ABSTRACT

Taylor, Zachary G. Management of axillary shoot growth and maleic hydrazide residues with diflufenzopyr in flue-cured tobacco (*Nicotiana tabacum*) (Under the direction of L. R. Fisher).

Maleic hydrazide (MH) controls axillary shoot (sucker) growth in tobacco and is used on more than 90% of the acreage in North Carolina. Residues of MH are the highest of any pesticide used in flue-cured tobacco production in the United States. Many export customers have MH residue limits that are below the average crop residue level. Flue-cured tobacco produced in the United States has therefore been at a competitive disadvantage because competitors in the export market do not use MH.

Research was conducted at the Central Crop Research Station near Clayton, NC and the Border Belt Tobacco Research Station near Whiteville, NC in 2003 and 2004 to evaluate an experimental compound from BASF, diflufenzopyr, (2-(1-[([3,5-difluorophenylamino] carbonyl)-hydrazono}ethyl)-3-pyridinecarboxylic acid), for the control of sucker growth in flue-cured tobacco. Diflufenzopyr was evaluated alone and in tank mixtures with a registered rate of flumetralin, and registered and reduced rates of MH. Treatments were arranged in a factorial design with MH at four rates (0, 0.6, 1.3, and 2.5 kg ai ha^{-1}), flumetralin at two rates (0 and 0.7 kg ai ha^{-1}), and diflufenzopyr at two rates (0 and 0.017 kg ai ha^{-1}). All treatments were applied approximately seven days after the second contact fatty alcohol application (equivalent to ten days after the removal of the terminal flower). Timing of diflufenzopyr application was based on extension recommendations for the proper timing for MH and flumetralin application.

Control of sucker growth with all treatments that included compounds currently registered for sucker control in tobacco in the United States (MH and flumetralin) was similar to previous research. Diflufenzopyr alone resulted in 64% sucker control, and control was similar to flumetralin alone and 0.6 and 1.3 kg of MH alone. Percent sucker control from diflufenzopyr alone however, was less than the standard treatment of a tank mixture of MH at 2.5 kg and flumetralin at 0.7 kg and was therefore below acceptable levels. Diflufenzopyr and MH at 1.3 kg (one-half the registered rate of MH) controlled sucker growth as well as any treatment in the experiment and was equivalent to the standard treatment. In addition, the three-way combination of diflufenzopyr, MH, and flumetralin allowed a further reduction in MH rate, down to 0.6 kg, without reducing sucker control compared to the standard treatment discussed above.

There were no yield differences at CCRS in either year. Yield at BBTRS in 2003 was improved with all chemical treatments and generally increased with increasing levels of sucker control. At BBTRS in 2004, however, seven of the eight treatments that included diflufenzopyr yielded less than chemical treatments that did not include diflufenzopyr. Chemical treatments did not consistently affect quality or average price, and differences in value per hectare were related to yield. Total alkaloids tended to be higher with treatments that resulted in high levels of sucker control. No treatment related differences in reducing sugars were observed.

Acceptable levels of sucker control can be achieved with the tank mixture of diflufenzopyr and the one-half the registered rate of MH (1.3 kg) or from diflufenzopyr, flumetralin and one-fourth the registered rate of MH (0.6 kg). Diflufenzopyr would therefore allow MH residues to be substantially reduced without reducing overall sucker control.

Management of axillary shoot growth and maleic hydrazide residues with diflufenzopyr in flue-cured tobacco (*Nicotiana tabacum*)

By

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BIOGRAPHY

Zachary Graham Taylor, son of Jane and Linwood Taylor, was born May 24th 1978, in Franklin Virginia. He was raised in Murfreesboro NC on a small cotton and peanut farm. After high school graduation, he attended Chowan College from the fall of 1996 until the spring of 1997. He then transferred to North Carolina State University in the fall of 1998, where he majored in Agronomy. He obtained a Bachelor of Science in Agronomy in the fall of 2001. Zach then entered a Master of Science program in the Crop Science Department at North Carolina State University under the direction of Dr. Loren R. Fisher.

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INTRODUCTION

Tobacco has been produced around the world for the last 1500 years (4) and is currently produced in 117 countries by nearly 33 million producers (2). Almost 65% of the world's tobacco is classified as flue-cured (*Nicotiana tabacum* L.)(6). In 2003 alone, 216 million kg of flue-cured tobacco were produced in the United States (1). In North Carolina, flue-cured and burley tobacco are important crops produced throughout the state, generating several billion dollars to local and state economies. In 2003, North Carolina produced 140 of the 216 million kg of flue-cured tobacco grown in the United States with an estimated value of US$700 million (1).

Tobacco is a flowering plant with a terminal meristem that suppresses growth of axillary shoots through hormonal activity. When the meristem begins to produce flowers, hormonal suppression of axillary shoot growth ends (18). The flower is removed in the button stage (11) to prevent the development of the seed head and to allow transfer of energy to the leaves to increase leaf size, weight, body, nicotine, and other chemical constituents (27). Hormones that inhibit axillary shoot growth are produced in the terminal bud; therefore removal of the terminal bud also removes apical dominance (4). Axillary shoots (more commonly referred to as suckers), primarily those in the top three to four leaf axils, will then begin to grow more vigorously (4). The suckers in the uppermost leaf axils will re-establish partial apical dominance and suppress growth of suckers in lower leaf axils (21). There are three potential suckers in each leaf axil; the well differentiated primary sucker attached to the main stem, the less differentiated secondary sucker attached to the adaxial surface of the leaf petiole, and a meristematic area outward on the leaf petiole (22). If suckers are not removed and/or if growth is not controlled, suckers will form a flower and seed head. (29). The result is lower cured leaf yield and physical and chemical quality of the tobacco (26). In research conducted by Fisher and Priest at two locations in 2003, tobacco that had the terminal flower removed (topped) and had uncontrolled sucker growth, yielded 37% less than tobacco that was topped and sucker growth was controlled (19). Tests conducted by Collins and Hawks found that tobacco plants that were topped but not suckered contained less total alkaloids and reducing sugars than tobacco that was topped and suckered (4). Suckers can also interfere with harvest, especially if the tobacco is mechanically harvested (5), and become a source of foreign matter in cured leaves (9).

