Teaching weed seedling identification and crop staging and a survey of weeds in peppermint fields
by Kristi Marie Carda

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Agronomy
Montana State University

Abstract:
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Weed seedling identification workshops were conduct in 23 locations around Montana during April and May, 1991. Crop staging workshops were also conducted in several locations around Montana during the fall of 1991 and the spring of 1992.

The success and popularity of the weed seedling identification and crop staging workshops indicates the need for more "hands-on" type workshops that relate to weed science as well as other areas.

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APPROVAL

of a thesis submitted by

Kristi Marie Carda

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Many farmers, ranchers, chemical dealers and chemical distributors don't know how to identify weed seedlings or stage small grains properly. If seedlings are not identified correctly and in a timely manner, correct herbicide selection is difficult. Correct staging of small grain crops is also extremely important since many of the herbicides available for use today require application at the proper crop growth stage to prevent crop damage.

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CHAPTER 1

LITERATURE REVIEW

Weed Seedling Identification

The cost of weed control is a significant annual expenditure for small grain producers. Proper and timely identification of weed seedlings is needed to obtain efficient weed control. Unfortunately, farmers in Montana, and elsewhere, are often not proficient at identifying weed seedlings. Effective techniques for teaching weed identification need to be developed.

Most plant identification keys are ineffective for seedling identification since they require flowering plants. Once weeds reach the flowering stage, it is too late for weed control to provide benefit. However, it is useful to identify weeds at maturity since the weeds that are present one year will most likely be a problem the next cropping season (Cramer, 1980).

Identification of weeds when they are small insures that the proper herbicides can be selected for application (Lindquist, 1989). Also, chemical control of weeds is usually more effective when seedlings are small (Stucky, 1984).

It can be very difficult to identify weeds while in the cotyledon stage since plant morphology changes profoundly as plant development occurs (Stucky, 1984). Agricultural producers often have difficulty making the connection between seedling and adult plants.

Crop Staging

Staging of small grain crops is important since it permits farmers and ranchers to apply herbicides, insecticides, and fungicides at the proper time. Correct timing of application insures the chemical will be most effective and cause the least amount of crop damage. Unfortunately losses are all too common in Montana from crop injury resulting from improper application timing.

Growth is defined as an increase in plant dry matter production (Kirby, 1986). The rate of growth of a cereal plant is partially dependent upon growing conditions so the higher the temperature or the longer the daylength, the more quickly development occurs. As the plant accumulates biomass, development becomes complex. However, the life cycle of a small grain plant can be divided into distinct phases which are easily recognized upon inspection (Kirby, 1986).

Resting small grain seed contains a fully developed shoot with three or four leaf initials, and an apical dome enclosed within the coleoptile (Kirby, 1977). After imbibition, root development occurs followed by coleoptile cell elongation (Kirby, 1986). Coleoptile elongation continues until emergence from the soil. Leaf primordia production continues and the initials formed may develop into leaves, tillers or ears depending on where they are formed (Kirby, 1986; Nerson, 1980). The first three to ten primordia form leaves, while the remaining primordia differentiate into elongated internodes or axillary (tiller) buds (Kirby, 1977). During early growth, excess ear and tiller primordia are produced which die if resources become limiting (Kirby, 1977; Rawson, 1969).

The first true leaf of the seedling plant emerges from the tip of the coleoptile soon after it emerges from soil. If the seed is sown deeply, the internode between the coleoptile and the first leaf elongates which places the crown of the plant just below the soil surface. This elongation does not occur if the seed is planted close to the soil surface (Kirby, 1986; Martin, 1990).

Emergence of the first leaf from the coleoptile marks the transition from the germination phase to the vegetative phase. The vegetative phase lasts until three to six leaves have emerged on the main shoot, and all leaves and spikelets have been produced (Kirby, 1986). The primordia develop rapidly and accumulate in the shoot apex during the initial growth phases. When the shoot apex has reached approximately 0.5 mm in length, ear or floral initiation takes place. This represents the transition period between the vegetative and the floral initiation phase. Even though there may be several days to several weeks between the first floral initiation (main tiller development) and the last floral initiation (secondary tiller development), plant development is somehow synchronized so that all fertile florets develop and ripen within two to three days of each other.

The initiation and development of tillers also takes place during this time. The shoot apex of each tiller has the potential to produce an ear. The yield potential of the plant is determined by the development of the main shoot and tillers (Kirby, 1977). When a small grain plant is in the tillering stage, herbicide application must be made at the correct time since improper or untimely application often results in crop damage and subsequent yield loss (Rawson, 1969).

Tiller initiation begins with growth of meristematic tissue located at the axil of a basal leaf. As growth of the meristematic tissue occurs, a prophyll develops. Its function is similar to the coleoptile since it protects the newly emerging growing point until it emerges from the leaf sheath. The tiller then develops in a manner similar to the main shoot (Kirby, 1986).

The pattern of tiller development in wheat and barley is similar. Tillering normally begins when a plant reaches the three leaf stage. A tiller bud develops in the axil of the coleoptile. Additional buds develop in the axil of each basal leaf (Kirby, 1986). Tiller bud initiation on the main stem ceases when culm elongation begins. Tillers will then begin development at the base of primary tillers, producing secondary and tertiary tillers.

A barley plant with 9 leaves will contain a maximum of five primary tillers consisting of a coleoptile tiller and four primary tillers which emerge from each of the four basal leaves. Numerous secondary and tertiary tillers may emerge from the primary tillers depending upon growing conditions.

The first primary tiller produced may become almost as large as the main shoot tiller. The primary, secondary, and tertiary tillers produce fewer leaves than the main shoot which is partially responsible for the synchronized development of shoots which permits ear emergence, flower fertilization, and seed ripening to take place almost simultaneously (Kirby, 1986). Stress caused by drought, shading, temperature extremes, or nutrient deficiency will cause some of the secondary and tertiary tillers to abort (Davidson, 1990). While small grain plant development is complicated and not easily understood, staging of small grain crops is routine and easily taught. Still, few producers stage their small grain crops prior to herbicide application.

There are several methods used to stage small grain plants including the Haun method, the Feeke's scale, and more recently, the Zadok's scale (Davidson, 1990; Martin, 1990), which is an expansion of the Feeke's scale (Zadoks, 1974). The Zadok scale was developed in an attempt to standardize an internationally recognized scale for recording cereal growth stage (Table 1). The Zadok scale divides the life cycle of a small grain plant into ten growth stages which are further broken down into ten secondary growth stages (Tottman, 1977; Zadoks, 1974).

This scale can be used for wheat (*Triticum aestivum*), barley (*Hordeum vulgare*) and oat (*Avena sativa*) plants, and has been adopted for use with rice (*Oryza sativa*) (Zadoks, 1974). Adaptation was necessary because rice is a transplanted crop in some parts of the world, and transplanting alters development slightly.

Table 1. The principal and secondary growth stages of the Zadok scale (Zadoks, 1974).

0		**Germination**	5		**Inflorescence**
	00	Dry Seed		50	
	01	Start of imbibition		51	First inflorescence just visible
	02			52	
	03	Imbibition complete		53	¼ of inflorescence emerged
	04			54	
	05	Radicle emerged from caryopsis		55	½ of inflorescence emerged
	06			56	
	07	Coleoptile emerged from caryopsis		57	¾ of inflorescence emerged
	08			58	Inflorescence fully emerged
	09	Leaf just at coleoptile tip		59	
1		**Seedling growth**	6		**Anthesis (flowering)**
	10	First leaf through coleoptile		60	
	11	First leaf unfolded		61	Beginning of anthesis
	12	2 leaves unfolded		62	
	13	3 leaves unfolded		63	
	14	4 leaves unfolded		64	
	15	5 leaves unfolded		65	Anthesis half-way
	16	6 leaves unfolded		66	
	17	7 leaves unfolded		67	
	18	8 leaves unfolded		68	
	19	9 or more leaves unfolded		69	
2		**Tillering**	7		**Milk development**
	20	Main shoot only		70	
	21	Main shoot and 1 tiller		71	Caryopsis water ripe
	22	Main shoot and 2 tillers		72	
	23	Main shoot and 3 tillers		73	Early milk
	24	Main shoot and 4 tillers		74	
	25	Main shoot and 5 tillers		75	Medium milk
	26	Main shoot and 6 tillers		76	
	27	Main shoot and 7 tillers		77	Hard dough
	28	Main shoot and 8 tillers		78	
	29	Main shoot and 9 or more tillers		79	
3		**Stem elongation**	8		**Dough development**
	30	Ear at 1 cm		80	
	31	First node detectable		81	
	32	2nd node detectable		82	
	33	3rd node detectable		83	Early dough
	34	4th node detectable		84	
	35	5th node detectable		85	Soft dough
	36	6th node detectable		86	
	37	Flag leaf just visible		87	Hard dough
	38			88	
	39	Flag leaf ligule just visible		89	
4		**Booting**	9		**Ripening**
	40			90	
	41	Flag leaf sheath extending		91	Caryopsis hard (hard to divide)
	42			92	Caryopsis hard (not dented)
	43	Boots just visibly swollen		93	Caryopsis loosening in daytime
	44			94	Over-ripe, straw dead, decaying
	45	Boots swollen		95	Seed dormant
	46			96	Viable seed 50% germination
	47	Flag leaf sheath opening		97	Seed not dormant
	48			98	Secondary dormancy induced
	49	First awns visible		99	Secondary dormancy lost

