Chapter 8

# Herbicides Used in Tobacco

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/56008

## 1. Introduction

Tobacco is a major and economically important crop in many countries worldwide, with 6.91 million tons produced annually, mainly in China, India, Brazil, Zimbabwe, Turkey, Indonesia, Russia, Malawi, nations of the European Union, and the United States [1]. In the United States alone, approximately 360,000 tons are produced annually at a value of more than $USD 1.25 billion [2]. Although there are at least 14 different types of tobacco grown around the world, all are affected by pests. Disease and insect pests are of primary importance in tobacco production, but weeds are also a major focus of pest control in tobacco. Although weeds may not cause as much direct damage to tobacco as diseases and insects, weeds present in tobacco can influence tobacco yield and quality, cause harvest interference, and serve as hosts for disease and insects. Although tobacco is considered to be very competitive with weeds relative to other crops, use of herbicides, usually supplemented with cultivation, is still a primary component of weed control. The objective of the research presented here is to provide a more thorough understanding of the effects of weeds in tobacco and the characteristics of major herbicides available to control these weeds in tobacco production in the United States.

### 1.1. Competitive effects of weeds on tobacco yield and quality

Weeds directly compete with tobacco for light, water, nutrients, carbon dioxide, and space and can negatively impact tobacco yield and quality. In addition, the quality of the final product may be further affected due to the presence of foreign plant material, referred to in the tobacco industry as Non-Tobacco Related Material (NTRM).

The most direct impact of weed competition in tobacco is reduced leaf yield. Leaf quality can also be negatively affected if weeds physically damage tobacco before or during harvest. Contamination of the harvested tobacco crop by green weed vegetation or reproductive parts of weeds has the largest effect on tobacco quality [3, 4]. Chemical exudates from weedy species that contaminate tobacco leaves and remain until the tobacco is processed can also impact leaf chemical balance and resulting flavor of manufactured tobacco products.

The critical weed-free period is a phrase that is used to describe the period during crop production in which weeds are most likely to reduce crop growth and yield. This is the time period during which weed control efforts must be maintained to prevent crop yield loss. The significance of the critical weed-free period is that, if the crop is maintained weed-free for this period, it will be able to effectively compete with late-emerging weeds without sustaining yield loss. Critical weed-free periods are influenced by the competitiveness of the individual crop species and weed species. For most crops, the critical weed-free period for most weeds is 4 to 6 weeks after crop emergence. Since tobacco is transplanted in the field rather than seeded, it is inherently more competitive with weeds than direct-seeded crops. For this reason, the critical weed-free period for tobacco may be 1 to 2 weeks shorter than for direct seeded crops. In addition, the large leaves which most types of tobacco produce makes it more competitive than many other crops by having a greater ability to reduce photosynthetic ability of weeds growing under the tobacco canopy. Flue-cured tobacco maintained free of common ragweed (*Ambrosia artemesiifolia* L.) for two weeks following transplanting did not sustain significant yield losses from common ragweed that emerged later [4]. For most weed species, maintaining weed-free or near weed-free conditions for 6 weeks after transplanting allows tobacco to shade out weeds that emerge later in the season [5]. In Greece, yield of burley and oriental tobacco increased significantly with weed-free periods of 3 or 4 weeks and decreased when weeds were allowed to compete with tobacco for more than 3 to 4 weeks after transplanting. When yield was reduced due to weed competition, there were also differences in chemical composition of the tobacco [6]. Natural populations of weeds that were allowed to compete with dark tobacco for the entire season resulted in a 28% to 40% reduction in total yield compared to tobacco plots treated with herbicides [7, 8].

If weeds are allowed to compete with tobacco for the entire season, the level of competition that weeds impose is also influenced by the density of the weeds that are present in the crop. In general, crop yield decreases as weed density increases. Different weed species also have different competitive ability with tobacco and thus can effectively compete at lower densities than other species. In general, dicots (broadleaf weeds) are more competitive with tobacco than monocots (grass weeds). Within broadleaf and grass weeds, individual species can be more competitive with tobacco than others. For example, among broadleaf species, Eastern black nightshade (*Solanum ptycanthum* L.) has a more rapid growth, higher photosynthetic ability, and a more erect growth habit than black nightshade (*Solanum nigrum* L.), and is more competitive with tobacco. Among grass species, giant foxtail (*Setaria glauca* L.) is more competitive than either green (*Setaria viridis* L.) or yellow foxtail (*Setaria faberii* L.). Much of these differences in competitiveness can be attributed to differences in plant size among species. Perennial weed species are also generally more competitive and difficult to control in tobacco than annual weed species. Perennial species generally have a more extensive root system and extensive energy reserves than annual species.

Differences in root elongation rate also influence differences in competitiveness by affecting water and nutrient absorption potential. Among weedy broadleaf species, common cocklebur

http://dx.doi.org/10.5772/56008

(*Xanthium strumarium* L.) has the greatest root elongation rate and extracts the greatest amount of moisture per unit area of soil [9]. Under field conditions, the water requirements for various weed species vary from 150 to 1900 kg water per kg dry matter produced. Of the nutrients that weeds and tobacco compete for, nitrogen is often the first nutrient to come into short supply as a result of competition. Weeds are commonly better assimilators of nutrients than crop plants, normally possessing 50 to 100% more nitrogen than the crop plant based on a whole plant dry weight basis [10].

Where water and nutrients are adequate, low light intensity that occurs from shading plays a major role in limiting plant growth. Plants compete for light by positioning their leaves to intercept available light more favorably than neighboring plants. Plants that exhibit more rapid early-season growth and have upright growth to grow taller than neighboring plants will be most successful in competition for light. Broadleaved crops such as tobacco have a distinct competitive advantage over grass plants or sedges that have narrow leaves. Tall, dense crops like tobacco successfully compete with shorter plants for light, particularly when weed emergence occurs later in the season after tobacco is well established and tobacco can easily impose a shading effect on newly emerged weed seedlings.

Aside from directly competing with tobacco to reduce marketable yield and quality, many weed species are troublesome with tobacco due to their ability to interfere with harvest operations. Tobacco crops that are heavily infested with weeds, even relatively non-competitive weeds, can have reduced yield through competition before harvest and even more during harvest. Weed species with twining or climbing growth habits such as morningglory species (*Ipomoea* spp.), honeyvine milkweed (*Ampelamus albidus* [Nutt.] Britt.), or common bindweed (*Convolvulus arvensis* L.) may not be very competitive with tobacco during the growing season, but can cause dramatic losses at harvest, even when weed densities are relatively low. A single climbing weed in a tobacco crop may become entangled in several tobacco plants and cause leaf damage and loss both prior to and during harvest. Infestations from weeds that become entwined around tobacco stalks are troublesome during hand harvest operations but even more troublesome for mechanical harvesting systems. Presence of morningglory at an average density of 1 plant per 10 $m^2$ has caused a 5% reduction in harvested yield of dark tobacco in Kentucky USA due to damage and leaf loss during hand harvest (W.A. Bailey, unpublished data). Mechanical harvesters that encounter morningglory entwined in tobacco at similar densities would likely incur greater leaf losses as well as sustain extensive damage to the harvester itself. Parts of weedy plants that remain in the tobacco crop through curing are more likely to become NTRM, causing extensive reduction in price and likely reduction in marketing opportunities for future crops.