For many years, growers used hand labor to remove suckers, which was a difficult and time-consuming practice (4). In a 1978 study, Seltmann found that approximately 60 worker hours of labor were required to hand sucker an acre of flue-cured tobacco when the suckers were removed when they were 10 to 20 cm long (4). The use of chemicals to control the growth of tobacco suckers in the United States dates to the 1940's when mineral oil was used to desiccate small suckers (25 and 17), but it was not until the introduction of maleic hydrazide (MH) in the 1950's that a significant reduction in hand labor required to remove suckers was achieved (18). MH is a true systemic inhibitor of plant cell division (18 and 20). It is a uracil anti-metabolite (4) and results in inhibition of mitosis and the loss of the layered organization in the tunica-corpus of the apical shoot meristem (3). In addition, it has been reported to inhibit DNA and RNA synthesis (27), uptake and assimilation of nitrate (8), respiration, and photosynthesis (7).

MH was first registered as a diethanolamine salt, but in the 1960's secondary amines came under toxicological scrutiny, and U.S. manufacturers reformulated their products as the potassium salt. The processing improvements made, nearly eliminated free hydrazine, a manufacturing impurity (20). In the 1970's over 1.7 million kg were produced in the U.S. and over 1.4 million kg were used for the control of sucker growth on nearly 400,000 ha of tobacco (25).

Once applied to actively growing tobacco plants, MH is rapidly absorbed and then translocated in both the xylem and phloem to meristems where it inhibits cell division but not cell elongation (18). Working with radio labeled MH, Tso found that twenty-eight days after treatment 30-40% of the absorbed (^{14}C)-MH was translocated to the roots and released into the nutrient solution, 12-22% remained in the plant, 14-18% was extracted as methanol-soluble metabolites, and 25-35% remained in the roots and other tissues as a methanol-insoluble residue (27). Because MH is translocated to meristems, application results in control of small suckers after application as well as the control of slightly larger suckers that will develop at a slower rate (4). Collins and Hawks also note that under normal conditions, MH can be expected to provide sucker control for about six weeks after application (4).

In the 1960's a group of fatty alcohols (commonly called contacts) were developed for control of sucker growth (27). Contacts used for sucker control are composed primarily of straight chain n-octanol and n-decanol alcohols (18) and control sucker growth by pooling in the leaf axil, rapidly evaporating, and causing desiccation of small suckers (30). Contacts received their name because they must contact the sucker to control it and do not provide any residual or systemic sucker control (11). The contact fatty alcohol is primarily used to suppress sucker growth until upper leaves are large enough for application of MH, preventing suckers from becoming too large for MH to control (4).

In the early 1980's, flumetralin was approved for use on flue-cured tobacco in the United States (18). Flumetralin is a dinitroaniline that controls sucker growth by stopping localized cell division and is therefore applied directly to the leaf axil to control the sucker (4). Flumetralin extended the length of time that suckers were controlled therefore reducing the need for excessive rates and/or reapplication of MH when the growing season was extended or sucker pressure was high (11).

The registered rate for MH in North Carolina is 2.5 to 3.4 kg ai ha^{-1} (11). Average MH residues in flue-cured tobacco in the United States from 1983 to 2002 have ranged from 89 to 178 ppm (10). Many factors influence MH residue levels including chemical characteristics, application rate, duration of time between application and harvest, stalk position, and environment (27). MH is resistant to decomposition from UV radiation and high temperature, and loss to volatilization. It is also fixed and not readily metabolized once in the plant (4). However, MH is very water-soluble and rainfall is the single most important factor that affects MH residue levels after application. Residues levels are typically lower in season where there is above average rainfall and higher with below average rainfall (18). Research (23), found that when 2.0 cm of irrigation water was applied 12 hours after the MH application, sucker control was unaffected, but MH residues were reduced when compared to the non-irrigated, from 62 to 30 ppm of MH (23). Further research showed that producers can have significantly lower MH residues if the first harvest can be delayed until the plants receive some amount of rainfall ranging from 0.01 to 1 cm (14).

Because of its high residues in tobacco, MH has been scrutinized by political and governmental agencies throughout the world. For example, in 1978 the Federal Republic of Germany enacted a new food law, which stipulated that all pesticides must be approved for use or meet tolerance levels established for foods (28). Tobacco was considered a food in this new law (13), and a tolerance of 80 ppm for MH residues was set for tobacco products sold in Germany (31). The European Union is one of the largest export customers for US tobacco and the US is the only significant exporter of tobacco that currently uses MH creating a competitive disadvantage (9).

There have been considerable research and grower education efforts to reduce MH residues in US tobacco. The North Carolina Cooperative Extension Service recommends several management practices that reduce MH residues including using a reasonable nitrogen rate to reduce sucker pressure, using contact fatty alcohols and flumetralin and not relying solely on MH for chemical control, using only registered rates of MH, and allowing at least one week between application and harvest (11). Educational efforts and the use of flumetralin may be partially responsible for a reduction in MH residues in recent years. From 1983-1992 MH residues averaged 125 ppm, but from 1993-2002 MH residues averaged 106 ppm. However, MH residues have still been consistently higher than the 80-ppm standard set by the European Union (10).

In preliminary research, an experimental compound from BASF, diflufenzopyr[1], has shown ability to suppress sucker growth in tobacco (12). Diflufenzopyr is a member of the semicarbazone herbicide family that inhibits polar auxin transport (15). According to Lym et. al. an auxin transport inhibitor suppresses the transport of naturally occurring indole acetic acid and synthetic auxin-like compounds in plants. In general, diflufenzopyr interferes with the auxin balance needed for plant growth (16). Diflufenzopyr was first developed as a herbicide and has shown activity on velvetleaf, field bindweed, and mesquite. (15). In addition, diflufenzopyr has been evaluated in combination with dicamba and other auxin herbicides to enhance their activity for perennial weed control (16).

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[1] Diflufenzopyr is experimentally known as BAS 654 H and BASF 131, BASF Corporation, Agricultural Products Group, P.O. Box 13528, Research Triangle Park, NC 27709.

The objectives of this research were: 1) to evaluate efficacy for sucker control and tolerance of tobacco to diflufenzopyr and 2) to evaluate the ability of diflufenzopyr to reduce the need for MH and therefore reduce MH residues.

METHODS AND MATERIALS

Research was conducted in 2003 and 2004 at the Central Crops Research Station (CCRS) near Clayton, NC and at the Border Belt Tobacco Research Station (BBTRS) near Whiteville, NC, to evaluate the use of diflufenzopyr for the control of axillary bud (sucker) growth in flue-cured tobacco (*Nicotiana tabacum* L.). Soils were a Plinthic Paleudults and a Typic Paleudults at CCRS and BBTRS in both years, respectively. Flue-cured cultivar ‘K326’was transplanted on May 9th in 2003 and April 26th in 2004 at CCRS and ‘K346’ was transplanted on April 30th in 2003 and April 22nd in 2004 at BBTRS. Tobacco was produced using normal production practices for each research station and according to extension recommendations, except for treatments imposed (24). Rainfall data in each location is shown in Table 1.

