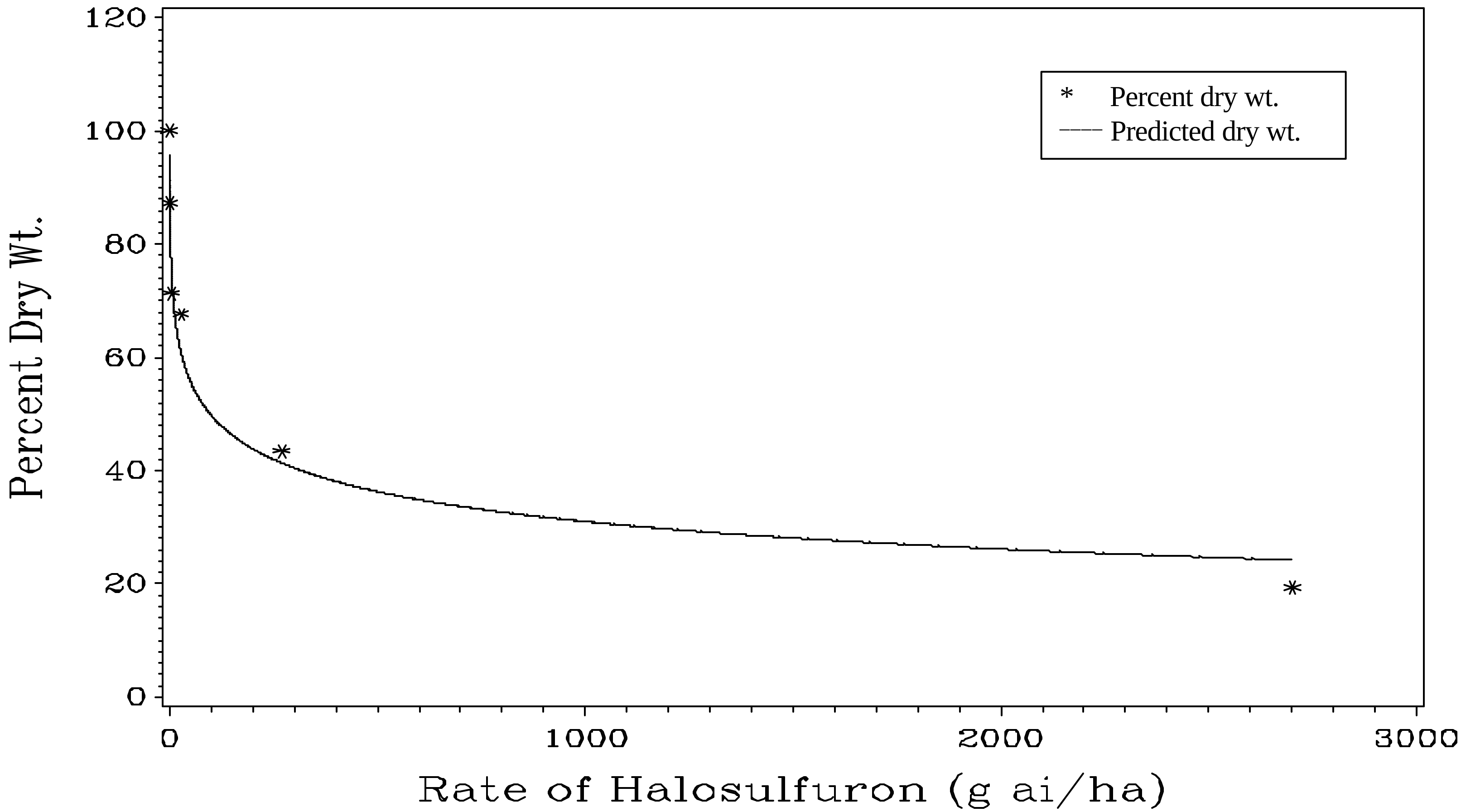

Figure 4. Non-linear regression of sulfonylurea-resistant (R3) smooth pigweed population treated with halosulfuron postemergence in the greenhouse.