### 1.2. Weeds as alternate hosts to other pests in tobacco

Weeds can act as a major host site for other tobacco pests such as diseases, insects, and nematodes. Many weeds that commonly occur around tobacco fields can harbor other pests and result in increased infection on tobacco crops. Generally, weed species that have the closest botanical relationship to tobacco, such as solanaceous weed species, are most likely to harbor pests that can infest tobacco. However, many plant species with little botanical relationship to tobacco can also serve as hosts. For example, *Datura* species such as Jimsonweed are common alternate hosts to at least 12 tobacco diseases, at least one nematodes species, and at least 3 major insect pests of tobacco. *Nicandra* species such as Apple-of-Peru are common alternate hosts to at least 4 major tobacco diseases including blue mold, brown spot, bushy top virus, and vein banding virus.

### 1.3. Diseases

Table 1 lists weed species that commonly act as alternate hosts for tobacco diseases. Many diseases have an extremely wide host range and so only the number of species, families, genera, or most common host species are listed. Reference materials [11-14] were used to construct Tables 1, 2. and 3.

| Disease | Causal Agent | Hosts Species | Plant Families | Common Weedy Hosts |
|---|---|---|---|---|
| Bacterial Wilt | *Pseudomonas solanacearum* | 197 | 33 | Common ragweed (*Ambrosia art*emisiifolia L.)<br>Pennsylvania smartweed (*Polygonum pennsylvanicum* L.) |
| Hollow stalk | *Erwinia* sp. | 120 | Solanaceae<br>Brassicaceae<br>Cucurbitaceae | *Solanum* sp. |
| Wildfire / Angular leafspot | *Pseudomonas syringae* pv. tabaci | Many | Most common: *Solanaceae* | Jimsonweed (*Datura stramonium* L.)<br>Smartweed species (*Polygonum* sp.)<br>Shepards-purse (*Capsella bursa-pastoris* L.)<br>Black nightshade (*Solanum nigrum* L.)<br>Barnyardgrass (*Echinochloa crus-galli* L.)<br>Dandelion (*Taraxacum officinale* Weber) |
| Tobacco Mosaic Virus (TMV) | Various | 350 | 29<br>Most common:<br>Solanaceae<br>Compositae<br>Hydrophyllaceae<br>Scrophulariaceae | Horsenettle (*Solanum carolinense* L.)<br>Ground cherry (*Physalis angulata* L.)<br>Jimsonweed (*Datura stramonium* L.) |
| Vein Banding Virus | Various | many | Most common: *Solanaceae* | (*Solanum* sp.)<br>*Chenopodium* sp. |

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| **Disease** | **Causal Agent** | **Hosts Species** | **Plant Families** | **Common Weedy Hosts** |
|---|---|---|---|---|
| | | | | Groundcherry species<br>(*Physalis* sp.)<br>Apple of Peru<br>Nicandra physaloides (L.) Pers. |
| Stolbur | Mycoplasma | 65 | 24 | Field Bindweed<br>(*Convolvulus arvensis* L.) |
| Aster yellows | Mycoplasma | 175 | 52 | Dodder<br>(*Cuscuta* sp.) |
| Tomato Spotted Wilt Virus (TSWV) | Various | 166 | 34 | Dandelion<br>(*Taraxacum officinale* L.)<br>Spiny amaranth<br>(*Amaranthus spinosus* L.)<br>Jimsonweed<br>(*Datura stramonium* L.)<br>Clasping coneflower<br>(Rudbeckia amplexicaulis Vahl.)<br>Brazilian vervain<br>(Verbena brasiliensis Velloso)<br>Mouseear chickweed<br>(Cerastium vulgatum)<br>Prickly lettuce<br>(Lactuca scariola)<br>Carpetweed<br>(Mollugo verticillata)<br>Blackseed plantain<br>(Plantago rugelii)<br>Hairy buttercup<br>(Ranunculus sardous)<br>Spiny sowthistle<br>(Sonchus asper)<br>Common chickweed<br>(Stellaria media)<br>Hairy bittercress<br>(Cardamine hirsuta)<br>Dogfennel<br>(Eupatorium capillifolium)<br>Carolina geranium<br>(Geranium carolinianum)<br>Purple cudweed<br>(Gnaphalium purpureum) |

| Disease | Causal Agent | Hosts Species | Plant Families | Common Weedy Hosts |
|---|---|---|---|---|
| | | | | Blue toadflax<br>(Linaria canadensis)<br>Carolina desert-chicory<br>(Pyrrhopappus carolinianus)<br>Wild radish<br>(Raphanus raphanistrum)<br>Venus' looking-glass<br>(Triodanis perfoliata) |
| Cucumber Mosaic Virus (CMV) | Various | many | 36 dicot families<br>4 monocot families | Carolina geranium<br>(*Geranium carolineanum* L.)<br>Cutleaf groundcherry<br>(*Physalis angulata* L.)<br>Dayflower<br>(*Commelina nudiflora* L.)<br>American pokeweed<br>(*Phytolacca americana* [L.] *var. rigida* [Small]<br>Caulkins & Wyatt<br>Common Chickweed<br>(*Stellaria media* L.)<br>Jimsonweed<br>(*Datura stramonium* L.)<br>Chenopodium sp. |
| Tobacco Etch Virus (TEV) | Various | 69 | 11 | *Solanum* sp.<br>Jimsonweed<br>(*Datura stramonium* L.) |
| Tobacco Vein Mottle Virus (TVMV) | Various | | *Solanaceae* | Horsenettle<br>(*Solanum carolinense* L.)<br>Cutleaf groundcherry<br>(*Physalis angulata* L.) |
| Bushy Top Virus | Various | | *Solanaceae* | Jimsonweed<br>(*Datura stramonium* L.)<br>Apple of Peru<br>(*Nicandra physaloides* [L.] Scop.) |
| Peanut Stunt Virus (PSV) | Various | | Fabaceae<br>Solanaceae | Kudzu<br>(*Pueraria thumbergiana* [Sieb. & Succ.] Benth.)<br>Jimsonweed<br>(*Datura strumonium* L.) |
| Alfalfa Mosaic Virus (AMV) | Various | 305 | 47 | Jimsonweed<br>(*Datura stramonium* L.) |