Experimental design was a randomized complete block with a factorial treatment arrangement and four replications. Plots were two rows wide, and were 13.7 m in length with 1.20 m between rows at BBTRS and 12.2 m in length with 1.14 m between rows at CCRS. All treatments were applied with a CO_2 powered backpack sprayer with a delivery volume of 467 L ha^{-1} at 138 kPa. Treatments were applied using three nozzles per row, with a 26 cm spacing between nozzles. The outside nozzles were a TG[1] 3 and the center nozzle was a TG 5.

Treatments consisted of maleic hydrazide (MH) at four rates (0, 0.6, 1.3, and 2.5 kg ai ha^{-1}), flumetralin at two rates (0 and 0.7 kg ai ha^{-1}), and diflufenzopyr at two rates (0 and 0.017 kg ha^{-1}). All treatments were applied approximately seven days after the second contact fatty alcohol application (equivalent to ten days after the removal of the terminal

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[1] TEEJET

flower). Timing of diflufenzopyr application was based on extension recommendations for the proper timing of MH and flumetralin application (24).

Cured leaf yield and quality, and sucker control data were collected from one row of the two-row plot to allow for a common border row between plots. Suckers were removed by hand from ten plants in each plot, counted and weighed. A control treatment with maximum sucker expression was established by removing the terminal flower from each plant and allowing unrestricted sucker growth (topped, but not suckered). Sucker weights in each treated plot were then compared to the maximum sucker expression data collected in the control to determine percent sucker control. The Tobacco Chemistry Lab at North Carolina State University performed analysis for total alkaloids and reducing sugars on a 50 g cured leaf sample, composited by weight over primings, for each plot. MH residue analyses were conducted on a composite cured leaf sample from each plot by Southern Testing, Wilson, NC. All data were subjected to an factorial analysis of variance (ANOVA) (Table 2) and treatment means were separated using a least significant difference value (LSD) at $P \geq 0.05$.

RESULTS

Data are reported for the appropriate main effects or interactions based on the ANOVA in Table 2. Sucker fresh weight per plant, yield, value, and total alkaloid data had a significant location by MH by flumetralin by diflufenzopyr interaction. Therefore, these data were analyzed by location and appropriate interactions and main effects are reported based on the ANOVA for each location. Means were separated using Fisher's F-protected LSD at $P \geq 0.05$.

Percent sucker control

When averaged over locations (Table 3), sucker control with MH alone ranged from 62 to 85%. There was no difference in percent sucker control between 0.6 and 1.3 kg ai/ha of MH alone, but 2.5 kg of MH alone improved sucker control compared to lower MH rates and controlled suckers as well as any treatment in the experiment. Flumetralin and diflufenzopyr alone resulted in 73 and 64% sucker control, respectively, and provided sucker control equivalent to either 0.6 or 1.3 kg of MH alone. However, neither flumetralin nor diflufenzopyr alone were as effective as MH at 2.5 kg.

The combination of MH and flumetralin resulted in a range of 79 to 93% sucker control and was not consistently affected by increasing MH rates. The combination of MH and diflufenzopyr resulted in sucker control ranging from 70 to 85%, increasing with increasing MH rates. Sucker control with 1.3 kg of MH and diflufenzopyr was as effective as MH at 2.5 kg or MH at 0.6 kg in combination with flumetralin, and was equivalent to the highest percent sucker control ratings in the experiments. The combination of diflufenzopyr and flumetralin resulted in 83% sucker control and was also as effective as any treatment in the experiment. The three-way combination of MH, flumetralin, and diflufenzopyr resulted in 84 to 87% sucker control, but was not better than diflufenzopyr or flumetralin with 1.3 kg or more of MH.

When percent sucker control data were averaged over flumetralin rates (Table 4), control was poor when MH or diflufenzopyr were not applied. Percent sucker control was not consistently improved by increasing MH rates or by the use of diflufenzopyr. When data were averaged over MH rates (Table 5), the use of flumetralin and/or the use of diflufenzopyr improved sucker control at three of four locations. The combination of flumetralin and diflufenzopyr was not consistently better than either compound alone, when averaged over MH rates.

Number of suckers per plant

When data were averaged over diflufenzopyr rates, no differences in the number of suckers per plant were observed with MH and flumetralin treatments at CCRS in 2003. At BBTRS in 2003 and 2004 the use of MH, and the MH and flumetralin combination, reduced the number of suckers per plant when averaged over diflufenzopyr rates. Increased rates of MH did not consistently decrease sucker number. The combination of MH and flumetralin reduced sucker number more than MH alone. At CCRS in 2004, treatments that included flumetralin also reduced sucker number per plant, but MH alone had very little effect on sucker number (Table 6).

When data were averaged over flumetralin and MH rates, no differences in sucker number per plant were observed at two of four locations (Table 7). However, at BBTRS in both years, the use of diflufenzopyr reduced sucker number per plant by more than 50%. When averaged over MH rates, sucker number per plant was reduced by the use of both diflufenzopyr and flumetralin (Table 8). The tank combination of diflufenzopyr and flumetralin did not further reduce sucker number per plant compared to flumetralin alone.

Fresh weight per sucker

When data were averaged over MH and flumetralin rates, diflufenzopyr had no effect on fresh weight per sucker at two of four locations (Table 9). At BBTRS in both years, however, diflufenzopyr reduced the fresh weight per sucker by 34 to 48%. When data were averaged over diflufenzopyr and flumetralin rates at CCRS in 2003, MH had no effect on fresh weight per sucker. MH reduced the fresh weight per sucker with the 0.6 kg rate or more at BBTRS in 2003, with the 2.5 kg rate at CCRS in 2004, and with the 1.3 kg rate or more at BBTRS in 2004 (Table 10). When averaged over locations and diflufenzopyr and MH rates, flumetralin consistently reduced fresh weight per sucker from 88 g to 70 g (Table 11).

Sucker fresh weight per plant

When data were averaged over flumetralin rates at CCRS in 2003 (Table 12), diflufenzopyr alone reduced sucker fresh weight per plant from 25 g to 14 g. The reduction in sucker fresh weight per plant was similar to what was observed with all rates of MH alone. The combination of diflufenzopyr and MH did not reduce sucker fresh weight per plant more than either compound applied alone.

At BBTRS in 2003 and 2004, all chemical treatments reduced sucker fresh weight per plant (Tables 13 and 14). The use of the MH and diflufenzopyr combination was similar to the combination of MH and flumetralin. The combination of MH, diflufenzopyr, and flumetralin at all rates of MH, any two-way treatment combination that included the higher rates of MH, and the combination of diflufenzopyr and flumetralin, resulted in a consistent reduction in sucker fresh weight per plant.