The secondary growth stage codes are helpful for determining the exact timing for correct herbicide applications. The number of leaves (codes 11-19) and the number of tillers (codes 21-29) per plant are especially useful.

This scale is also useful for describing the plant stage when a certain operation was performed (Perry, 1986; Zadoks, 1974). By using a complete Zadok plant description, the exact plant stage is described (Perry, 1986). For example, a small grain plant with five leaves unfolded, a main shoot and three tillers, with the first node detectable would be classified Z=15,23,33. Normally, only the highest number is important for a herbicide application (Nelson, 1990) however the other numbers could prove useful in explaining crop damage if it occurs.

Landes and Porter (Landes, 1990) modified the Zadok scale for staging wild oat (Avena fatua L.) growth. The pattern of growth of this weed differs slightly from wheat (winter and spring), barley, and rye (Table 2).

When sampling a field to determine growth stage, producers are urged to use the "M" or zig-zag pattern to collect plants (Martin, 1990; Sanders, 1987). This method insures that collection points represent the entire field so differences in plant development from one area to the next will be recorded. When a collection point is reached, the "Point Method" should be used for plant selection (Nelson et al, 1990). The person staging should drop to one knee and place an index finger on the soil surface. Stage the plant nearest to your finger to ensure a random sample.

Table 2. Proposed decimal code of development for wild oats (*Avena fatua* L.) (Landes, 1990).

0		**Germination**	5		**Floret differentiation**
	00	Dry seed		50	
	01	Start of imbibition		51	Floret primordium stage: round meristematic dome above lemma initials visible
	02			52	
	03	Imbibition complete		53	Stamen primordium stage: three bulges on the floret meristem visible
	04			54	
	05	Radicle emerged from seed		55	Stamen division stage: four compartments clearly distinctive
	06			56	
	07	Coleoptile emerged from seed		57	
	08			58	
	09	Leaf at tip of coleoptile		59	
1		**Vegetative development**	6		**Anthesis**
	10	First leaf through coleoptile		60	
	11	Apex with 1 leaf primordium		61	Beginning of anthesis
	12	Apex with 2 leaf primordium		62	
	13	Apex with 3 leaf primordium		63	
	14	Apex with 4 leaf primordium		64	
	15	Apex with 5 leaf primordium		65	50% anthesis
	16	Apex with 6 leaf primordium		66	
	17	Apex with 7 leaf primordium		67	
	18	Apex with 8 leaf primordium		68	
	19	Apex with 9 or more leaf primordium		69	Anthesis complete
2		**Branch formation (1st-order branches only)**	7		**Milk development**
	20	Main axis only		70	
	21	1 branch initial detectable		71	Seed watery ripe
	22	2 branch initials detectable		72	
	23	3 branch initials detectable		73	Early milk
	24	4 branch initials detectable		74	
	25	5 branch initials detectable		75	Medium milk
	26	6 branch initials detectable		76	
	27	7 branch initials detectable		77	Late milk
	28	8 branch initials detectable		78	
	29	9 or more branch initials detectable		79	
3		**Transition period**	8		**Dough development**
	30	Ear at 1 cm		80	
	31			81	
	32	2nd-order branches initiated		82	
	33	3rd-order branches initiated		83	Early dough
	34	4th-order branches initiated		84	
	35	5th-order branches initiated		85	Soft dough
	36	6th-order branches initiated		86	
	37	7th-order branches initiated		87	Hard dough
	38	8th-order branches initiated		88	
	39	9th-order branches initiated		89	
4		**Spikelet differentiation**	9		**Ripening**
	40	Tip of main axis undifferentiated		90	
	41	Spikelet primordium just visible on main axis		91	Seed hard (difficult to divide)
	42			92	Seed hard (dented by thumbnail)
	43			93	Seed loosening
	44			94	Over-ripe, straw dead and collapsing
	45	Glume primordium stage: two ridges appear at right angles to the plane of 1st-order branches		95	Seed dormant
	46			96	Viable seed giving 50% germination
	47			97	Seed not dormant
	48			98	Secondary dormancy induced
	49	Lemma primordium stage: prominent ridges between glumes visible		99	Secondary dormancy lost

Once the growth stage has been determined, the proper herbicide can be selected. For example, wheat is susceptible to phenoxy herbicide injury from emergence to the four-leaf stage, and from jointing to the soft dough stage of growth (Z=10-14 and 31-85) (Kirby, 1986). Phenoxy herbicide application at these stages can reduce plant height, delay maturity, deform plants, reduce yield, increase seed protein, reduce germination and reduce test weight (Nelson et al, 1990).

Use of these scales has simplified the process of plant staging. It is now possible to teach chemical distributors, chemical dealers, farmers, and ranchers to stage small grain crops accurately which permits accurate communication when staging small grain crops.

Peppermint Production

Peppermint has been cultivated as a crop in Montana for 23 years. In the past ten years, the number of acres in production has increased dramatically. Peppermint is a high value cash crop that is grown and harvested for the oil the plant contains. This oil is used for human consumption in candies, toothpaste, and other food stuffs.

The *Mentha* species has been cultivated for centuries by many cultures. It is believed that the word Mentha was derived from *Menthe*, a nymph who was loved by Pluto. Pluto's jealous wife, Proserpina, transformed Menthe into the green herb mint (Macleod, 1968).

The Egyptians mentioned the use of mint for medicinal purposes as early as 2800 B.C. The Ancient Greeks used mint for scenting their bathwater, while the Arabs offered a cup of strong mint tea as a customary gesture of hospitality. In more recent times, Theodore Roosevelt cultivated a mint patch at the White House for use in beverages. During prohibition, mint patches were destroyed because the herb is used as a flavoring in an alcoholic drink commonly served in the South - the mint julep (Bubel, 1985).

The genus *Mentha* is a member of the very large Labiatae family, which includes other herbs such as sage, thyme, marjoram, rosemary, basil, and lavender. There are approximately 25 species of mint in the world, many of which grow wild. Only eight species are commonly grown under cultivation. The three most common cultivated species are spearmint (*Mentha viridis*), peppermint (*Mentha piperita*), and pennyroyal (*Mentha pulegium*)(Macleod, 1968). Wild populations are common throughout the temperate regions of the world. Mint is cultivated in Argentina, Australia, France, Germany, Great Britain, India, Italy, Japan, Yugoslavia, and the United States. The United States is the largest commercial source of peppermint oil in the world, and most is produced in the Pacific Northwest (Farrell, 1985).

Mints are easily recognized by their perennial growth habit, square stem and paired, shallowly toothed leaves. Stems grow to a height of 45 to 90 cm with flowers appearing as spikes at the terminal ends of stems or in clusters rising from the leaf axils. Flower color may be white, pink, or lavender. Due to the shallow root system, mint plantings thrive under moist, humid conditions. While most mint species tolerate some shading, they thrive when grown in full sunlight. Plants grown in shade contain less aromatic oil (Bubel, 1985).

After establishment, mints produce rhizomes which aggressively invade the area surrounding each plant. Mentha species are normally propagated by cuttings. Mints hybridize readily and plants true to species are difficult to obtain from seed (Bubel, 1985).