http://dx.doi.org/10.5772/56008

| Disease | Causal Agent | Hosts Species | Plant Families | Common Weedy Hosts |
|---|---|---|---|---|
| Tobacco Leaf Curl Virus (TLCV) | Various | Many | 14<br>Most common:<br>Malvaceae<br>Euphorbiaceae<br>Fabaceae<br>Solanaceae | *Datura* sp.<br>*Physalis* sp.<br>*Solanum* sp.<br>*Sida* sp.<br>Least snoutbean<br>(*Rhynchosia minima* [L.] DC) |
| Beet Curly Top Virus (BCTV) | Various | 244 | | Bristly starbur<br>(*Acanthospermum hispidum* L.) |
| Tobacco Rattle Virus (TRV) | Various | 380 | Many | Shepards-purse<br>(*Capsella bursa-pastoris* L.)<br>Black nightshade<br>(*Solanum nigrum* L.)<br>Common chickweed<br>(*Stellaria media* L.)<br>Henbit<br>(*Lamium amplexicaule* L.)<br>Redroot pigweed<br>(*Amaranthus retroflexus* L.)<br>Spiny sowthistle<br>(*Sonchus asper* [L.] All.)<br>Flixweed<br>(*Descurainia sophia* L.)<br>Redstem filaree<br>(*Erodium cicutarium* L.) |
| Tobacco Ringspot Virus (TRSV) | Various | Many | Many<br>Most common:<br>Solanaceae<br>Compositae<br>Cucurbitaceae<br>Scrophulariaceae | Common ragweed<br>(*Ambrosia artemisiifolia* L.)<br>Wild carrot<br>(*Daucus carota* L.)<br>Dandelion<br>(*Taraxacum officinale* L.)<br>Horsenettle<br>(*Solanum carolinense* L.)<br>Groundcherry<br>(*Physalis* sp.)<br>Common pokeweed<br>(*Phytolacca americana* L.)<br>Jimsonweed<br>(*Datura stramonium* L.) |

| Disease | Causal Agent | Hosts Species | Plant Families | Common Weedy Hosts |
|---|---|---|---|---|
| Tobacco Streak Virus (TSV) | Various | Many | 31 | Common burdock (*Arctium minus* [Hill] Bernh.)<br>Field bindweed (*Convolvulus arvensis* L.)<br>Plantain (*Plantago* sp.)<br>White clover (*Trifolium repens* L.)<br>*Crotalaria* sp.<br>Jimsonweed (*Datura stramonium* L.) |
| Tobacco necrosis virus (TNV) | *Olpidium brassicae* (Wor.) Dang | 88 | 37 | |
| Tobacco stunt virus (TSV) | *Olpidium brassicae* (Wor.) Dang | | | *Chenopodium* sp. |
| Potato Virus Y (PVY) | Various | | *Solanaceae* (most common), also *Amaranthaceae, Chenopodiaceae, Compositae, Fabaceae* | |
| Damping off Stem/root rot | *Pythium* sp. | | At least 270 genera | |
| Sore shin | *Rhizoctonia solani* Kuhn | 230 | 66 | |
| Southern Stem/ Root Rot | *Sclerotium rolfsii* Sacc. | 189 | *Compositae* | |
| Fusarium wilt | *Fusarium oxysporum* (Schlecht) Wr. f. *nicotianae* Johnson | Many | | |
| Verticillium wilt | *Verticillium alboatrum* Reinke and Berth | 250 | Dicots | |
| Olpidium seedling blight | *Olpidium brassicae* (Wor.) Dang | Many | Most common:<br>Cruciferae<br>Graminae<br>Brassicacae | Shepards-purse (*Capsella bursa-pastoris* [L.]Medik)<br>Common lambsquarters (*Chenopodium album* L.) |

| **Disease** | **Causal Agent** | **Hosts Species** | **Plant Families** | **Common Weedy Hosts** |
|---|---|---|---|---|
| | | | | White poplar<br>(*Populus alba* L.) |
| Black Root Rot | *Thielaviopsis basicola* (Berk. And Br.) Ferraris | 137 | 33<br>Most common:<br>Fabacae<br>Solanaceae<br>Cucurbitaceae | |
| Charcoal Rot | *Macrophominapha seoli* (Maubl.) | >300 | | |
| Blue Mold | Peronospora tabacina D. B. Adam | Mainly *Nicotiana* | *Solanaceae* | Poorman's orchid<br>(*Schizanthus pinnatus* Ruiz & Pav.<br>Egyptian henbane)<br>(*Hyoscyamus muticus* L.)<br>Lanceleaf groiundcherry<br>(*Physalis lancifolia* L.)<br>Belladonna<br>(*Atropa belladonna* L.)<br>Apple of Peru<br>*Nicandra physalodes* (L.) Scop.) |
| Brown Spot | *Alternaria alternata* | 56 | 19<br>Most common:<br>*Solanaceae* | Jimsonweed<br>(*Datura stramonium* L.)<br>Apple of Peru<br>(*Nicandra physalodes* [L.] Scop.) |
| Powdery mildew | *Erysiphe cichoracearum* DC | Many | 115 genera<br>Main families:<br>Cucurbitaceae<br>Compositae | |
| Frogeye leafspot | *Cercospora nicotianae* Ellis. & Everhart | 28 | 16 | |
| Anthracnose | Colletotrichum nicotianae Boning | Many | Many | Some grasses<br>Common pokeweed<br>(*Phytolacca americana* L.)<br>Geranium<br>(*Geranium* sp.)<br>Lettuce<br>(*Lactuca* sp.) |

**Table 1.** Common weeds that serve as alternate hosts for tobacco diseases.

*Nematodes*

Table 2 lists weed species that act as alternate hosts to nematodes that may infect tobacco.

| Nematode species | Genus | Number of Hosts Species | Number of Plant Families | Common weedy hosts |
|---|---|---|---|---|
| Root knot nematode | *Meloidogyne* sp. | >3,000 | Most major plant families.<br>Dicots and monocots. | |
| Tobacco cyst nematode | *Globodera* sp. | At least 45 | Most common:<br>*Solanaceae* | |
| Brown root rot (Lesion nematodes) | *Pratylenchus* sp. | >500 | Most common:<br>Graminae<br>Fabaceae<br>Solanaceae<br>Compositae | Large crabgrass<br>(*Digitaria sanguinalis* L.)<br>Horsenettle<br>(*Solanum carolinense* L.) |
| Stem-break (Stem and Bulb nematode) | *Ditylenchus dipsaci* [Kuhn] Filipjev | >400 | 44 | |
| Stunt nematode | *Tylenchorhynchus* sp. | Many | Many<br>Common families:<br>Graminae<br>Solanaceae | |
| Stubby root nematode | *Trichodorus* sp. | At least 51 | 15<br>Most common:<br>Fabaceae<br>Graminae<br>Euphorbiaceae | Fescue<br>(*Festuca* sp.)<br>Lettuce<br>(*Lactuca* sp.)<br>Vetch<br>(*Vicia* sp.)<br>Wild onion<br>(*Allium canadense* L.)<br>Lespedeza<br>(*Lespedeza* sp.)<br>Showy crotalaria<br>(*Crotalaria spectabilis* L.)<br>Jimsonweed<br>(*Datura stramonium* L.) |