At CCRS in 2004 (Table 15), data were averaged over diflufenzopyr rates. The use of flumetralin consistently reduced sucker fresh weight per plant. Flumetralin alone, averaged over diflufenzopyr rates, was more effective than any MH treatment.

Yield

There were no differences in yield at CCRS in 2003 or 2004 (data not shown). At BBTRS in 2003 and 2004 all chemical treatments yielded higher than the non-treated control with unrestricted sucker growth (Tables 16 and 17). At BBTRS in 2003, the highest yielding treatments were also the treatments that had the highest percent sucker control (Tables 4 and 5). At BBTRS in 2004, tobacco treated with diflufenzopyr consistently yielded less than tobacco treated with MH and/or flumetralin.

Average price

When averaged over diflufenzopyr rates, tobacco that received no MH or flumetralin brought a lower average price than treated tobacco at BBTRS in 2003 and 2004 (Table 18). When averaged over flumetralin rates, tobacco that received no MH or diflufenzopyr brought a lower average price than treated tobacco at BBTRS in 2003 and 2004(Table 19). The price range for all other treatments at all locations was narrow and no consistent differences were observed. When data were averaged over locations (Table 20), all treated tobacco had a higher average price than the control. In all cases, lower average selling price was related to low levels of sucker control.

Value per hectare

No differences in value per hectare were observed at CCRS in 2003 or 2004. At BBTRS in 2003 and 2004 value was significantly reduced when treatments did not result in adequate sucker control (Tables 21 and 22). At BBTRS in 2004, tobacco treated with diflufenzopyr consistently had lower value per hectare than tobacco treated with only MH and/or flumetralin and is directly related to reduced yield with diflufenzopyr treatments.

Quality

When averaged over diflufenzopyr and flumetralin rates, use of MH improved grade indices (regardless of rate) at both locations in 2003, but did not affect grade index in 2004 (Table 23). When averaged over diflufenzopyr rates and locations, the lowest grade index was observed when only diflufenzopyr was applied (Table 24). All other differences in grade index were very inconsistent across treatments and locations.

Total alkaloids and reducing sugars

There were no differences in total alkaloids at CCRS in 2003. At BBTRS in 2003, alkaloid levels in the non-treated tobacco were nearly 50% less than tobacco with some level of sucker control. In addition, treatments that resulted in the highest level of sucker control also had the highest alkaloid levels (Tables 4, 5, and 25). Similar results were observed at CCRS and BBTRS in 2004. Treatments that included flumetralin at CCRS in 2004 and treatments that included MH at BBTRS in 2004, tended to have the highest alkaloid levels, but also had the highest levels of sucker control (Tables 26 and 27). There were no differences in reducing sugars in either year (Table 2).

Residues of MH and diflufenzopyr

MH residue data for selected treatments were collected at BBTRS in 2003 and BBTRS and CCRS in 2004 (Table 28). Diflufenzopyr residue data are shown from previous research in 2002 (Table 28). Residues of MH varied greatly across locations and were dependent upon environment (9). MH residues ranged from below the detection limit of 10 ppm up to 31 ppm with 0.6 kg, from 12 to 84 ppm with 1.3 kg, and from 25 to 152 ppm with 2.5 kg of MH. At all locations, MH residues increased with increasing MH rates. MH residues were not affected by the combination of diflufenzopyr and MH. Diflufenzopyr residues were below the detection limit of 0.05 ppm, even with rates substantially higher than those used is these experiments.

DISCUSSION

Control of sucker growth with all treatments that included compounds currently registered for sucker control in tobacco in the United States (MH and flumetralin) was similar to previous research (24) (Tables 3,4, and 5). Diflufenzopyr alone resulted in 64% sucker control, and control was similar to flumetralin alone and 0.6 and 1.3 kg of MH alone (Table 3). Percent sucker control from diflufenzopyr alone, however, was less than the standard treatment of a tank mixture of MH at 2.5 kg and flumetralin at 0.7 kg and is therefore below acceptable levels. Diflufenzopyr and MH at 1.3 kg (one-half the registered rate of MH) controlled sucker growth as well as any treatment in the experiment and was equivalent to the standard treatment. In addition, the three-way combination of diflufenzopyr, MH, and flumetralin allowed a further reduction in MH rate, down to 0.6 kg, without reducing sucker control compared to the standard treatment. The tank mixture of diflufenzopyr and flumetralin also resulted in sucker control equivalent to the standard treatment discussed above. However, sucker control with flumetralin in this experiment was better than in previous research (24) and better than would be expected when applied with typical grower equipment. Flumetralin requires contact with the leaf axils to control sucker growth. Treatments were applied with a backpack sprayer, which resulted in greater precision of application than is typically achieved with high clearance or tractor mounted sprayers used by growers.

Diflufenzopyr also reduced sucker number and size of suckers. Fresh weight per sucker was reduced by diflufenzopyr at two of four locations (Table 9). Sucker number was reduced by approximately 32 % by diflufenzopyr when averaged over MH rates. However, diflufenzopyr was not as effective as flumetralin, which reduced sucker number by 75%, and the combination of diflufenzopyr and flumetralin did not reduce sucker number more than flumetralin alone (Table 8).

There were no yield differences at CCRS in either year. Yield at BBTRS in 2003 was improved with all chemical treatments and generally increased with increasing levels of sucker control. At BBTRS in 2004, however, seven of the eight treatments that included diflufenzopyr yielded less than chemical treatments that did not include diflufenzopyr. Yield losses were not related to poor sucker control and no visual injury from diflufenzopyr was observed; therefore there is no apparent reason for the yield reduction. Chemical treatments did not consistently affect quality or average price and differences in value per hectare were related to yield. Total alkaloids tended to be higher with treatments that resulting in high levels of sucker control, which is consistent with previous research (27). No treatment related differences in reducing sugars were observed.

Acceptable levels of sucker control can be achieved with the tank mixture of diflufenzopyr and one-half the registered rate of MH (1.3 kg) or from diflufenzopyr, flumetralin, and one-fourth the registered rate of MH (0.6 kg). Diflufenzopyr would therefore allow MH residues to be substantially reduced without reducing overall sucker control (Table 3 and 28).