Of the three mint species, I will discuss peppermint (*Mentha piperita*), the specie grown in Montana for the remainder of this chapter. Peppermint is thought to be a cross between spearmint (*Mentha spicata*) and water mint (*Mentha aquatica*). Peppermint has lance-shaped leaves on short stems and exists as two distinct strains. The first recognized strain is referred to as black mint, and has purple-tinged stems. The second strain, is white mint, has lighter green leaves, a more slender stem and a milder aroma and flavor (Bubel, 1985). The volatile oil produced is used to flavor foods, medicines, tooth paste, chewing gums, cordials, tobacco products, and liqueurs (Farrell, 1985, Williams, 1977).

Roots are normally dug and planted in the fall in rows 60 to 90 cm apart, on 30 cm centers. After emergence in the spring, the rows appear sparse. A solid stand is obtained in 2 to 3 years. Fields may need to be renovated by lightly discing, corrugating, or shallow plowing to disrupt the root system which prevents the crop from choking itself out.

Peppermint is vulnerable to insects, nematodes and diseases. An insect that causes problems for peppermint producers is the two spotted spider mite *(Acari: Tetranychidae)*. The major nematode problems in the Flathead valley of Montana include root-lesion nematode (*Pratylenchus penetrans* Cobb, 1917; Filipjev and Stekhoven, 1941), pin nematode (*Paratylenchus spp.*), stubby root nematode (*Trichodorus spp.*), and ring nematode (*Criconemella spp.*). Diseases include *Verticillium* wilt (*Verticillium dahliae* Kleb.) and rusts.

Insects:

The two spotted spider mite is the most widely distributed pest of peppermint (Hollingsworth, 1982). The major damage caused by the two spotted spider mite is injury to the cuticle and epidermal cells on leaves, which disrupts leaf surface layers and destroys the underlying mesophyll cells. Mesophyll damage affects the ultrastructure of the remaining mesophyll cells, reduces gas exchange from the leaf, and reduces plant growth. Spider mite populations are influenced by many factors including climate, intraspecific competition, host plant condition, predators, and agricultural practices (Hollingsworth, 1982).

Feeding injury leads to increased water loss at night, which results in water stress during the daytime (DeAngelis, 1983). Outbreaks of two spotted spider mites usually occur during hot, dry periods (Hollingsworth, 1982) when daytime water demand is high. The resulting stress reduces production of secondary plant products, including the essential oil monoterpines. The epidermal disruption reduces essential oil production which is synthesized primarily in glandular structures located on the epidermis (DeAngelis, 1983).

Nematodes:

Nematodes, commonly referred to as roundworms, are microscopic in size (DeAngelis, 1983; Leonard, 1991; Hollingsworth, 1982). Nematodes are appendageless, nonsegmented, wormlike invertebrates possessing a body cavity and a complete digestive tract (mouth, an alimentary canal, and an anus). Nematodes vary greatly from 82 *u*m to over 1nm in length.

There are about 2,200 nematode species that attack plants which cause approximately $5 billion in losses in the United States in 1991 (DeAngelis, 1983). Plant parasitic nematodes can be broken down into two basic groups - ecto- or endoparasites. Ectoparasites feed on the outside of the root by forcing their stylet (mouth-spear) into the root tissue. These nematodes remain on the outer root surface throughout their life cycle. Endoparasites tunnel through the root structures, spending all or part of their life cycle inside the plant tissue leaving holes or lesions where pathogen invasion leads to further damage (Clark, 1980; Macleod, 1968; Williams, 1977). Some nematodes can travel through plant tissue to attack leaves and blossoms (Clark, 1980).

Nematodes when unaided, can only spread 30 to 90 cm per year. They are widely spread by movement in infested soil on shoes, tools and transplants. Wind and water erosion can also spread nematode infestations to new locations (Clark, 1980; Kimpinski, 1984; Poinar, 1983).

Diseases:

Verticillium wilt (*Verticillium dahliae* Klebahn), a soil borne fungus, is also a serious problem in peppermint production (Brandt, 1984). This disease has caused abandonment of thousands of acres of highly productive land in the midwest during the 1940s and 1950s. The disease was later spread to the peppermint acreages in the Willamette River valley in Oregon and the Columbian basin in Washington due mainly to the fact that new peppermint plantings are started by using stolons from previous plantings. This forces growers to constantly move to "new land" to prevent crop losses after the disease had built up in the soil (Green, 1975).

Effective control of verticillium wilt is difficult and expensive. Chemical soil fumigation provides effective, but short term control. A more effective and more cost conscious control program can be obtained through the use of crop rotations to alternate crops that are resistant to the disease. This helps reduce the amount of inoculum in the soil so peppermint can be planted back into once highly infected fields.

CHAPTER 2

WEED SEEDLING IDENTIFICATION

Introduction

The ability to identify weed seedlings is an important tool in crop production. If weed seedlings are not identified correctly and in a timely manner, correct herbicide selection is difficult. Correct herbicide selection is becoming more complicated with the increase in herbicide resistance which often requires that two or more herbicides be applied in a tankmix for optimal weed control.

Correct identification of weed seedlings is routine and is best performed by scouting fields early when weed seedlings are small. Many producers and agribusiness personnel in Montana cannot identify weed seedlings partially because there hasn't been an effective learning method.

The purpose of this project was to develop a "hands-on", portable workshop to teach farmers, county agents, government employees, and agricultural business professionals to identify weed seedlings using a simple key and live plant material.

Methods and Materials

A broadleaf weed seedling key (Figure 1) was developed by Nelson (1986) which features twenty-two of the most common broadleaf weed species found in cultivated crop land in Montana (Table 3). A workshop was developed which combined use of the key with field quality weed seedlings. The first objective was to develop a planting calender which would allow enough time for weed seedlings to develop to the two leaf stage of growth when presented to an audience.

Plastic flats 30 by 60 by 10 cm deep were filled with moist greenhouse soil [1/3 Bozeman Silt Loam, 1/3 spagnum peat moss, 1/3 washed concrete sand (v/v/v)] that was mixed, steam pasteurized at 90° C for one hour prior to use. Seed of twenty-two species was planted in separate rows, 2.5 cm apart and 1.25 cm deep. The plants were grown 90 cm under 1000 watt metal halide lights under a 24 hour photoperiod to prevent flowering. The greenhouse was maintained at a daytime temperature of 21 ± 2° C and a nighttime temperature of 65 ± 2° C. Flats were watered in the morning to discourage development of powdery mildew (*Erysiphe* spp.). After emergence, seedlings were watered sparingly in the morning, to control development of damping off (*Pythium* spp.).

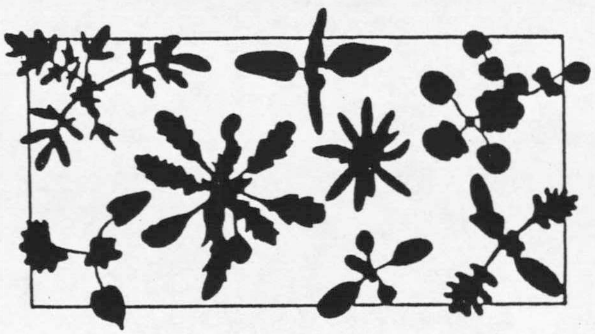
The number of days after planting to emergence, full cotyledon stage, and first and second true leaf stages was recorded for each species. The experiment was repeated twice.

A planting calendar (Table 4) was developed and maintained so that each species was planted on the appropriate day before a workshop. Individual seedlings in the two true leaf stage were transplanted into plastic "cell packs", each containing six 4 by 4 by 6 cm deep cells approximately one week before each workshop to permit recovery from transplant shock.

Results and Discussion

After the planting calender was developed, a letter was sent to each county extension agent in Montana offering a weed seedling identification workshop to the first fifteen agents to respond. The initial intent was to present workshops during April and May, 1991, however, workshops were taught around the state for almost two years due to popularity.

Eighteen of the twenty-two weed species on the key were used for the workshops. The four species not included were waterpod, henbit, and hairy nightshade due to a shortage of seed, and cutleaf nightshade which did not germinate consistently.