**Table 2.** Common weeds that serve as hosts for nematodes.

http://dx.doi.org/10.5772/56008

*Insects*

Table 3 lists weeds species that serve as alternate hosts for insects that may attack tobacco.

| Insect | Genus | Number of host species | Number of host families | Common Weedy Hosts |
|---|---|---|---|---|
| Green peach aphid<br>Red tobacco aphid | Myzus persicae<br>Myzus nicotianae | Many | Many<br>Most common:<br>Solanaceae<br>Amaranthaceae,<br>Chenopodaceae,<br>Compositae,<br>Fabaceae<br>Brassicacae | *Solanum* sp.<br>*Chenopodium* sp.<br>Groundcherry<br>(*Physalis virginiana* Mill.)<br>Virginia pepperweed<br>(*Lepidium virginicum* L.)<br>Tansymustard<br>(*Descurainia pinnata* L.)<br>Curly dock<br>(*Rumex crispus* L.)<br>Jimsonweed<br>(*Datura stramonium* L.)<br>Common chickweed<br>(*Stellaria media* L.)<br>Dayflower<br>(*Commelina* sp.)<br>Kudzu<br>(*Pueraria lobata* L.)<br>Common ragweed<br>(*Ambrosia artemisiifolia* L.) |
| Western Flower Thrips | *Frankliniella* sp. | Many | Many | Dandelion<br>(*Taraxacum officinale* L.)<br>Spiny amaranth<br>(*Amaranthus spinosus* L.)<br>Jimsonweed<br>(*Datura stramonium* L.) |
| Flea beetle | *Epitrix* sp. | Many | Many | Horsenettle<br>(*Solanum carolinense* L.)<br>Morningglory sp.<br>(*Ipomoea* sp.) |
| Cabbage looper | *Trichoplusia ni* | Many | Solanaceae<br>Brassicaceae | Black nightshade<br>(*Solanum nigrum* L.)<br>Wild mustard<br>(*Brassica napus* L.)<br>Peppergrass<br>(*Lepidium* spp.) |

| Insect | Genus | Number of host species | Number of host families | Common Weedy Hosts |
|---|---|---|---|---|
| Cutworms | *Lepidoptera* sp. | Many | Many | Field bindweed (*Convolvulus arvensis* L.)<br>Canada thistle (*Cirsium arvense* L.) |
| Hornworm | *Manduca sexta* | | *Solanaceae* only | Horsenettle (*Solanum carolinense* L.)<br>Jimsonweed (*Datura stramonium* L.)<br>Nightshade species |
| Budworm | *Heliothis virescens* F. | Many | Many | Beardstongue (*Penstemon laevigatus* Aiton)<br>Beggarweed (*Desmodium* spp.)<br>Bicolor lespedeza (*Lespedeza bicolor* Turcz.)<br>Black medic (*Medicago lupulina* L.)<br>Cranesbill (*Geranium dissectum* L.)<br>Deergrass (*Rhexia* spp.)<br>Dock (*Rumex* spp.)<br>Groundcherry (*Physalis* spp.)<br>Japanese honeysuckle (*Lonicera japonica* Thunb.)<br>Lupine (*Lupinus* spp.)<br>Morningglory (*Ipomoea* spp.)<br>Passionflower (*Passiflora* spp.)<br>Prickly sida (*Sida spinosa* L.)<br>Sunflower (*Helianthus* spp.)<br>Toadflax |

| Insect | Genus | Number of host species | Number of host families | Common Weedy Hosts |
|---|---|---|---|---|
| | | | | (*Nuttallanthus canadensis* [L.] D.A. Sutton) Velvetleaf (*Abutilon theophrasti* Medik.) |

**Table 3.** Common weeds that serve as hosts for insects.

### 1.4. Most common and troublesome weeds in tobacco

It is not the intention here to list every possible weed problem that exists in tobacco. Some species can be found in numerous tobacco growing regions while others are region specific. However, several plant families do have species that are common and problematic in many tobacco production regions. According to a weed survey conducted across several tobacco-growing regions of the world in 2006 (W. A. Bailey, unpublished data), the five most common and troublesome weed genera in tobacco are: *Amaranthus*, *Cyperus*, *Digitaria*, *Chenopodium*, and *Ipomoea.* Descriptions of each genera are adapted from references [15, 16, 17]. Table 4 lists the most common and troublesome weeds in the most prevalent tobacco growing regions around the world based on the 2006 survey of tobacco growing regions.

| Weed Species | Plant Family | Scientific Name |
|---|---|---|
| *Broadleaf seed species:* | | |
| Redroot pigweed | *Amaranthaceae* (pigweed family) | *Amaranthus retroflexus* |
| Yellow nutsedge | *Cyperaceae* (sedge family) | *Cyperus esculentus* |
| Ivyleaf morningglory | *Convolvulaceae* (morningglory family) | *Ipomoea hederacea* |
| Common lambsquarters | *Chenopodiaceae* (Goosefoot family) | *Chenopodium album* |
| Common ragweed | *Asteraceae* (sunflower family) | *Ambrosia artemisiifolia* |
| Horsenettle | *Solanaceae* (nightshade family) | *Solanum carolinense* |
| *Grass weed species:* | | |
| Large crabgrass | *Poaceae* (grass family) | *Digitaria sanguinalis* |
| Goosegrass | *Poaceae* (grass family) | *Eleusine indica* |
| Fall panicum | *Poaceae* (grass family) | *Panicum dichotomiflorum* |
| Giant foxtail | *Poaceae* (grass family) | *Setaria faberi* |
| Johnsongrass | *Poaceae* (grass family) | *Sorghum halepense* |

**Table 4.** Most common and troublesome weeds in tobacco worldwide.

## 2. Cultural practices for weed control in tobacco

### 2.1. Site selection, rotation, and scouting

Integrated weed management involves using practices that reduce weed infestations but does not necessarily eliminate all weeds. Weed control can range from poor to excellent, depending on the characteristics of the weed species involved and the effectiveness of the control practices used. A small number of weeds with relatively lower competitive ability than tobacco can be allowed to remain in the crop without negatively influencing yield, quality, or harvest efficiency. Weed control practices available for tobacco can be placed into four general groups: 1) preventative; 2) cultural; 3) mechanical or physical; and 4) chemical.