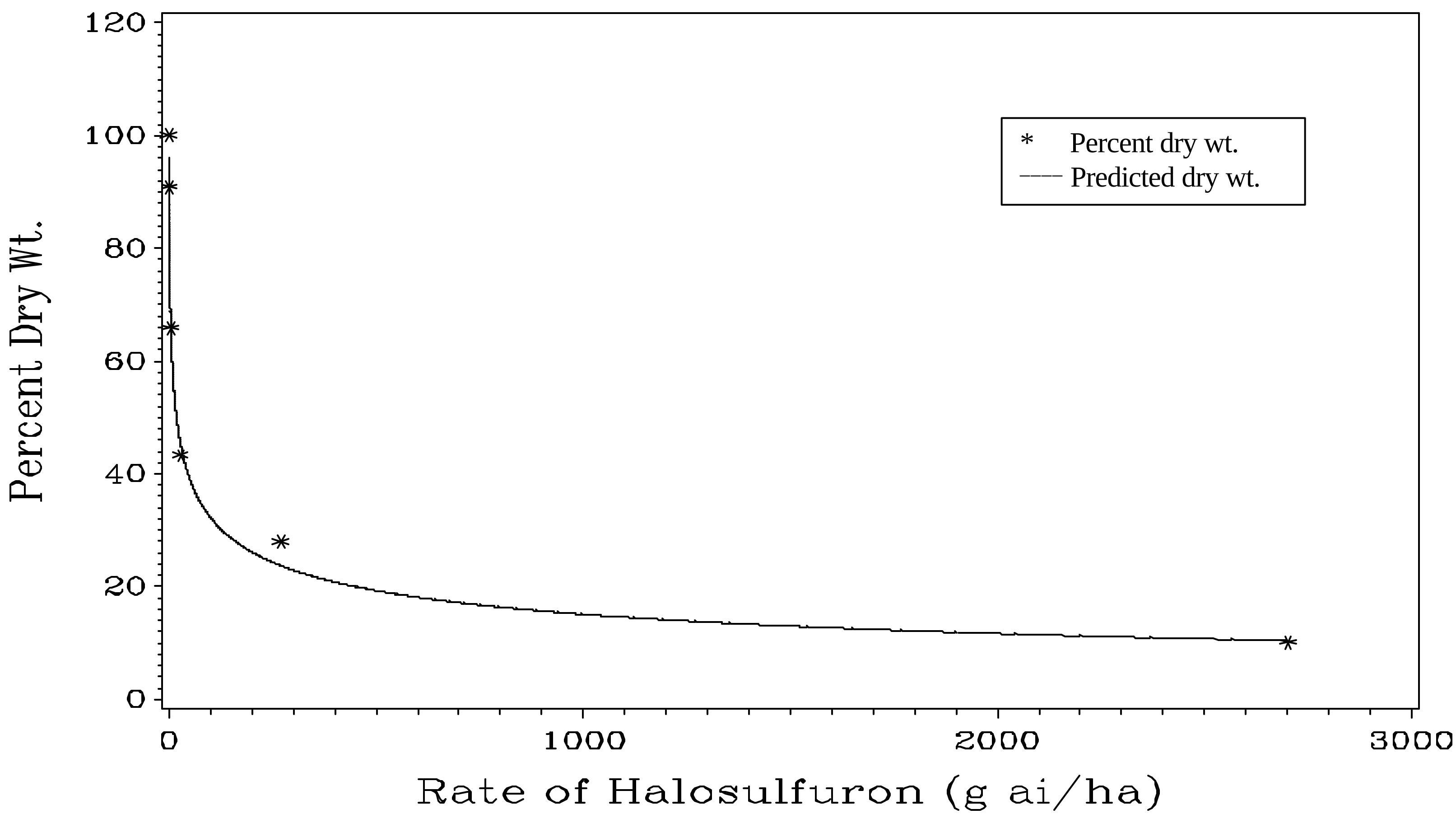

Figure 5. Non-linear regression of sulfonylurea-resistant (R4) smooth pigweed population treated with halosulfuron postemergence in the greenhouse.