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Table 1. Monthly sum of daily precipitation from pre-transplant to harvest at CCRS[1] and BBTRS[2] in 2003 and 2004

	CCRS		BBTRS	
Month	2003	2004	2003	2004
	. . . . .cm.	. . . .		
February	12.7	8.1	24.4	9.2
March	16.0	4.2	29.4	1.4
April	11.3	5.3*	32.2*	9.0*
May	8.4*	7.9	25.6	9.4
June	8.8	12.7	4.9	6.8
July	23.7	13.7	23.3	9.1
August	22.6+	27.3	6.4	18.9+
September		3.4+	15.0+	
TOTAL	103.5	82.6	161.2	63.8

[1]Central Crops Research Station
[2]Border Belt Tobacco Research Station
* denotes the month of transplanting. For CCRS in 2003, transplant date was May 9th and 2004 transplant date was April 26th . For BBTRS in 2003, transplant date was April 30th and 2003 transplant date was April 22nd. + denotes the month of final harvest. Data collected from the State Climate Office of North Carolina.

Table 2. Analyses of variance (p-values) for fresh weight per plant, number of suckers per plant, fresh weight per sucker, percent sucker control, yield, price index, acre index, grade index, total alkaloid concentration, and reducing sugar concentration.

SOURCE	df	Fresh weight/ plant	Suckers/ plant	Fresh weight/ sucker	Percent sucker control	Yield	Average price	Value per hectare	Grade index	Total alkaloids	Reducing sugars
FLM[1]	1	0.0001	0.0001	0.0157	0.0001	0.0010	0.0735	0.0010	0.1788	0.0001	0.3673
DIF[2]	1	0.0001	0.0075	0.0007	0.0001	0.0054	0.0853	0.0125	0.1176	0.5649	0.3722
MH[3]	3	0.0001	0.0201	0.0001	0.0001	0.0001	0.0001	0.0001	0.0035	0.0001	0.6750
MH * FLM	3	0.0001	0.0845	0.6347	0.0001	0.0001	0.0007	0.0001	0.0255	0.0020	0.8321
MH * DIF	3	0.0001	0.0558	0.3131	0.0001	0.0001	0.0038	0.0001	0.1412	0.0283	0.0727
FLM * DIF	1	0.0001	0.0052	0.1653	0.0007	0.0065	0.6252	0.0122	0.6138	0.0013	0.2796
Loc[4] *FLM	3	0.0001	0.0001	0.4622	0.0010	0.2628	0.5448	0.2360	0.8140	0.0001	0.2753
Loc * MH	9	0.0001	0.0001	0.0001	0.0666	0.0004	0.0001	0.0001	0.0430	0.0001	0.0715
Loc * DIF	3	0.0001	0.0173	0.0125	0.1205	0.0001	0.1742	0.0001	0.9609	0.0076	0.4401
Loc * FLM * DIF	3	0.0005	0.4336	0.5876	0.0162	0.0037	0.1971	0.0012	0.6754	0.0828	0.5576
Loc * MH * DIF	9	0.0001	0.5398	0.5237	0.0310	0.0018	0.0075	0.0015	0.1457	0.2022	0.4259
MH * FLM * DIF	3	0.0001	0.2768	0.3233	0.0002	0.0056	0.0054	0.0008	0.0893	0.0001	0.8411
Loc * MH * FLM	9	0.0001	0.0007	0.1513	0.5080	0.0035	0.0159	0.0009	0.5200	0.0009	0.4821
Loc * MH * FLM * DIF	9	0.0037	0.9301	0.5336	0.6955	0.0141	0.1551	0.0107	0.2856	0.0012	0.0838

[1]FLM = flumetralin
[2]DIF = diflflufenzopyr
[3]MH = maleic hydrazide
[4]Loc = location

Table 3. Percent sucker control with maleic hydrazide, flumetralin, and diflufenzopyr averaged over locations

	Percent control[1]			
	No diflufenzopyr		Diflufenzopyr[2]	
MH[3]	No flumetralin	Flumetralin[4]	No flumetralin	Flumetralin
kg ai / ha	. . . .%	. . . .		
0	0 f	73 b-e	64 e	83 abc
0.6	66 de	82 abc	70 cde	84 abc
1.3	62 e	93 a	79 a-d	84 abc
2.5	85 ab	79 a-d	85 ab	87 ab

[1]Means followed by the same letter are not significantly different.
[2]0.017 kg ai / ha
[3]Maleic hydrazide
[4]0.7 kg ai / ha

Table 4. Percent sucker control at four locations with maleic hydrazide and diflufenzopyr averaged over flumetralin rates

		Percent control[1]			
MH[2]	Diflufenzopyr	CCRS[3] 2003	BBTRS[4] 2003	CCRS 2004	BBTRS 2004
kg ai / ha		. . . .%.			
0	0	23 e	35 b	49 b	45 c
0	0.017	57 cd	82 a	61 a	93 ab
0.6	0	80 ab	81 a	56 a	79 b
0.6	0.017	48 d	92 a	71 a	96 ab
1.3	0	67 a-d	91 a	60 a	92 ab
1.3	0.017	65 a-d	97 a	68 a	97 ab
2.5	0	76 abc	97 a	57 a	100 a
2.5	0.017	82 a	97 a	64 a	100 a

[1]Means followed by the same letter within each column are not significantly different.
[2]Maleic hydrazide
[3]Central Crops Research Station
[4]Border Belt Tobacco Research Station

Table 5. Percent sucker control at four locations for flumetralin and diflufenzopyr averaged over maleic hydrazide rates

		Percent control[1]			
Flumetralin	Diflufenzopyr	CCRS[2] 2003	BBTRS[3] 2003	CCRS 2004	BBTRS 2004
kg ai / ha		. . . .	%.		
0	0	50 c	65 b	40 c	62 b
0.7	0	73 a	87 a	71 b	96 a
0	0.017	68 ab	89 a	47 c	94 a
0.7	0.017	58 bc	95 a	86 a	99 a

[1]Means followed by the same letter within each column are not significantly different.
[2]Central Crops Research Station
[3]Border Belt Tobacco Research Station

Table 6. Number of suckers per plant at four locations with maleic hydrazide and flumetralin averaged over diflufenzopyr rates

		Suckers per plant[1]			
MH[2]	FLM[3]	CCRS[4] 2003	BBTRS[5] 2003	CCRS 2004	BBTRS 2004
kg ai/ha		. . . . .number of suckers / plant			
0	0	0.78 a	3.26 a	4.05 b	3.65 a
0	0.7	0.33 a	1.01 bc	1.15 c	0.65 cd
0.6	0	0.29 a	2.00 b	3.75 b	2.28 b
0.6	0.7	0.21 a	0.83 b	0.78 c	0.45 d
1.3	0	0.30 a	1.05 bc	4.20 b	1.75 bc
1.3	0.7	0.33 a	0.28 c	1.98 c	0.56 c
2.5	0	0.18 a	0.50 c	7.25 a	0.33 d
2.5	0.7	0.33 a	0.19 c	1.45 c	0.06 d