Broadleaf Weed Seedling Key

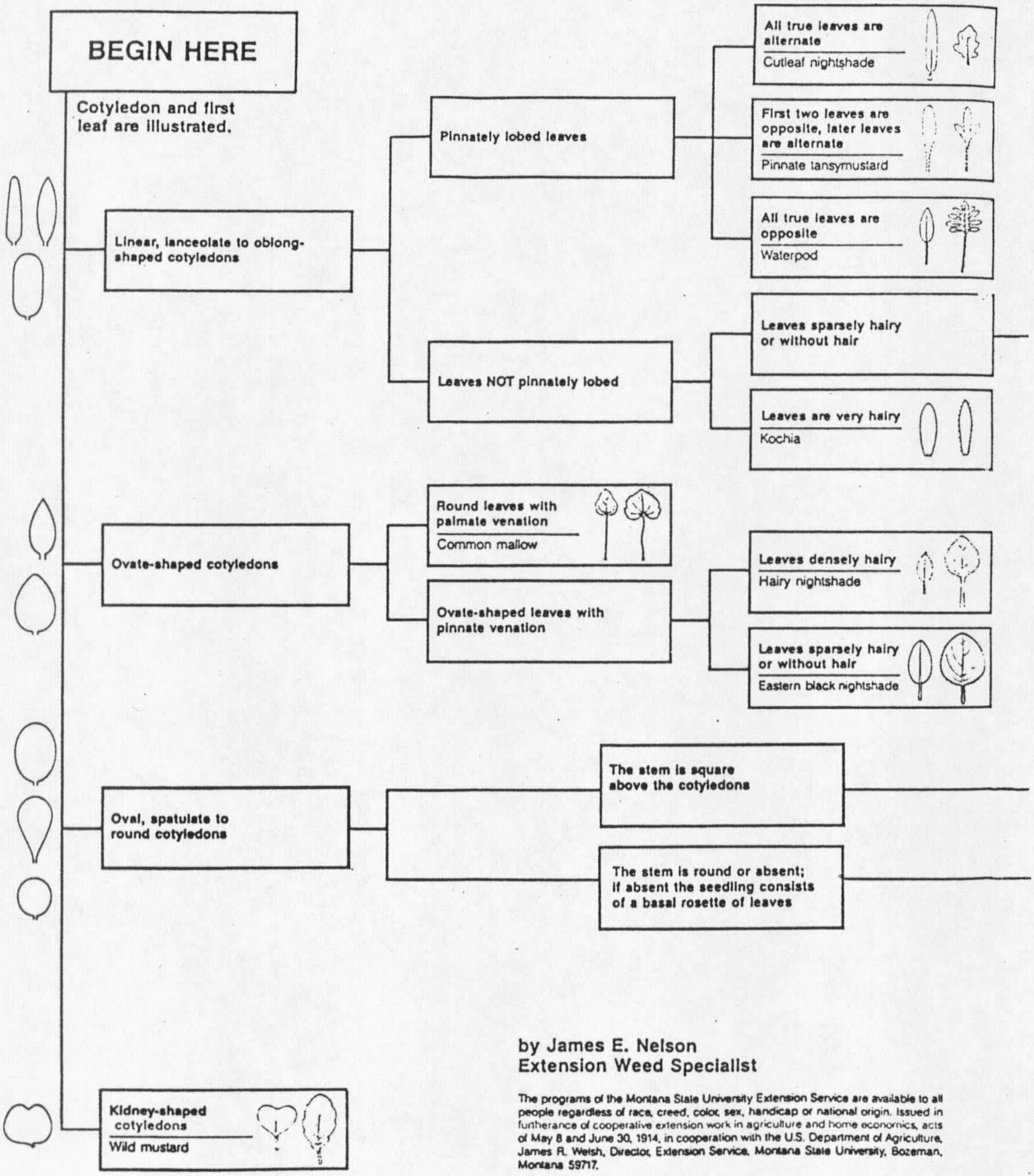
Extension Service   Montana State University, Bozeman   EB 7   Reprinted June 1989

Figure 1. The broadleaf weed seedling key (Nelson, 1986).

(Continued)

Figure 1. The broadleaf weed seedling key (Nelson, 1986). (Continued)

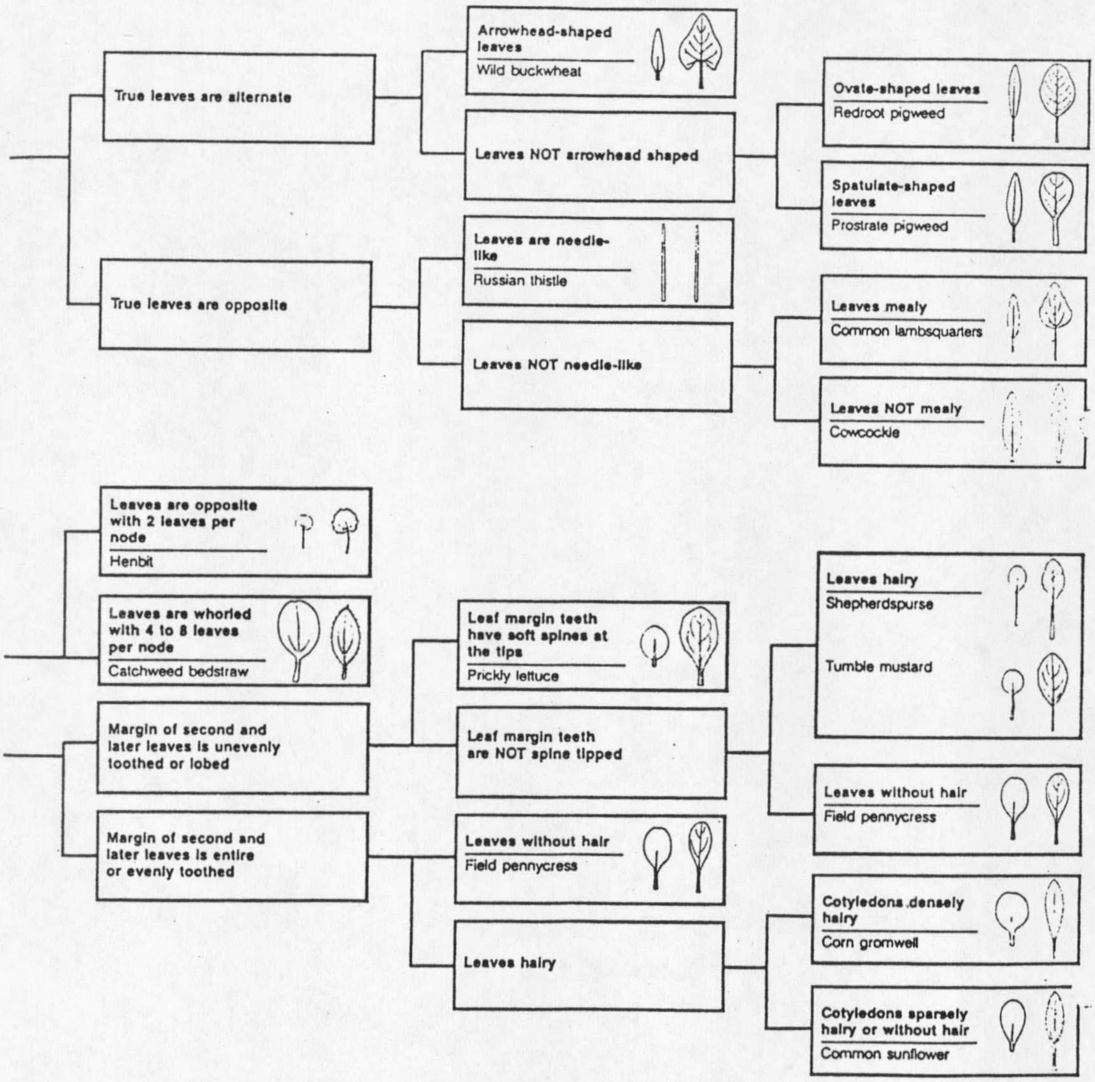
BROADLEAF WEED SEEDLING KEY



by James E. Nelson
Extension Weed Specialist

(Continued)

Figure 1. The broadleaf weed seedling key (Nelson, 1986). (Continued)



(Continued)

Figure 1. The broadleaf weed seedling key (Nelson, 1986). (Continued)

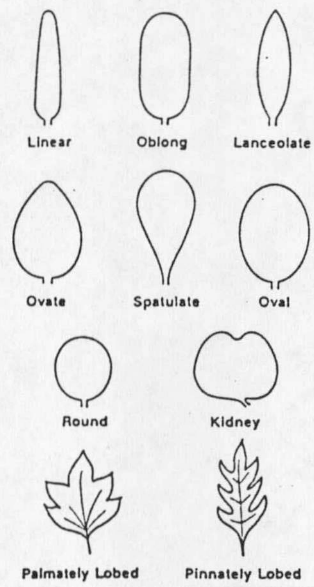
Identification of broadleaf weed seedlings is critical to their control. Weed species vary in their response to herbicides; therefore it is necessary to select the right herbicide to control a particular species. Controlling weeds in the early stages of growth not only increases the effectiveness of control measures, but also reduces crop losses due to weed competition.