Preventative weed control involves taking measures to prevent the introduction, establishment, or spread of weed species into areas that are not currently infested with these species. Preventative weed control practices for tobacco can include measures such as using weed-free seed and weed-free transplants, weed-free animal manures if manures are used as a nutrient source, weed-free transplanting and tillage equipment, and elimination of weed infestations in areas bordering tobacco fields. Preventative weed control can also include manually eradicating weeds in and around fields before they can mature and produce seed to proliferate their infestation.

Choosing sites for tobacco production that have low weed populations is also a major means of preventative weed control. Many sites may have good production characteristics, such as well-drained, fertile soil, with minimal potential for erosion or loss from disease, but may contain heavy populations of highly competitive weeds that can limit tobacco production. Some fields may become so infested with heavy populations of troublesome weeds that it is no longer feasible to grow tobacco in those fields, even when the most appropriate herbicides are used correctly. Sites chosen for tobacco production should have relatively low weed populations and, ideally, should not contain weed species that cannot be controlled by herbicides registered for use in tobacco.

Proper site selection for tobacco involves planning, observation, and knowledge of weed populations in fields several seasons prior to growing tobacco in those fields. Entire fields or portions of fields that contain particularly noxious or troublesome weeds should be avoided. Fields being considered for tobacco production should be observed while they are fallow and while they are in production of other crops for at least 2 seasons in order to get an idea of the weed species that are present. Having knowledge of the weed species that will occur in a field and where the heaviest infestations occur will help the grower plan the best choice of herbicide system, application rate and method, and total weed management system.

Once a site is chosen and tobacco is transplanted, scouting during the production season is also an important means of cultural weed control. Scouting involves intensively observing the crop on a weekly basis in at least four random areas of each hectare in the field. Weekly scouting is important to reveal the status of emerging weed problems in the field, but also to observe any potential insect and disease problems that may be developing. Knowing the status of weeds in the field allows for planning of any needed control measures of herbicide applica-

http://dx.doi.org/10.5772/56008

tions, cultivation, or hand weeding. Scouting allows for timely operations that will be more effective than attempting to control weeds after they become more mature.

### 2.2. Field preparation and cultivation

Where conservation tillage (no-tillage or strip-tillage) practices are not imposed, primary tillage with moldboard plowing, chisel plowing, and disking are the major methods used in field preparation for tobacco in the United States. Primary tillage is the major method of destroying weeds and preparing the ground for tobacco transplanting. Moldboard plowing is the primary means of turning under residue to allow decomposition and is most necessary with grass crops or annual grass weeds, while chisel plowing and disking are secondary tillage practices that aid in destruction of residue and help level the ground in preparation for tobacco transplanting. Field cultivators or mechanical rotary tillers are also used as a finishing tool just prior to transplanting.

Mechanical cultivation is still a necessary supplemental weed control practice in conventional tillage tobacco production because herbicides generally do not control all weeds that occur in tobacco production. Cultivation can also aid in soil aeration when soil crusting occurs, but also contributes to soil erosion and soil drying near the surface. No more than two cultivations are necessary for tobacco. Excessive or late cultivation can injure tobacco root systems, causing problems with water and nutrient uptake while also potentially increasing problems with tobacco mosaic virus, black shank (*Phytophthora nicotianae* Breda de Haan), and Granville wilt (*Pseudomonas solanacearum* E. F. Smith). Cultivation should be made shallow in the top 5 cm of soil so that tobacco roots are not injured and weed seed present below the herbicide treated area are not disturbed and allowed to germinate.

## 3. Herbicides used for weed control in tobacco

Herbicides play an important role in weed control, particularly in commercial tobacco production in more developed countries. Of all the pesticides used in tobacco production, herbicides make up the smallest percentage, approximately 10.4% [18]. The number of herbicides registered for use in tobacco has remained constant for several years and exhibits little signs of growth. There are approximately 50 different chemicals registered for use as herbicides for tobacco worldwide and they take on many different trade names and formulations depending on which regions they are used in. Recently, the presence of generic manufacturers has played an increasing role with many of these products having varying compositions and labels that may differ significantly from the original manufacturer's specifications. Although several herbicides are registered for control of weed species in tobacco, certain herbicides are not registered in all countries or regions. Readers should refer to herbicide registrations for the specific country or region of interest, and follow use instructions given on all product labels.

Similar to common names of weeds, trade names of herbicides vary around the world depending on the company marketing the product, local regulations, and regulatory parameters. With any pesticide application, it is essential that the correct product be selected for the identified target weed species and that the product has a legal registration for use on tobacco in a given country. There may also be cases where a product has a legal registration for use on tobacco in that country but the tobacco manufacturers do not want the product applied to the crop due to leaf residue issues or other concerns. Over the past two decades, analytical techniques have allowed manufacturing companies to accurately evaluate residue levels of tobacco pesticides on cured leaves. In some cases, these residue levels have prompted companies to discourage the use of some products.

Herbicides may be applied in many different ways, but most herbicides for use in tobacco are applied to the soil prior to weed emergence, and many must be applied prior to tobacco transplanting. Some of these herbicides are applied as pretransplant surface (PRETR) applications and others are applied as pretransplant incorporated (PTI) applications where the herbicide is mechanically incorporated into top 2.5 to 5 cm of soil. Seed of most annual weed species occur in this depth of soil and therefore it is advantageous to keep herbicides at this depth. All soil-applied herbicides need adequate soil moisture in order to be effective, and incorporation increases the availability of moisture for herbicide activation and prevents loss of the herbicide through volatilization into the atmosphere. Only a limited number of herbicides are registered for use in tobacco and none control all weeds that may occur. Therefore, much attention should be given to planning weed control strategies [19, 4].

Spray applicators should always remember to follow application instructions given on the label and also insure that the herbicide is registered for use in tobacco in the area where it is to be applied. The following is a listing and description of herbicides currently used in tobacco in various parts of the world for control of grasses, sedges, and broadleaf weeds. The general application guidelines described and weed spectrum of control are based on the use of these herbicides in tobacco within the United States. Consult the product labels of these herbicides for additional information.

### 3.1. Herbicides commonly used in tobacco

On a worldwide basis, the most commonly used herbicides for tobacco include alachlor, clomazone, metolachlor, napropamide, pebulate, pendimethalin, sethoxydim, and sulfentrazone. The following are descriptions of the weed control properties and basic use patterns.