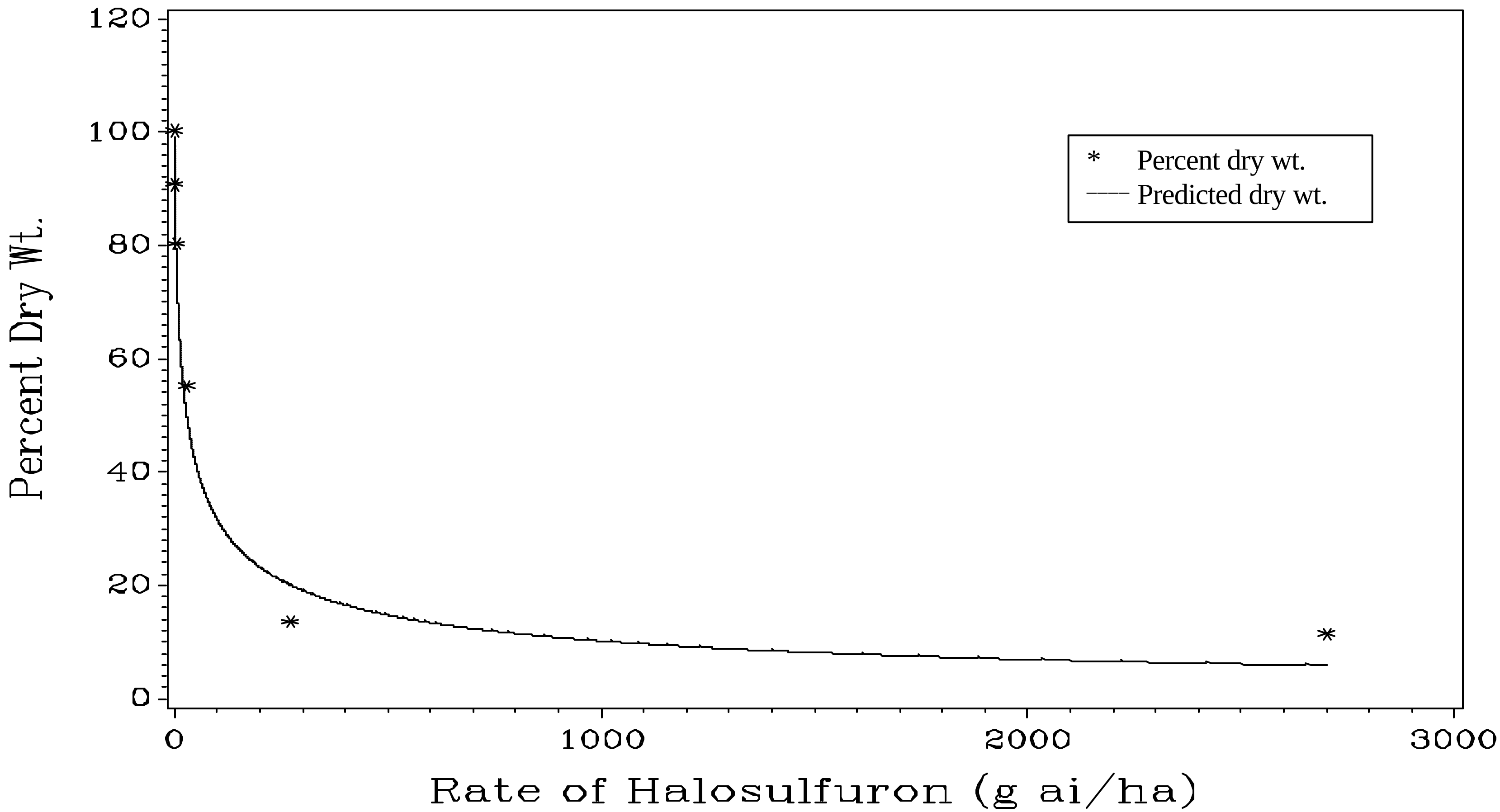

Figure 6. Non-linear regression of sulfonylurea-resistant (R5) smooth pigweed population treated with halosulfuron postemergence in the greenhouse.