This key provides an easy and reliable means for identifying broadleaf weed seedlings. To use the key you need to understand how the key is organized and be able to recognize a few simple characteristics used to identify broadleaf weeds.

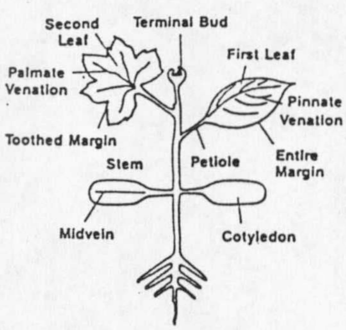
Broadleaf seedlings must be examined with great care. One characteristic seldom is sufficient to identify the weed. The following steps will help you use the identification key and insure correct seedling identification.

1. Collect several samples of the plant to be identified.
2. Use a hand lens when available to make plant characteristics easier to see.
3. Begin on the left side of the key and proceed step by step to the right. Do not skip any steps.

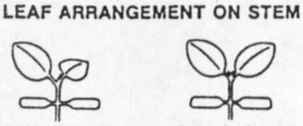
COTYLEDON AND LEAF SHAPES



PLANT PARTS



LEAF ARRANGEMENT ON STEM



Alternate Leaves
One leaf per node.
New leaf is smaller.

Opposite Leaves
Attached at same node on opposite sides of stem. Leaves at the same node are of similar size.

TERMINOLOGY

Alternate Leaves—One leaf attached per node. Newest leaf is of smaller size.

Cotyledon—Seed leaves; the first pair of leaflike structures, usually paired, appearing above ground in most dicotyledonous plants.

Entire Leaf Margins—Leaf margins that are smooth without sawtoothed or irregularly notched edges.

Lobe—A division or segment of a leaf.

Margin—The border or edge of any plant part.

Mealy—Covered with a small, white bran-like bloom.

Midvein—The central vein of a leaf.

Node—That part of the stem from which leaves or branches arise.

Opposite Leaves—Leaves attached at the same node on opposite sides of the stem. Newest leaf pair are of similar size.

Palmate—Three or more lobes or veins arising from one point.

Petiole—The stalk of a leaf.

Pinnate—Lobes or veins arranged on two sides of the midvein.

Rosette—A basal cluster of leaves in a circular form without discernible upright stem.

Toothed Leaf Margins—Sawtoothed or irregularly notched leaf edges.

Whorled—Three or more leaves attached at the same node, often arranged in a whorl around the stem.

Table 3. Weed species included in the broadleaf weed seedling key (Nelson, 1986).

Common Name	Latin Name
wild mustard	*Brassica kaber* (D.C.) Wheeler
common mallow	*Malva neglecta* Wallr.
cutleaf nightshade	*Solanum triflorum* Nutt.
pinnate tansymustard	*Descurainia pinnata* (Walt.) Britt
waterpod	*Ellisia nyctelea* L.
kochia	*Kochia scoparia* (L.) Schrad.
hairy nightshade	*Solanum sarrachoides* Sendt.
Eastern black nightshade	*Solanum nigrum* L.
henbit	*Lamium amplexicaule* L.
catchweed bedstraw	*Galium aparine* L.
wild buckwheat	*Polygonum convolvulus* L.
Russian thistle	*Salsola iberica* Sennen
prickly lettuce	*Lactuca serriola* L.
field pennycress	*Thlaspi arvense* L.
redroot pigweed	*Amaranthus retroflexus* L.
prostrate pigweed	*Amaranthus blitoides* S.Wats.
common lambsquarters	*Chenopodium album* L.
cowcockle	*Vaccaria pyramidata* Medic.
corn gromwell	*Lithospermum arvense* L.
sheperdspurse	*Capsella bursa-pastoris* (L.) Medic.
common sunflower	*Helianthus annuus* L.
tumble mustard	*Sisymbrium altissimum* L.

Table 4. A planting date calendar for eighteen weed species.

Weed Seedling Group	Days after planting to reach 2 leaf stage	Weed Species
I	33	sheperdspurse prostrate pigweed
II	28	tumble mustard field pennycress redroot pigweed Eastern black nightshade
III	25	pinnate tansy mustard catchweed bedstraw wild buckwheat
IV	22	Russian thistle prickly lettuce common lambsquarters cowcockle corn gromwell wild sunflower
V	18	common mallow
VI	14	kochia wild mustard

At each workshop, the instructor taught the participants how to use the key with the aid of a slide set which illustrated the differences in cotyledon shape, leaf shape, and leaf arrangement on the stem. After a fifteen minute slide presentation, the first cell pack of seedlings and a key were distributed to each participant. The first cell pack contained the six easiest weed seedlings to identify. The seedlings, in order of ease of identification were wild mustard, kochia, redroot pigweed, cowcockle, eastern black nightshade, and catchweed bedstraw.

The instructor guided participants through the key to identify each weed seedling. After successful identification of each seedling, a slide of the adult plant was shown so producers could visually associate the seedling with the mature, flowering plant. Many producers who didn't recognize the seedling were surprised when the familiar mature plant was shown. After the first six weed seedlings were correctly identified, the second cell pack was distributed.

The second cell pack included Russian thistle, common mallow, wild buckwheat, tumble mustard, corn gromwell, and field pennycress. Participants identified each weed seedling without help. The instructor helped only upon request. After giving participants a few minutes to identify each plant, the instructor went through the key to help those who incorrectly identified seedlings. This helped participants determine where errors had occurred as they used the key, and to answer any questions that arose. A slide of the adult plant was shown again. This systematic process of identifying weeds of increasing difficulty helped build participant's confidence. After successfully identifying the six seedlings in each of the first two cell packs, they were prepared for the six most difficult seedlings.

The third cell pack contained common lambsquarters, prostrate pigweed, common sunflower, pinnate tansy mustard, prickly lettuce, and sheperdspurse. These seedlings were used as a test to measure the competence of the workshop presenter. Each participant had to identify each weed seedling without help from the instructor. After all identifications were made, the instructor measured the identification success rate for each species. A slide showing the adult plant was again shown after each weed seedling was identified.

Cell packs sufficient for five meetings were placed in a six-shelf rack which fit the bed of a pickup truck covered with a fiberglass shell. Plants could be used for more than one meeting, and as many as four participants could use a single cell pack, so the number of plants needed for several meetings was lower than first expected. Plants were placed inside the crew cab pickup truck when temperatures fell below freezing.

The weed seedling identification workshop was conducted in 34 locations in Montana (Table 5). A slide set was developed in the event that plant material was accidently lost to freezing. The slide set contained a slide of each seedling in the cotyledon to two true leaf stage along with a slide of the mature plant. It seemed that participants were able to use the key successfully with slides, however participants seemed to learn more when live plant material was used because plant characteristics including hairs, spines, and characteristic fragrances were not demonstrated.

A teaching guide (Appendix A) that included tips about each seedling was developed for the slide set. It contained hints and important facts needed for successfully teaching weed seedling identification. The teaching guide was especially useful for instructors who were not initially familiar with the seedlings.

Table 5. Dates and locations of weed seedling identification workshops.