[1]Means followed by the same letter within each column are not significantly different.
[2]Maleic hydrazide
[3]FLM = flumetralin
[4]Central Crops Research Station
[5]Border Belt Tobacco Research Station

Table 7. Number of suckers per plant at four locations with diflufenzopyr averaged over flumetralin and maleic hydrazide rates

	Suckers per plant[1]			
Diflufenzopyr	CCRS[2] 2003	BBTRS[3] 2003	CCRS 2004	BBTRS 2004
kg ai/ha	. . . . .number of suckers / plant			
0	0.36 a	1.52 a	2.99 a	1.73 a
0.017	0.32 a	0.76 b	3.16 a	0.70 b

[1]Means followed by the same letter within each column are not significantly different.
[2]Central Crops Research Station
[3]Border Belt Tobacco Research Station

Table 8. Number of suckers per plant with flumetralin and diflufenzopyr averaged over maleic hydrazide rates and locations

	Suckers per plant[1]	
Flumetralin	No diflufenzopyr	Diflufenzopyr[2]
kg ai /ha	. . . . number of suckers / plant.	
0	2.64 a	1.80 b
0.7	0.65 c	0.67 c

[1]Means followed by the same letter are not significantly different.
[2]0.017 kg ai / ha

Table 9. Fresh weight per sucker at four locations with diflufenzopyr averaged over maleic hydrazide and flumetralin rates

	Fresh weight per sucker[1]			
Diflufenzopyr	CCRS[2] 2003	BBTRS[3] 2003	CCRS 2004	BBTRS 2004
kg ai/ ha	. . . . .g / sucker.			
0	26 a	163 a	102 a	75 a
0.017	35 a	108 b	85 a	39 b

[1]Means followed by the same letter are not significantly different.
[2]Central Crops Research Station
[3]Border Belt Tobacco Research Station

Table 10. Fresh weight per sucker at four locations with maleic hydrazide averaged over diflufenzopyr and flumetralin rates

	Fresh weight per sucker[1]			
MH[2]	CCRS[3] 2003	BBTRS[4] 2003	CCRS 2004	BBTRS 2004
kg ai / ha	. . . . .g / sucker.			
0	36 a	230 a	121 a	107 a
0.6	37 a	109 b	87 ab	70 ab
1.3	29 a	88 b	87 ab	46 b
2.5	20 a	116 b	79 b	5 c

[1]Means followed by the same letter within each column are not significantly different.
[2]Maleic hydrazide
[3]Central Crops Research Station
[4]Border Belt Tobacco Research Station

Table 11. Main effect of flumetralin on fresh weight per sucker averaged over locations

Flumetralin	Fresh weight per sucker[1]
kg ai / ha	. . . . g / sucker. . . . .
0	88 a
0.7	70 b

[1]Means followed by the same letter are not significantly different.

Table 12. Sucker fresh weight per plant at CCRS[1] in 2003 with maleic hydrazide and diflufenzopyr, averaged over flumetralin rates

	Sucker fresh weight[2]	
MH[3]	No diflufenzopyr	Diflufenzopyr[4]
kg ai/ha	. . . . g / plant	
0	25 a	14 b
0.6	5 b	15 ab
1.3	10 b	10 b
2.5	7 b	6 b

Source	df	Pr > F
Maleic hydrazide (MH)	3	0.0043
Flumetralin (FLM)	1	0.4393
MH * FLM	3	0.8101
Diflufenzopyr (DIF)	1	0.6707
MH * DIF	3	0.0422
FLM * DIF	1	0.0842
MH * FLM * DIF	3	0.7459

[1]Central Crops Research Station
[2]Means followed by the same letter are not significantly different.
[3]Maleic hydrazide
[4]0.017 kg ai / ha

Table 13. Sucker fresh weight per plant at BBTRS[1] in 2003

	Sucker fresh weight[2]			
	No diflufenzopyr[3]		Diflufenzopyr	
MH[4]	No flumetralin	Flumetralin[5]	No flumetralin	Flumetralin
kg ai/ha	. . . . .g / plant			
0	1199 a	350 b	293 bc	148 d-g
0.6	268 bcd	188 cd	170 c-f	28 g
1.3	177 cde	37 fg	37 fg	26 g
2.5	48 efg	31 g	41 fg	25 g

Source	df	Pr > F
Maleic hydrazide (MH)	3	0.0001
Flumetralin (FLM)	1	0.0001
MH * FLM	3	0.0001
Diflufenzopyr (DIF)	1	0.0001
MH * DIF	3	0.0001
FLM * DIF	1	0.0002
MH * FLM * DIF	3	0.0001

[1]Border Belt Tobacco Research Station
[2]Means followed by the same letter are not significantly different.
[3]0.7 kg ai / ha
[4]Maleic hydrazide
[5]0.017 kg ai / ha

Table 14. Sucker fresh weight per plant at BBTRS[1] in 2004

	Sucker fresh weight[2]			
	No diflufenzopyr		Diflufenzopyr[3]	
MH[4]	No flumetralin	Flumetralin[5]	No flumetralin	Flumetralin
kg ai/ha	. . . . .g / plant			
0	1017 a	111 de	138 cd	20 fg
0.6	373 b	53 fg	65 ef	9 g
1.3	170 c	9 g	36 fg	33 fg
2.5	3 g	4 g	4 g	0 g

Source	df	Pr > F
Maleic hydrazide (MH)	3	0.0001
Flumetralin (FLM)	1	0.0001
MH * FLM	3	0.0001
Diflufenzopyr (DIF)	1	0.0001
MH * DIF	3	0.0001
FLM * DIF	1	0.0001
MH * FLM * DIF	3	0.0001

[1]Border Belt Tobacco Research Station
[2]Means followed bt the same letter are not significantly different.
[3]0.017 kg ai / ha
[4]Maleic hydrazide
[5]0.7 kg ai / ha

Table 15. Sucker fresh weight per plant at CCRS[1] in 2004 with maleic hydrazide and flumetralin, averaged over diflufenzopyr rates

	Sucker fresh weight[2]	
MH[3]	No flumetralin	Flumetralin[4]
kg ai/ha	. . . . g / plant	
0	634 a	98 d
0.6	386 bc	76 d
1.3	461 ab	93 d
2.5	296 b	213 c

Source	df	Pr > F
Maleic hydrazide (MH)	3	0.2153
Flumetralin (FLM)	1	0.0001
MH * FLM	3	0.0150
Diflufenzopyr (DIF)	1	0.3257
MH * DIF	3	0.6082
FLM * DIF	1	0.6172
MH * FLM * DIF	3	0.4127