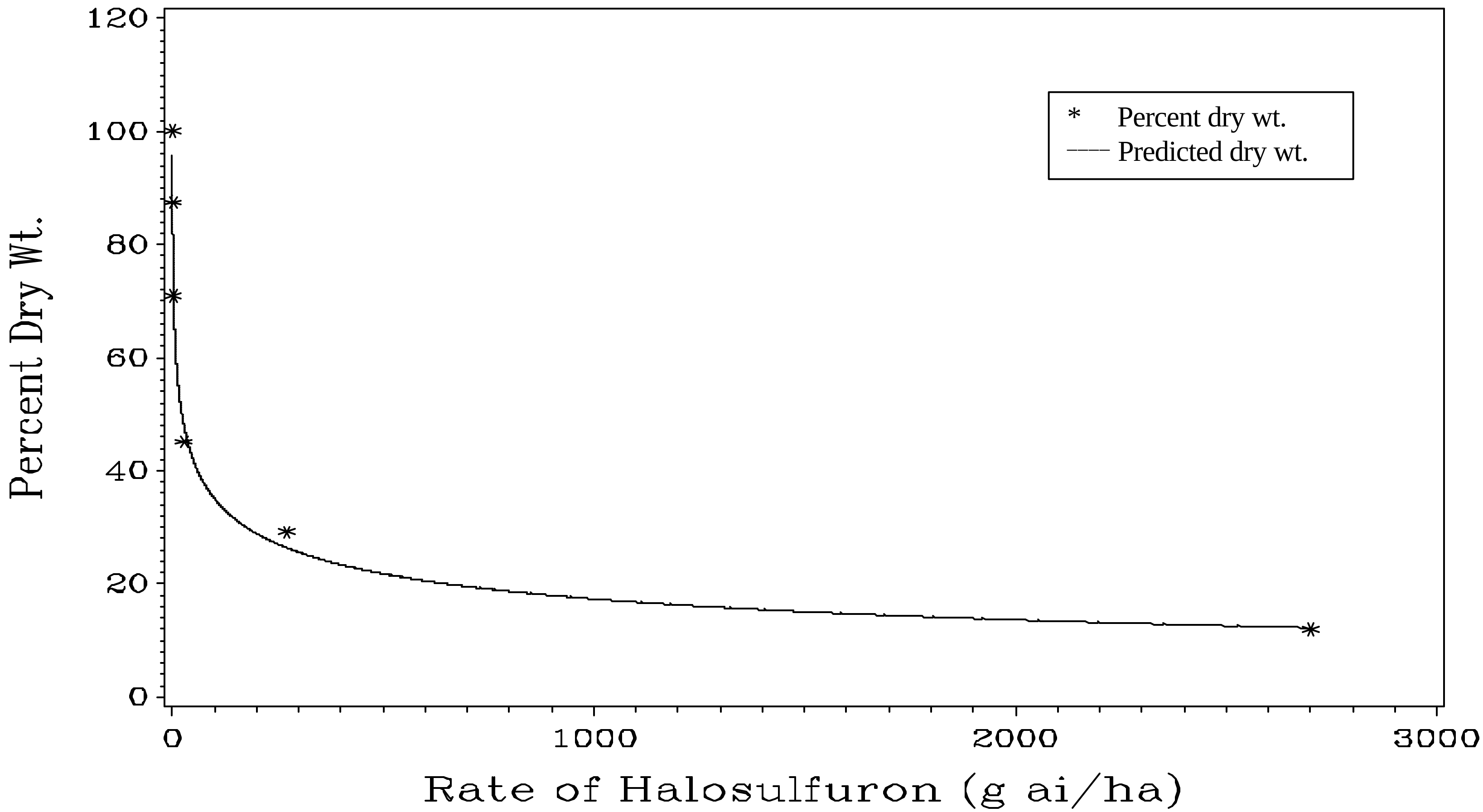

Table 28. Control of yellow nutsedge in zucchini and yellow squash with halosulfuron preemergence and postemergence in 2000 and 2001.[a]

Halosulfuron rate	Application method	Yellow nutsegde control		
		Zucchini squash 2000	Yellow squash 2000	Yellow squash 2001
—— g ai/ha ——		—— % ——		
0	NONE	2 f[c]	0 d	0 f
4	PRE	0 f	0 d	31 e
9	PRE	21 e	12 d	37 e
18	PRE	36 de	57 c	53 d
27	PRE	44 d	68 bc	70 c
4	POST[b]	63 c	65 bc	76 bc
9	POST	72 bc	82 ab	85 ab
18	POST	83 ab	92 a	91 a
27	POST	94 a	95 a	95 a
0	Weeded	0 f	0 d	0 f
0	Untreated	0 f	0 d	0 f
LSD		18	23	11

[a]All treatments except the checks included clomazone at 175 g ai ha^{-1} and ethalfluralin at 630 g ai ha^{-1} applied PRE.

[b]All POST treatments contained 0.25% v/v non-ionic surfactant.

[c]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 29. Control and dry weight of yellow nutsedge plants grown in the greenhouse and treated with halosulfurom postemergence in 1999 and 2000.[a]

Halosulfuron rate	Yellow nutsedge			
	Control	Dry Weight	Control	Dry Weight
	1999		2000	
——— g ai/ha ———	——— % ———	——— g ———	——— % ———	——— g ———
0	0 d[b]	3.07 a	0 d	4.39 a
4	81 c	0.39 b	74 c	0.46 b
9	82 bc	0.39 b	76 bc	0.83 b
18	88 ab	0.35 b	81 ab	0.64 b
27	92 a	0.03 b	82 a	0.49 b
LSD	6	0.85	6	0.44

[a]All POST treatments contained 0.25% v/v non-ionic surfactant.
[b]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

Table 30. Control of rice flatsedge with halosulfuron postemergence near Mappsburg, VA in 2001. [a]

	Control	
Halosulfuron rate	Test 1	Test 2
g ai ha^{-1}	%	
0	0 c[b]	0 c
4	68 b	87 ab
9	70 b	85 b
18	85 a	86 ab
27	94 a	96 a
LSD	11	11

[a]All POST treatments contained 0.25% v/v non-ionic surfactant.

[b]Means followed by the same letter do not differ at the 0.05 significance level by Fisher's protected least significant difference within a column.

VITA

Brian Wayne Trader was born to Elijah Thomas Trader and Debra Jean Trader on August 18, 1978 in Nassawadox, Virginia. From the summers of 1997 through 2001 he worked at the Eastern Shore Agricultural Research and Extension Center, near Painter VA, conducting weed control research. He received a Bachelor of Science degree, majoring in Horticultural Crops from Virginia Polytechnic Institute and State University, College of Agriculture in December of 2000. He began working on a Master of Science degree in the department of Plant Pathology, Physiology, and Weed Science on a graduate research assistantship under the supervision of Dr. Henry Wilson in January of 2001.

Brian W. Trader