Location/Conducted by	Date	# of Attendants
Willow Creek/Carda, Fay	Jan. 22, 1991	30
Circle/Carda	April 3, 1991	68
Denton/Carda	April 5, 1991	10
Lewistown/Carda	April 5, 1991	8
Moccasin/Carda	April 4, 1991	4
Wilsall, afternoon/Carda	April 8, 1991	20
Wilsall, evening/Carda	April 8, 1991	23
Belgrade/Carda	April 11, 1991	22
Ryegate/Carda	April 16, 1991	7
Roundup/Carda	April 16, 1991	2
Hysham/Carda	April 17, 1991	8
Forsyth/Carda	April 17, 1991	4
Broadus/Carda	April 18, 1991	18
Noxon/Carda	April 24, 1991	3
Hot Springs/Carda	April 24, 1991	3
Scobey/Carda	May 7, 1991	5
Sidney/Carda	May 8, 1991	8
Great Falls/Carda	May 13, 1991	17
Chester/Carda	May 14, 1991	15
Cutbank/Carda	May 15, 1991	2
Shelby/Carda	May 15, 1991	10
Conrad/Carda	May 16, 1991	9
Dutton/Carda	May 16, 1991	6
Bozeman/Wright	July 14, 1991	30
Bozeman/Carda	Nov. 2, 1991	22

(Continued)

Table 5. Dates and locations of weed seedling identification workshops. (Continued)

Location/Conducted by	Date	# of Attendants
Bozeman, ICPM/Carda	Jan 13, 1992	35
Roundup/Orville Moore	Feb. 11, 1992	25
Kalispell, Equity Supply/Carda	Feb 12, 1992	58
Bozeman, Alfafla/Carda	Feb. 18, 1992	40
Conrad, Cenex/Carda	Feb. 24, 1992	45
Bozeman, Aviation/Carda	Feb. 26, 1992	21
Dutton High Schoot/Brent Hitchcock	March 14, 1992	15
Poplar/Dallas O'Connor	March 19, 1992	30
Bozeman, Master Gardners/Carda	May 7, 1992	5

CHAPTER 3

CROP STAGING

Introduction

Correct staging of small grain crops is extremely important since many of the herbicides available for use require application at the proper crop growth stage to prevent crop damage. Producers who do not properly stage small grain crops will often lose crop yield to herbicide injury.

When choosing the herbicide(s) to use, the weed species present in a field and their growth stage must also be considered (Chapter 2). Identification of these two factors, weed identification and crop staging, enables producers to match the best herbicide for both the crop and weed spectrum which can change both from field to field and from year to year.

Many producers in Montana and elsewhere do not stage their small grain crops to determine when to spray. While it is difficult to estimate the income lost due to crop damage or uncontrolled weeds, it is certainly a significant loss.

The purpose of this project was to develop a mobile, interactive workshop to teach crop staging to producers, chemical dealers, county agents, and others involved in cereal grain production.

Methods and Materials

Barley, spring wheat and winter wheat seed was planted 2.5 cm deep every 12 cm in rows 7.5 cm apart in 45- by 90- by 7.5-cm deep flats filled with moist soil [1/3 Bozeman Silt Loam, 1/3 sphagnum peat moss and 1/3 washed concrete sand (v/v/v)], that was steam pasteurized at 90° C for one hour before using. The greenhouse was maintained at a daytime temperature of 21 ± 2° C and a fourteen hour light photoperiod; nighttime temperature was maintained at 18 ± 2° C with a ten hour dark period. Observations from other temperature regimes and varying photoperiods indicated this to be the proper growing conditions. Other growing conditions resulted in plants that were spindly and lacked general vigor.

Plants were grown to the desired stage (Table 6) and carefully pulled from the soil. The soil was rinsed from the roots, plants were wrapped in wet paper towels, covered with plastic garbage bags and placed in cardboard boxes for shipping by air express or UPS for delivery the next day.

Table 6. Planting dates for growing small grains in the greenhouse.

Crop Stage Desired	Planting Date (Weeks Before Workshop)
2-3 leaf	3-4
3-4 leaf	4-5
4-5 leaf	5-6
5-6 leaf	6-7

Results and Discussion

Twenty-one degrees centigrade proved to be the optimum temperature for germination and plant development. If temperatures exceeded 21° C, plants grew tall and spindly and did not tiller well.

If four-, five-, and six-leaf or larger plants were needed, supplemental nitrogen fertilizer was required. A solution containing Peter's fertilizer formulation 20-10-20 with trace elements (W.R. Grace Company, Fogelsville, PA) was applied to soil at a rate of 100 ppm nitrogen at the three- to four-leaf stage. Plants in later stages of development required weekly fertilization to remain healthy.

Only fifteen seeds were planted per flat since small grain plants would not tiller under crowded conditions. For best development after emergence, supplemental light was necessary. Flats were located on greenhouse benches 90 cm under 1000-watt metal halide lights with a fourteen-hour photoperiod. The lights were raised as the plants grew to maintain the 90-cm distance between the plants and the light source. After seeding, flats were watered every other day until emergence. When emergence occurred, flats were watered daily, but care was taken to avoid both overwatering and drouth stress. Water requirements increased significantly after the plants began to tiller.

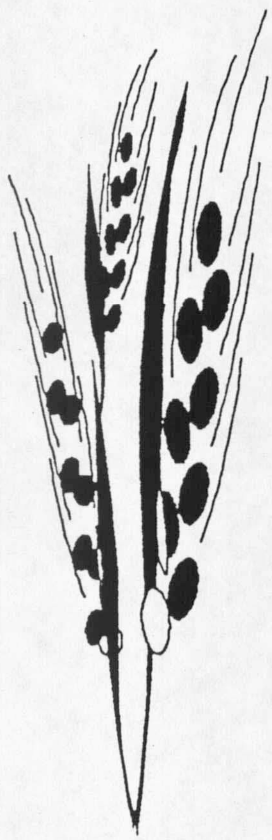
After the planting calendar was developed, a pamphlet was developed that included a description of the Zadok scale (Zadok et al, 1974), a list of definitions relating to the Zadok scale, and a chart containing the thirteen most commonly used herbicides in Montana (Figure 2). The chart matched the Zadok numbers with the proper time of application for each herbicide in winter wheat, spring wheat and barley.

Barley plants were superior to wheat for teaching purposes because the leaves are wider and less spindly than wheat leaves when produced under greenhouse conditions. Barley tillered more readily than wheat, resulting in a compact plant identical to field grown plants. The plants developed approximately one leaf per week. Node elongation occurred when plant development reached five to six leaves.

Workshops were held at several locations in the state. After evaluating the success of the workshops, modifications were made and a training session was held for people interested in teaching crop staging. Those in attendance were eligible to receive plants from the author to teach crop staging workshops in 1992. The cost of plants was $35.00 per 100 plants in the three- to four-leaf stage, and $50.00 per 100 plants in the five- to six-leaf stage. Plants in the latter stage were useful for demonstrating tiller production and teaching node elongation.

Figure 2. Small grain staging pamphlet used for proper herbicide application using the Zadok scale.

Staging Small Grains for Proper Herbicide Application



Using the *Zadok* Scale

(Continued)

Figure 2. Small grain staging pamphlet used for proper herbicide application using the Zadok scale. (Continued)

Anthesis - Flowering.
Boot - Area inside sheath where seed head begins to swell before emergence from the sheath.
Caryopsis - Grain kernel.
Coleoptile - Protective covering over shoot. Shoot breaks through after emerging from soil.
Coleoptile tiller - Tiller that arises from the seed (below the crown area).
Early dough - The grain contents are soft and cheesy.
Early milk - The grain contains white, watery liquid.
Flag leaf - Last leaf to emerge before head appears.
Hard dough - The grain contents are dry and cannot be squeezed out.
Imbibition - The process when the seed absorbs water for seed germination.
Inflorescence - The seed head.
Internode - The space between nodes.
Jointing = stem elongation - The growth process when the nodes begin to separate, resulting in the head emerging from the stem.
Late milk - The grain contents are wet and sticky when crushed.
Ligule - Membranous structure located at the base of a leaf, behind the stem.
Main shoot - Largest tiller; gives rise to primary tillers.
Medium milk - The grain is nearly full length and contains a soft, wet center in a watery liquid.
Node - Area on the tiller where stem elongation occurs.
Primary tiller - Tillers that arise in the axils of the main shoot leaves.
Radicle - The root as it emerges from the seed.
Sheath - Central part of stem where leaves are attached.
Spikelet - Individual floret group on the seed head.
Unfloded leaf - A leaf is considered to be unfolded when the ligule has emerged from the sheath of the proceeding leaf.