[1]Central Crops Research Station
[2]Means followed by the same letter are not significantly different.
[3]Maleic hydrazide
[4]0.7 kg ai / ha

Table 16. Yield at BBTRS[1] in 2003

	Yield[2]			
	No diflufenzopyr		Diflufenzopyr[3]	
MH[4]	No flumetralin	Flumetralin[5]	No flumetralin	Flumetralin
kg ai / ha	. . . .	.kg / ha.	. . . .	
0	1522 g	2399 f	2490 ef	2719 a-d
0.6	2690 b-e	2748 a-d	2569 def	2604 c-f
1.3	2763 a-d	2806 abc	2782 a-d	2742 a-d
2.5	2912 ab	2921 a	2785 a-d	2621 c-f

Source	df	Pr > F
Maleic hydrazide (MH)	3	0.0001
Flumetralin (FLM)	1	0.0018
MH * FLM	3	0.0001
Diflufenzopyr (DIF)	1	0.0866
MH * DIF	3	0.0001
FLM * DIF	1	0.0051
MH * FLM * DIF	3	0.0297

[1]Border Belt Tobacco Research Station
[2]Means followed by the same letter are not significantly different.
[3]0.017 kg ai / ha
[4]Maleic hydrazide
[5]0.7 kg ai / ha

Table 17. Yield at BBTRS[1] in 2004

	Yield[2]			
	No diflufenzopyr		Diflufenzopyr[3]	
MH[4]	No flumetralin	Flumetralin[5]	No flumetralin	Flumetralin
kg ai / ha	. . . . .kg / ha.			
0	2589 d	3948 a	3352 c	3236 c
0.6	3594 abc	3922 a	3319 c	3328 c
1.3	3805 ab	3776 ab	3286 c	3281 c
2.5	3834 a	3856 a	3392 bc	3242 c

Source	df	Pr > F
Maleic hydrazide (MH)	3	0.0221
Flumetralin (FLM)	1	0.0194
MH * FLM	3	0.0070
Diflufenzopyr (DIF)	1	0.0001
MH * DIF	3	0.0330
FLM * DIF	1	0.0018
MH * FLM * DIF	3	0.0031

[1]Border Belt Tobacco Research Station
[2]Means followed by the same letter are not significantly different.
[3]0.017 kg ai / ha
[4]Maleic hydrazide
[5]0.7 kg ai / ha

Table 18. Average price at four locations with maleic hydrazide and flumetralin averaged over diflufenzopyr rates

		Average price			
MH[2]	Flumetralin	CCRS[3] 2003	BBTRS[4] 2003	CCRS 2004	BBTRS 2004
kg ai / ha		. . . .	$US / kg.	. . . .	
0	0	3.43 c	2.73 e	3.65 b	3.83 b
0	0.7	3.48 bc	3.17 d	3.67 ab	3.98 a
0.6	0	3.52 b	3.30 c	3.65 b	3.96 a
0.6	0.7	3.45 c	3.34 bc	3.70 ab	3.96 a
1.3	0	3.48 bc	3.37 ab	3.67 ab	3.98 a
1.3	0.7	3.59 a	3.34 bc	3.67 ab	3.98 a
2.5	0	3.50 b	3.43 a	3.72 a	4.00 a
2.5	0.7	3.43 c	3.30 c	3.72 a	3.94 a

[1]Means followed by the same letter within each column are not significantly different.
[2]Maleic hydrazide
[3]Central Crops Research Station
[4]Border Belt Tobacco Research Station

Table 19. Average price at four locations with maleic hydrazide and diflufenzopyr averaged over flumetralin rates

		Average price			
MH[2]	Diflufenzopyr	CCRS[3] 2003	BBTRS[4] 2003	CCRS 2004	BBTRS 2004
kg ai / ha		. . . .$US / kg.			
0	0	3.43 c	2.71 e	3.63 b	3.87 b
0	0.017	3.48 bc	3.17 d	3.70 a	3.96 a
0.6	0	3.45 c	3.28 c	3.72 a	3.98 a
0.6	0.017	3.52 ab	3.37 ab	3.63 b	3.94 a
1.3	0	3.48 bc	3.41 a	3.67 ab	4.00 a
1.3	0.017	3.56 a	3.30 c	3.67 ab	3.98 a
2.5	0	3.43 c	3.39 ab	3.70 a	3.98 a
2.5	0.017	3.48 bc	3.34 bc	3.72 a	3.96 a

[1]Means followed by the same letter within the same column are not significantly different.
[2]Maleic hydrazide
[3]Central Crops Research Station
[4]Border Belt Tobacco Research Station

Table 20. Average price with maleic hydrazide, flumetralin, and diflufenzopyr averaged over locations

	Average price			
	No diflufenzopyr		Diflufenzopyr[2]	
MH[3]	No flumetralin	Flumetralin[4]	No flumetralin	Flumetralin
kg ai / ha	. . . .$US / kg.			
0	3.26 b	3.56 a	3.56 a	3.59 a
0.6	3.63 a	3.61 a	3.59 a	3.63 a
1.3	3.65 a	3.63 a	3.59 a	3.67 a
2.5	3.67 a	3.59 a	3.65 a	3.61 a

[1]Means followed by the same letter are not significantly different.
[2]0.017 kg ai / ha
[3]Maleic hydrazide
[4]0.7 kg ai / ha

Table 21. Value per hectare at BBTRS[1] in 2003 with diflufenzopyr and flumetralin averaged over maleic hydrazide rates

	Value[2]			
	No diflufenzopyr		Diflufenzopyr[3]	
MH[4]	No flumetralin	Flumetralin[5]	No flumetralin	Flumetralin
kg ai / ha	. . . .	$US / ha.		
0	3507 f	7514 e	7820 de	8802 bcd
0.6	8886 bcd	9005 abc	8533 cde	8911 bcd
1.3	9617 abc	9427 abc	9126 abc	9123 abc
2.5	10099 a	9728 ab	9506 abc	8647 b-e

Source	df	Pr > F
Maleic hydrazide (MH)	3	0.0001
Flumetralin (FLM)	1	0.0146
MH * FLM	3	0.0001
Diflufenzopyr (DIF)	1	0.0999
MH * DIF	3	0.0001
FLM * DIF	1	0.0612
MH * DIF * FLM	3	0.0178

[1]Border Belt Tobacco Research Station
[2]Means followed by the same letter are not significantly different.
[3]0.017 kg ai / ha
[4]Maleic hydrazide
[5]0.7 kg ai / ha