#### *3.1.1. Alachlor*

Alachlor is a chloroacetamide herbicide that inhibits lipid biosynthesis and the synthesis of proteins, gibberellins, lignin, and anthocyanin production in susceptible plants. Alachlor controls many common annual grasses such as crabgrass (*Digitaria* sp.), foxtail (*Setaria* sp.), goosegrass (*Eleusine indica* [L.] Gaertn.), fall panicum (*Panicum dichotomiflorum* Michx.), and barnyardgrass (*Echinochloa crus-galli* [L.] P. Beauv.); as well as yellow nutsedge (*Cyperus esculentus* L.), but is of limited value for control of broadleaf weeds. Alachlor applications for tobacco are normally applied prior to transplanting and shallowly incorporated in the top 2.5 to 5 cm of soil, but may also be applied pretransplant without incorporation. Alachlor is a

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liquid formulation and the normal use rate is approximately 2.2 to 3.4 kg ai/ha. NOTE: Alachlor is a restricted use herbicide due to oncogenicity (tumor causing potential in laboratory animals) and alachlor has also been identified as having the potential to leach through the soil into ground water, particularly where soils are coarse and groundwater is near the surface [19, 20].

*3.1.2. Clomazone*

Clomazone is a carotenoid and chlorophyll inhibitor that causing bleaching/whitening in susceptible plants. Clomazone controls several common annual grasses species such as crabgrass (*Digitaria* spp.), *Panicum* spp., and foxtails (*Setaria* spp.). In addition to grass control, clomazone also controls jimsonweed (*Datura stramonium* L.), common lambsquarters (*Chenopodium album* L.), hairy galinsoga (*Galinsoga quadriradiata* Cav.), common ragweed (*Ambrosia artemisiifolia* L.), and velvetleaf (*Abutilon theophrasti* Medik.). Clomazone is normally applied as a soil surface PRETR application, but can also be applied over-the-top of tobacco within 7 days of transplanting as tobacco shows good tolerance to this herbicide. Although clomazone is usually applied to the soil surface with no incorporation, it can be incorporated into the soil surface provided that caution is taken not to incorporate deeper than 5 cm. Clomazone is available in liquid formulations and the normal use rate is approximately 0.84 to 1.1 kg ai/ha [19, 20].

*3.1.3. Metolachlor*

Metolachlor is a chloroacetamide herbicide similar to alachlor that has the same mode of action and same basic spectrum of weed activity, controlling numerous annual grass weeds and yellow nutsedge (*Cyperus esculentus* L.), but has limited activity against broadleaf weeds. Metolachlor applications for tobacco are normally applied prior to transplanting and shallowly incorporated in the top 2.5 to 5 cm of soil, but may also be applied pretransplant without incorporation. Metolachlor is normally a liquid formulation and the use rate is approximately 1.1 to 2.1 kg ai/ha [19, 20].

*3.1.4. Napropamide*

Napropamide is an acid amide herbicide that inhibits several metabolic processes including lipid biosynthesis and the synthesis of proteins and gibberellins. Napropamide is used primarily for the control of annual grasses such as crabgrass (*Digitaria* spp.), *Panicum* spp., and foxtails (*Setaria* spp.). Napropamide also provides some control of small-seeded broadleaf weeds such as pigweed (*Amaranthus* spp.) and common lambsquarters (*Chenopodium album* L.). Napropamide is highly volatile and should be mechanically incorporated immediately after application, and preferably in the same operation as the application. Application of napropamide is normally made prior to transplanting. Napropamide is available in dry and liquid formulations and the normal use rate is approximately 1.1 kg ai/ha [19, 20].

*3.1.5. Pebulate*

Pebulate is a thiocarbamate herbicide that inhibits lipid formation in sensitive plants. Pebulate controls annual grasses such as crabgrass (*Digitaria* spp.) and foxtails (*Setaria* spp.) as well as suppression of certain small-seeded broadleaf weeds such as pigweeds (*Amaranthus* spp.) and common lambsquarters (*Chenopodium album* L.). In addition, pebulate is one of the few herbicides available for use in tobacco that provides good suppression of nutsedge sp. (*Cyperus* spp.). Similar to napropamide, pebulate is highly volatile and should be incorporated immediately after application, preferably in the same operation. Pebulate is applied prior to tobacco transplanting at a use rate of approximately 4.5 kg ai/ha [19, 20].

#### *3.1.6. Pendimethalin*

Pendimethalin is a dinitroanaline herbicide that inhibits mitosis in susceptible plants. Pendimethalin provides excellent control of annual grasses and certain small-seeded broadleaf weeds. Pendimethalin provides excellent control of crabgrass species (*Digitaria* spp.), foxtail species (*Setaria* spp.), *Panicum* species, and goosegrass (*Eleusine indica* [L.] Gaertn.), and also provides some control of broadleaf species such as pigweed (*Amaranthus* spp.) and common lambsquarters (*Chenopodium album* L.). Pendimethalin is normally applied as a PTI application to a well-prepared soil surface up to 60 days prior to transplanting tobacco. Pendimethalin should be incorporated into the top 2.5 to 5 cm of soil within 7 days after application. Pendimethalin is available as liquid formulations and normal use rate is approximately 1.4 to 1.7 kg ai/ha [19, 20].

#### *3.1.7. Sethoxydim*

Sethoxydim is a cyclohexanedione herbicide that inhibits lipid biosynthesis in susceptible grass species. Sethoxydim only controls grasses, so it is totally safe to broadleaf crops such as tobacco. Sethoxydim has no soil residual activity and is the only true postemergence herbicide that can be applied over-the-top of tobacco later than 7 days after transplanting. Sethoxydim may be applied up to 42 days prior to tobacco harvest. Sethoxydim is effective on annual grass species such as crabgrass (*Digitaria* spp.), *Panicum* species, and foxtails (*Setaria* spp.), and also controls perennial grasses such as shattercane (*Sorghum bicolor* L.) and Johnsongrass (*Sorghum halepense* L.). Application must be made to emerged, actively growing grasses to be effective. For perennial shattercane and Johnsongrass, sethoxydim is most effective if grass plants are allowed to get 45 to 60 cm tall before application. Do not cultivate within 5 days before application or 7 days after application. Crop oil concentrate at 1% of the spray volume per hectare is recommended with sethoxydim application. Recommended rates of sethoxydim are approximately 0.3 kg ai/ha. For spot treatment by hand, prepare 1 to 1.5% sethoxydim solution with 1% crop oil concentrate and spray grass plants until wetted [19, 20].