(Continued)

Figure 2. Small grain staging pamphlet used for proper herbicide application using the Zadok scale. (Continued)

0 Germination
00 Dry seed
01 Start of imbibition
02 Imbibition
03 Imbibition complete
04 Radicle emerging from seed
05 Radicle emerged from seed
06 Coleoptile emerging from seed
07 Coleoptile emerged from seed
08 Leaf elongating thru coleoptile
09 Leaf just at coleoptile tip

1 Seedling Growth
10 First leaf through coleoptile
11 First leaf unfolded
12 2 leaves unfolded
13 3 leaves unfolded
14 4 leaves unfolded
15 5 leaves unfolded
16 6 leaves unfolded
17 7 leaves unfolded
18 8 leaves unfolded
19 9 or more leaves unfolded

2 Tillering
20 Main shoot only
21 Main shoot and 1 tiller
22 Main shoot and 2 tillers
23 Main shoot and 3 tillers
24 Main shoot and 4 tillers
25 Main shoot and 5 tillers
26 Main shoot and 6 tillers
27 Main shoot and 7 tillers
28 Main shoot and 8 tillers
29 Main shoot and 9 or more tillers

3 Stem Elongation
30 Ear at 1 cm (pseudostem erect)
31 First node detectable
32 2nd node detectable
33 3rd node detectable
34 4th node detectable
35 5th node detectable
36 6th node detectable
37 Flag leaf just visible
38 Flag leaf partly emerged
39 Flag leaf ligule just visible

4 Booting
40 Flag leaf fully emerged
41 Flag leaf sheath extending
42 Boot beginning to swell
43 Boot just visibly swollen
44 Boot are swelling
45 Boot swollen
46 Head ready to emerge from boot
47 Flag leaf sheath opening
48 Flag leaf sheath open
49 First awns visible

5 Inflorescence (ear/panicle) emergence
50 First spikelet of inflorescence visible
51 First spikelet of inflorescence visible
52 First spikelet emerging
53 1/4 of inflorescence emerged
54 1/3 of inflorescence emerged
55 1/2 of inflorescence emerged
56 2/3 of inflorescence emerged
57 3/4 of inflorescence emerged
58 Inflorescence emerged
59 Pre-anthesis

6 Anthesis (Flowering)
60 Beginning anthesis
61
62
63
64
65 Anthesis half-way
66
67
68
69 Anthesis complete

7 Milk Development
70 Kernel shell developed
71 Kernel contents very watery
72 Kernel contents turning white
73 Early milk
74 Kernel contents beginning to solidify
75 Medium milk
76 Kernel contents are wet and sticky
77 Late milk
78 Kernel contents are sticky
79 Kernel contents are soft and sticky

8 Dough Development
80
81
82
83 Early dough
84
85 Soft dough
86
87 Hard dough
88
89

9 Ripening
90 Seed hard (thumbnail dent remains)
91 Seed hard (difficult to divide)
92 Seed hard (not dented by thumbnail)
93 Seed loosening in daytime
94 Over-ripe, straw dead and collapsing
95 Seed dormant
96 Viable seed giving 50% germination
97 Seed not dormant
98 Secondary dormancy induced
99 Secondary dormancy lost

(Continued)

Figure 2. Small grain staging pamphlet used for proper herbicide application using the Zadok scale. (Continued)

Herbicide	Winter Wheat	Spring Wheat and Barley
Ally	2 leaf to just before boot stage Z=12-39	Same as winter wheat. Z=12-39
Banvel SGF	Apply in spring after resumption of growth prior to jointing. Z=13-30	Apply to spring wheat before it exceeds the 5 leaf stage. (Z=12-15) Apply to barley before in exceeds the 4 leaf stage. (Z=12-14)
Bronate	Apply after 3 leaf stage but before boot stage. Z=13-39	Same as winter wheat. Z=13-39
Buctril	From emergence up to boot stage. Z=10-39	Same as winter wheat. Z=10-39
Curtail	From 4 leaf up to jointing. Z=14-29	Same as winter wheat. Z=14-29
Curtail M	From 3 leaf up to jointing. Z=13-29	Same as winter wheat. Z=13-29
Express	From 2 leaf stage but prior to emergence of flag leaf. Z=12-36	Same as winter wheat. Z=12-36
Harmony Extra	From 2 leaf stage but prior to 3rd node stage. Z=12-33	From 2 leaf stage prior to appearance of 1st node stage. Z=12-31
MCPA Amine	From 4 leaf stage prior to jointing. Z=14-29	Same as winter wheat. Z=14-29
MCPA Ester	3 to 4 leaf fully tillered up to boot stage. Z=14-42	Same as winter wheat. Z=14-42
Tordon 22K	Apply in spring after resumption of growth until early jointing. Z=13-31	3 leaf to early jointing. Z= 13-30
2,4-D Amine	Spray after tillering but before jointing. Z=14-29	Same as winter wheat. Z=14-29
2,4-D Ester LV-4 LV-6	After grain is fully tillered but before jointing. Z=15-29	Same as winter wheat. Z=15-29

Once plants were removed from soil and placed in boxes for shipping, they would remain fresh for seven to ten days if kept moist in a refrigerator (6 to 8° C). One shipment of plants could be used for workshops for one week.

Sales representatives from the Sandoz Crop Protection Corporation made excellent use of the plants. They conducted 65 workshops over a four month period in 1992 using plants in the three- to four- and five- to six-leaf stage, growth stages that are critical when using Banvel® (dicamba), a Sandoz product.

Producers believe that staging is complicated and difficult so it is important to remember that producers have this preconceived, deeply ingrained belief. When teaching crop staging it is important to emphasize that staging small grain crops is simple, once a few skills are mastered.

Workshop participants were introduced to crop staging through the use of a slide set. The first slide illustrated a plant with two leaves which was used to discuss the purpose of the coleoptile and the physical differences between the first and later leaves. When staging it is important to determine if the leaf at the base of the plant is actually the first leaf when counting leaves on the main tiller. If the first leaf is missing, which is often the case under field conditions, improper herbicide application can occur if the plants have not begun to tiller.

As use of the slide set progressed, staging became more complicated, since the plants had three, then four leaves. Participants could easily count the number of leaves so a plant was shown that had begun to tiller. At this point, emphasis must be placed on the fact that you only count leaves on the main tiller, not the leaves on secondary and tertiary tillers. This is done by finding the prophyll of each tiller. The prophyll, like the coleoptile protects the emerging growing point. Once the prophyll is located, the participants should remove any secondary and tertiary tiller tissue enclosed within the prophyll. The remaining plant parts emanate from the main tiller and can be easily counted.

When plant development reaches the five- to six-leaf stage, the node elongates, and the seed head emerges. Most of the participants did not realize that seed head development began at such an early stage. This stage of development is critical for herbicide application. Later applications of herbicides often effect the developing seed head and significantly reduce yields.

At this point in the workshop, participants were given the pamphlet (Figure 4) and the Zadok scale was explained. The Zadok scale permits whoever is staging their crop to record a precise description of plant development at the time of herbicide application. When using the Zadok scale, only the highest number is used when determining which herbicide to apply.

Participants were especially appreciative of the herbicide list on the back page of the pamphlet which provided the proper crop stage of application for each herbicide listed.

Plants were given to each participant. Normally, plants in the three- to four- and the five- to six-leaf stages were used. This limited the amount of plant material needed but was sufficient to demonstrate plant development. The first plant, in the three- to four-leaf stage, was used to familiarize participants with both counting leaves, and to observe the rounded tip of the first leaf. Later leaves have a more pointed leaf tip.

The second plant, in the five- to six-leaf stage, was used to demonstrate tillering, and node elongation. Plants in this stage usually have one to three tillers and at least one node. Once the main tiller was located and the number of leaves counted, the number of nodes was determined. Participants would run their fingers along the main tiller feeling for "bumps" which are the nodes or joints. After locating nodes, the main tiller was cut longitudinally with a razor blade to facilitate location of the developing seed head. Often what felt like one node was actually two since node separation had already taken place. A node wasn't counted as a separate node until it was 1 cm or more above the node below it.