Table 22. Value per hectare at BBTRS[1] in 2004

	Value[2]			
	No diflufenzopyr		Diflufenzopyr[3]	
MH[4]	No flumetralin	Flumetralin[5]	No flumetralin	Flumetralin
kg ai / ha	. . . .	.$US / ha.	. . . .	. . . .
0	9600 d	15958 a	13306 c	12822 c
0.6	14351 abc	15679 a	13072 c	13106 c
1.3	15185 ab	15190 ab	13126 c	13029 c
2.5	15435 a	15331 a	13531 bc	12795 c

Source	df	Pr > F
MH	3	0.0120
Flumetralin (FLM)	1	0.0139
MH * FLM	3	0.0016
Diflufenzopyr (DIF)	1	0.0001
MH * DIF	3	0.0176
FLM * DIF	1	0.0008
MH * FLM * DIF	3	0.0010

[1]Border Belt Tobacco Research Station
[2]Means followed by the same letter are not significantly different.
[3]0.017 kg ai / ha
[4]Maleic hydrazide
[5]0.7 kg ai / ha

Table 23. Grade index at four locations with maleic hydrazide averaged over diflufenzopyr and flumetralin rates

	Grade index[1]			
MH[2]	CCRS[3] 2003	BBTRS[4] 2003	CCRS 2004	BBTRS 2004
kg ai / ha				
0	52.2 b	32.8 b	70.9 a	80.9 a
0.6	56.2 ab	44.1 a	68.3 a	82.8 a
1.3	59.9 a	46.5 a	69.1 a	84.1 a
2.5	54.6 ab	43.9 a	70.4 a	83.4 a

[1]Means followed by the same letter within each column are not significantly different.
[1]Based on U.S. Government grades; 1-100 scale, with 100 being the best.
[2]Maleic hydrazide
[3]Central Crops Research Station
[4]Border Belt Tobacco Research Station

Table 24. Grade index with maleic hydrazide and flumetralin rates averaged over diflufenzopyr rates and locations

	Grade index[1]	
MH[2]	No flumetralin	Flumetralin[3]
kg ai / ha		
0	57.1 c	61.3 bc
0.6	60.9 bc	64.7 ab
1.3	63.8 ab	65.9 a
2.5	65.2 ab	61.0 bc

[1]Means followed by the same letter are not significantly different.
[1] Based on U.S. Government grades; 1-100 scale, with 100 being the best.
[2]Maleic hydrazide
[3]0.7 kg ai / ha

Table 25. Total alkaloids at BBTRS[1] in 2003 with flumetralin, diflufenzopyr, and maleic hydrazide rates

	Total alkaloids[2]			
	No diflufenzopyr		Diflufenzopyr[3]	
MH[4]	No flumetralin	Flumetralin[5]	No flumetralin	Flumetralin
kg ai / ha	. . . .	. . . . %.	. . . .	. . . .
0	1.75 e	3.37 a-d	3.10 d	3.15 d
0.6	3.38 a-d	3.21 cd	3.11 d	3.41 a-d
1.3	3.16 d	3.63 ab	3.44 a-d	3.66 ab
2.5	3.28 bcd	3.69 a	3.42 a-d	3.58 abc

Source	df	Pr > F
Maleic hydrazide (MH)	3	0.0001
Flumetralin (FLM)	1	0.0001
MH * FLM	3	0.0017
Diflufenzopyr (DIF)	1	0.0178
MH * DIF	3	0.0256
FLM * DIF	1	0.0067
MH * FLM * DIF	3	0.0001

[1]Border Belt Tobacco Research Station
[2]Means followed by the same letter are not significantly different.
[3]0.017 kg ai / ha
[4]Maleic hydrazide
[5]0.7 kg ai / ha

Table 26. Total alkaloids at CCRS[1] in 2004 with flumetralin, diflufenzopyr, and maleic hydrazide rates

	Total alkaloids[2]			
	No diflufenzopyr		Diflufenzopyr[3]	
MH[4]	No flumetralin	Flumetralin[5]	No flumetralin	Flumetralin
kg ai / ha	. . . .	%.		
0	1.63 d	2.02 ab	1.78 bcd	1.83 a-d
0.6	1.72 cd	2.02 ab	1.71 cd	1.86 a-d
1.3	2.07 a	1.69 cd	1.75 bcd	1.79 bcd
2.5	1.92 abc	2.01 ab	1.92 abc	1.85 a-d

Source	df	Pr > F
Maleic hydrazide (MH)	3	0.3126
Flumetralin (FLM)	1	0.1435
MH * PP	3	0.0124
Diflufenzopyr (DIF)	1	0.1301
MH * DIF	3	0.9272
FLM * DIF	1	0.5500
MH * FLM * DIF	3	0.0417

[1]Central Crops Research Station
[2]Means followed by the same letter are not significantly different.
[3]0.017 kg ai / ha
[4]Maleic hydrazide
[5]0.7 kg ai / ha

Table 27. Main effect of maleic hydrazide on total alkaloids at BBTRS[1] in 2004 averaged over locations

MH[2]	Total alkaloids[3]
kg ai / ha	. . . .%. . . . .
0	2.03 b
0.6	2.33 a
1.3	2.17 ab
2.5	2.25 a

Source	df	Pr > F
Maleic hydrazide (MH)	3	0.0091
Flumetralin (FLM)	1	0.8234
MH * FLM	3	0.3199
Diflufenzopyr (DIF)	1	0.4421
MH * DIF	3	0.4084
FLM * DIF	1	0.1032
MH * FLM * DIF	3	0.1482

[1]Border Belt Tobacco Research Station
[2]Maleic hydrazide
[3]Means followed by the same letter are not significantly different.

Table 28. Maleic hydrazide and diflufenzopyr residue levels at the BBTRS[1], CCRS[2], and OTRS[3] locations

Treatment	Rate	BBTRS 2003	BBTRS 2004	CCRS 2004	CCRS 2002	OTRS 2002
	kg ai/ha	. . . .	. . . .	. . . . ppm . . .	. . . .	. . . .
MH[4]	0.63	31	10	BDL[5]		
MH	1.26	68	30	12		
MH	2.52	152	58	25		
MH Diflufenzopyr	0.63 0.017	25	10	BDL[5]		
MH Diflufenzopyr	1.26 0.017	84	16	12		
MH Diflufenzopyr	2.52 0.017	119	35	25		
Diflufenzopyr	0.281				BDL[6]	BDL[6]
Diflufenzopyr	0.561				BDL[6]	BDL[6]

[1]Border Belt Tobacco Research Station
[2]Central Crops Research Station
[3]Oxford Tobacco Research Station
[4]Maleic hydrazide
[5]Below detection limit of 10 ppm, by Southern Testing and Research Laboratories, 3809 Airport Dr. NW, Wilson NC 27896-8649
[6]Below detection limit of 0.05 ppm, by BASF