#### *3.1.8. Sulfentrazone*

Sulfentrazone is an aryl triazolinone herbicide that inhibits photosynthesis by inhibiting the enzyme protoporphyrinogen oxidase. Sulfentrazone provides partial control and suppression of annual grasses such as crabgrass (*Digitaria* spp.), *Panicum* sp., foxtails (*Setaria* spp.), and goosegrass (*Eleusine indica* L.). However, its main attribute is control of nutsedge species (*Cyperus* spp.) and troublesome broadleaf weed species such as nightshade species (*Solanum* spp.), groundcherry species (*Physalis* spp.), morningglory species (*Ipomoea* spp.), smartweed species (*Polygonum* spp.), pigweed species (*Amaranthus* spp.), and common lambsquarters (*Chenopodium album* L.). Sulfentrazone must be applied prior to transplanting tobacco and should be applied to the soil surface without incorporation. If incorporation is used, it must not be deeper than 5 cm from the soil surface. Currently, sulfentrazone is also marketed in the United States in a prepackaged combination with carfentrazone. Carfentrazone is a postemergence burn down herbicide designed for broadleaf weed control prior to transplanting. Sulfentrazone is available as a liquid formulation and normal use rate is approximately 0.28 to 0.42 kg ai/ha [19, 20].

#### *3.1.9. Burndown of weeds or cover crops in conservation tillage production systems*

No-tillage and strip-tillage tobacco production requires that any existing vegetation, whether it be weed growth or cover crop, be killed prior to transplanting tobacco without using extensive tillage as in conventional tillage tobacco production. Paraquat is a common herbicide that is used as a burndown prior to tobacco transplanting in no-tillage tobacco in the United States. Paraquat should be applied as a broadcast application to actively growing weeds or cover crops no larger than approximately 15 cm in height. Use rates for paraquat for burndown prior to tobacco transplanting are approximately 0.7 to 1.1 kg ai/ha. Glyphosate may also be used to burndown existing vegetation prior to tobacco transplanting as a broadcast application at approximately 0.28 kg ai/ha. Glyphosate should be applied 30 days or more prior to tobacco transplanting and paraquat should be applied several days prior to tobacco transplanting. Carfentrazone may also be used in conservation tillage tobacco prior to transplanting at use rates up to 0.027 kg ai/ha. Carfentrazone has generally not been as effective as paraquat or glyphosate for pretransplant burndown in conservation tillage tobacco [19].

### 3.2. Weed control expected from herbicides used in tobacco

Although there are a limited number of herbicides registered for tobacco relative to other crops that occupy more total area, the herbicides available for use in tobacco generally provide adequate weed control, particularly when supplemented with cultivation in conventional tillage production systems.

The following are results from herbicide experiments conducted in dark tobacco in western Kentucky USA from 2005 to 2007. Treatments included all residual herbicides that were currently registered for use in tobacco. Soil type was a Grenada silt loam (fine-silty, mixed, thermic Oxyaquic Fraglossudalf) with 1.8% organic matter and pH of 6.4. Tobacco plots were prepared by conventional tillage with moldboard plowing and disking. Final field preparation and incorporation of herbicide treatments that required incorporation was done with a field cultivator. Fertilization and other crop production practices were according to standard recommendations [21]. Experiments were arranged in a randomized complete block design with 4 replications and plots were 4 rows, 4.1 m wide by 12.2 m long. Herbicide treatments were applied one day prior to transplanting as broadcast applications using $CO_2$-pressurized sprayers with flat fan nozzles calibrated to deliver 187 L/ha at 120 kPa. 'Narrowleaf Madole' dark tobacco was then transplanted on 1-m row spacing and 81-cm plant spacing within rows. Crop injury and weed control was evaluated using a 0 to 100% scale where 0 = no plant injury and 100 = plant death [22]. Tobacco injury data shown in Table 5 is from 2 weeks following transplanting while weed control data shown in Table 6 is from one week prior to harvest. Dark tobacco was fire-cured using standard practices [21] and yield and quality data are shown in Table 7.

Herbicide treatments evaluated included sulfentrazone, clomazone, sulfentrazone plus clomazone, pendimethalin, pendimethalin followed by sulfentrazone, pebulate, napropamide, and pebulate plus napropamide. All herbicide treatments were applied using maximum use rates allowed on U.S. labels. Sulfentrazone and clomazone treatments were applied as pretransplant applications to the soil surface while pendimethalin, pebulate, and napropamide treatments were incorporated immediately after application. Tobacco was cultivated twice early in the season following transplanting as is the standard practice.

As these data illustrate, there is potential to observe mild crop injury under some conditions following application of these tobacco herbicides (Table 5). Greatest potential for injury occurred following sulfentrazone and pendimethalin applications, although injury was never greater than 11% in any year and tobacco recovered quickly.

These data also illustrate that combinations of two tobacco herbicides provide more effective control of a broader spectrum of weeds than any one tobacco herbicide (Table 6). Sulfentrazone applied alone effectively controlled yellow nutsedge and ivyleaf morningglory, but was not as effective on large crabgrass and common ragweed. Conversely, clomazone was effective on large crabgrass and common ragweed but not as effective on yellow nutsedge and ivyleaf morningglory. The most effective herbicide treatment evaluated across these four weed species was sulfentrazone and clomazone applied together. Pendimethalin followed by sulfentrazone was also a very effective treatment, but did not control common ragweed as well as sulfentrazone plus clomazone. Pebulate plus napropamide also provided better weed control than either herbicide applied alone, but this combination was still not as effective as sulfentrazone plus clomazone or pendimethalin followed by sulfentrazone on the weed species evaluated here.

Although obvious differences in weed control were seen, these differences did not always translate to yield, quality, or gross revenue differences (Table 7). Total yield of dark tobacco treated with herbicides ranged from 2,765 kg/ha with pendimethalin alone to 3,051 kg/ha with pendimethalin followed by sulfentrazone with minimal differences in total yield between treatments. Herbicide treatments increased total yield by at least 359 kg/ha compared to tobacco that was only cultivated without herbicide treatment. Differences in quality grade index were also few, ranging from 61.9 to 70.1 across all treatments. There were no differences is gross revenue between herbicide treatments, with gross revenue ranging from 11,163 to 12,911 $USD/ha with herbicide treated tobacco, compared to 9,377 $USD/ha with tobacco that was only cultivated with no herbicide treatment.

## 4. Conclusion

Although tobacco is considered a very competitive crop, weeds can directly impact tobacco by limiting yield and quality, and causing interference of harvest and other field operations.

http://dx.doi.org/10.5772/56008

In addition, weeds can more indirectly affect tobacco by harboring several major tobacco diseases, insects, and nematodes. Weed control practices for tobacco include field site selection, rotation, scouting, and many fields receive intensive tillage prior to transplanting and cultivation following transplanting. In many areas of the world, weed control for tobacco is almost exclusively a manual task using hand weeding and animal-drawn cultivation implements. Although tobacco is not a food crop, the high value of tobacco relative to other crops makes manual weed management practices economically feasible in some regions.

In more developed regions, however, the use of herbicides is the main component of weed control practices in tobacco. Mechanical cultivation is still used to supplement herbicides in most fields, as no-tillage or reduced tillage production systems have not been adopted as readily in tobacco as in other crops like corn, soybean, and small grains. Although only a limited number of herbicides are available for use in tobacco compared to grain crops, the herbicides that are available have generally provided adequate weed control, particularly when supplemented with cultivation. Of the herbicides that are available, combinations of two herbicides are generally more effective than a single herbicide and some herbicide combinations are more effective than others. Data presented here indicate that sulfentrazone plus clomazone or pendimethalin followed by sulfentrazone were the most effective herbicide programs for weed control in dark tobacco.

| | | | Tobacco Injury[c] | | |
|---|---|---|---|---|---|
| **Herbicide Treatment** | **Application Timing** | **Application Rate** | **2005** | **2006** | **2007** |
| | | --- kg ai/ha --- | --------- 0 to 100% --------- | | |
| Sulfentrazone | PRETR[b] | 0.42 | 2 bc | 3 bc | 0 b |
| Clomazone | PRETR | 1.12 | 1 bc | 0 c | 0 b |
| Sulfentrazone + Clomazone | PRETR | 0.42 + 1.12 | 3 bc | 4 b | 0 b |
| Pendimethalin | PTI[a] | 1.66 | 5 b | 11 a | 2 a |
| Pendimethalin fb[a] Sulfentrazone | PTI fb PRETR[b] | 1.66 + 0.42 | 10 a | 5 b | 2 a |
| Pebulate | PTI | 4.48 | 2 bc | 3 bc | 0 b |
| Napropamide | PTI | 2.24 | 1 bc | 2 bc | 0 b |
| Pebulate + Napropamide | PTI | 4.48 + 2.24 | 2 bc | 5 b | 0 b |
| Untreated Control | - | - | 0 bc | 0 c | 0 b |

[a]Data collected from herbicide trials conducted near Murray, KY USA in 2005, 2006, and 2007. Injury data presented by year.

[b] Abbreviations: fb = followed by; PRETR = pretransplant; PTI = pretransplant incorporated.

[c]Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at P=0.05.

**Table 5.** Early-season tobacco injury observed from herbicide treatments.

| Herbicide Treatment | Application Timing | Application Rate | Weed Control[c] | | | |
|---|---|---|---|---|---|---|
| | | | Large crabgrass | Yellow nutsedge | Common ragweed | Ivyleaf morningglory |
| | | --- kg ai/ha --- | --------- 0 to 100% --------- | | | |
| Sulfentrazone | PRETR[b] | 0.42 | 61 c | 91 a | 31 e | 90 b |
| Clomazone | PRETR | 1.12 | 86 a | 17 c | 83 a | 62 c |
| Sulfentrazone + Clomazone | PRETR | 0.42 + 1.12 | 89 a | 96 a | 85 a | 97 a |
| Pendimethalin | PTI[a] | 1.66 | 89 a | 23 c | 42 d | 73 b |
| Pendimethalin fb[a] Sulfentrazone | PTI fb PRETR[b] | 1.66 + 0.42 | 96 a | 93 a | 54 c | 94 ab |
| Pebulate | PTI | 4.48 | 54 c | 77 b | 53 c | 35 de |
| Napropamide | PTI | 2.24 | 72 b | 22 c | 68 b | 31 e |
| Pebulate + Napropamide | PTI | 4.48 + 2.24 | 75 b | 78 b | 71 b | 39 d |
| Untreated Control | - | - | 0 d | 0 d | 0 f | 0 f |

[a]Data collected from herbicide trials conducted near Murray, KY USA in 2005, 2006, and 2007, weed control data pooled over years.

[b]Abbreviations: fb = followed by; PRETR = pretransplant surface application; PTI = pretransplant incorporated application.

[c]Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at P=0.05.

**Table 6.** Late-season weed control from herbicides and herbicide systems currently used in dark tobacco production in the U.S.[a]

| Herbicide Treatment | Application Timing | Application Rate | Stalk Position[ab] | | | | Quality Grade Index[c] | Gross Revenue[d] |
|---|---|---|---|---|---|---|---|---|
| | | | Lug | Second | Leaf | Total | | |
| | | kg ai/ha | -------------kg/ha-------------- | | | | 0-100 | $/ha |
| Sulfentrazone | PRETR | 0.42 | 405 a | 580 ab | 1992 a | 2977 ab | 64.9 ab | 12,497 a |
| Clomazone | PRETR | 1.12 | 355 ab | 579 ab | 2010 a | 2943 ab | 70.1 a | 12,911 a |
| Sulfentrazone + Clomazone | PRETR | 0.42 + 1.12 | 394 a | 595 a | 2028 a | 3017 ab | 64.4 ab | 12,598 a |
| Pendimethalin | PTI | 1.66 | 351 ab | 565 ab | 1843 a | 2765 b | 61.9 ab | 11,163 ab |
| Pendimethalin fb[e] Sulfentrazone | PTI fb PRETR | 1.66 + 0.42 | 375 ab | 617 a | 2059 a | 3051 a | 63.4 ab | 11,883 a |

| Herbicide Treatment | Application Timing | Application Rate | Stalk Position[ab] Lug | Second | Leaf | Total | Quality Grade Index[c] | Gross Revenue[d] |
|---|---|---|---|---|---|---|---|---|
| | | kg ai/ha | -------------kg/ha-------------- | | | | 0-100 | $/ha |
| Pebulate | PTI | 4.48 | 351 ab | 569 ab | 1958 a | 2877 ab | 63.6 ab | 11,779 a |
| Napropamide | PTI | 2.24 | 355 ab | 594 a | 1879 a | 2828 ab | 66.7 ab | 12,067 a |
| Pebulate + Napropamide | PTI | 4.48 + 2.24 | 370 ab | 603 a | 2031 a | 3004 ab | 65.9 ab | 12,430 a |
| Untreated Control | - | - | 314 b | 499 b | 1592 a | 2406 c | 66.2 ab | 9,377 b |

[a]Data collected from herbicide trials conducted near Murray, KY USA in 2005, 2006, and 2007. Tobacco yield data pooled over years.

[a]Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at P=0.05.

[b]Tobacco leaves removed by stalk position following fire-curing. Lug corresponds to lower stalk leaves, second from midstalk, and leaf from upper stalk.

[c]Quality grade index is a numerical representation of Federal quality grade received for tobacco and is a weighted average of grade index for all stalk positions.

[d]Gross revenue is the total gross value of tobacco (in $USD) based on Federal grade and price support values.

[e]Abbreviations: fb = followed by; PRETR = pretransplant; PTI = pretransplant incorporated.

**Table 7.** Effect of herbicide treatment on dark-fired tobacco yield, quality grade index, and gross revenue[a].

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