The staging workshops were popular. Participants repeatedly stated they had been trying unsuccessfully to stage plants for many years. They were especially impressed that small grain head development was easily observed at the five- to six-leaf stage. This observation made it easy to teach the relationship between improper herbicide application timing and crop injury. The success and popularity of the staging workshops indicates the need for more "hands on" workshops related to weed science.

CHAPTER 4

A WEED SURVEY OF PEPPERMINT FIELDS IN THE FLATHEAD VALLEY, MONTANA

Introduction

Peppermint has been grown in the Flathead valley of Montana since 1968. The oil is sold primarily for human consumption, so the crop must be grown weed-free for flavor and color purposes. Few herbicides are registered for weed control in peppermint. Although numerous cultural and chemical control practices exist, weeds continue to be a problem for the peppermint producer.

A weed survey, was conducted in 34 out of a total of 58 mint fields during June of 1991. The purpose of this survey was to identify the weed species in peppermint fields, to determine which weed control practices were being used, and to determine the effectiveness of the various control practices. In addition, producers completed a questionnaire for each field to provide background information on the weed control practices used including cultural practices, herbicide use, and crop rotations in the cropping seasons before and after peppermint production. Producers were asked to identify the weed they felt most troublesome in each peppermint field.

Methods and Materials

Thirty-four of the 58 peppermint fields listed with the Western Montana Mint Growers Association of Kalispell, MT were surveyed in June, 1991. Peppermint is commonly grown in a field for five to six years, so an effort was made to select fields of each age in an attempt to record weed species shift over time. Permission to survey fields was obtained from each producer. The survey method used was developed by Thomas (1985). Twenty locations were sampled in each field. The locations were selected using an "M" pattern (Figure 3). At each location, weed species per m^2 were counted in a wire frame, using common names accepted by the Weed Science Society of America. Unknown species were identified by Todd Keener, Research Specialist II, Northwestern Agricultural Research Center, Kalispell, MT.

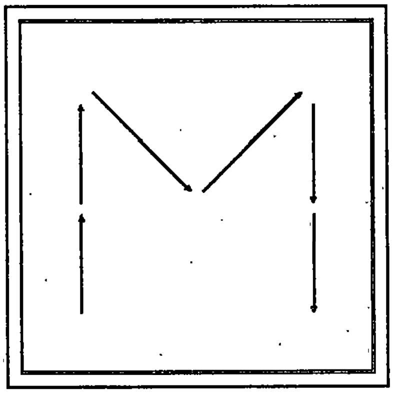


Figure 3. The "M" surveying pattern used ensured each field was uniformly and randomly sampled.

Weed populations were quantified using the seven measurements described below:

Frequency measured the number of fields in which a given species occurred at least once. Frequency is expressed as a percentage of the fields containing the weed out of 34 surveyed fields. The equation used was:

$$F_k = \frac{\sum_{n=1}^{n} Y_i}{n} x\ 100$$

Where F_k = frequency value for species k
Y_i = presence (1) or abscence (0) of species k in field i
n = number of fields surveyed

Field Uniformity measured the number of individual sampling locations in which a species occurred. It was expressed as a percentage of the total number of sampling locations for all fields (34 fields x 20 sampling locations). Field uniformity is a valuable measurement in that it measures the distribution of a weed species in all of the fields surveyed. High uniformity indicates that a weed species occurs frequently throughout all of the fields surveyed. The equation was:

$$U_k = \frac{\sum_{n=1}^{n} \sum_{n=1}^{20}}{20n} X_{ij} \; x \; 100$$

where U_k = field uniformity value for species k
x_{ij} = presence (1) or absence (0) of species in quadrant j in a given field

Occurrence Field Uniformity measures the number of sampling locations in which a species occurred in a given field. It was expressed as a percentage of the total number of sampling locations of those fields where the species occurred. Occurrence field uniformity measures the distribution of a weed species throughout those fields where that species occurs. A high occurrence field uniformity indicates that a weed species occurs frequently throughout the field where that weed species was found. This value is especially useful for farmers who do not have the weed so they can provide the management needed to prevent its introduction into a given field. The equation used was:

$$UA_k = \frac{\sum_{n=1}^{n} \sum_{n=1}^{20}}{20 \; (n-a)} X_{ij} \; x \; 100$$

where UA_k = occurrence field uniformity value for species k
a = the number of fields in which the species is absent

Mean Field Density was calculated by totalling each field density for a species and dividing by the total number of fields surveyed. Mean field density measures the average density of a weed species throughout all of the fields surveyed. The equation used to calculate density (D_i) was:

$$D_i = \frac{\sum_{n=1}^{20}}{20} Z_j$$

where D_i = density (expressed as number/m^2) value of species in field i
Z_j = number of plants in quadrant j (a quadrant is 1.0 m^2)

Mean field density (MFD_k) was calculated by:

$$MFD_k = \frac{\sum_{n=1}^{34}}{n} D_i$$

Mean Occurrence Field Density was calculated by totalling each field density for a given species and dividing only by those fields where the species occurred. Mean occurrence field density measures the average density of a weed species in only those fields where it occurred. The equation used was:

$$MOFD_k = \frac{\sum_{n=1}^{n}}{n-a} D_i$$

where a = the number of fields in which a species is absent

The <u>Relative Abundance (RA)</u> is a composite value of the frequency, occurrence, and density for a species. Relative abundance has no units and is used to compare the relative abundance of one species to another. For example, a species with an RA of 36 would be twice as abundant as a species with an RA of 18.

The equation to calculate RA was:

$$RA = RF_k + RU_k + RD_k$$

where

$$RF_k = \frac{\text{frequency of species } k}{\text{sum of frequencies for all species}} \times 100$$

$$RU_k = \frac{\text{field uniformity of species } k}{\text{sum of uniformities for all species}} \times 100$$

$$RD_k = \frac{\text{mean field density of species } k}{\text{sum of MFD for all species}} \times 100$$

A questionnaire was completed for each field surveyed to obtain background information on the field and weed control practices used. Information collected included ownership, location of the field (section, township and range), soil type, row spacing, variety, expected yield, perception of major weed problem(s), crop rotations before and after mint production, seedbed preparation, cultural practices before, during and after peppermint production, herbicides used, fertilizer rates, and irrigation dates and amounts.

<u>Results and Discussion</u>

The questionnaire filled out by each producer interviewed, included 10 questions about their farm, the problems encountered in peppermint production, the producers perception of the worst weed problem, crop rotations used, seedbed preparation, and cultural practices used during and after peppermint production. A total of 19 peppermint producers were interviewed, but only 16 producers had fields surveyed. Producers ranged in years of production from first-year production to one farmer who had produced peppermint for 23 years (Figure 4).

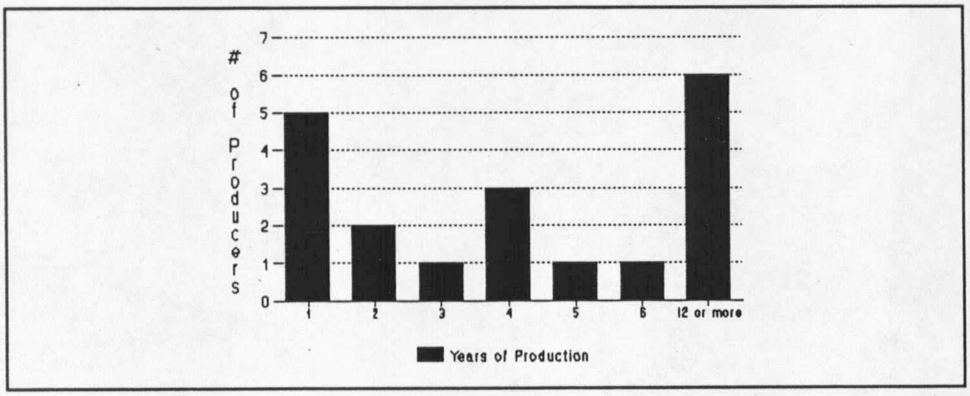


Figure 4. The number of years farmers have been in peppermint production.

Of the 19 farmers interviewed, 17 liked growing peppermint. Two producers said they weren't sure if they liked growing peppermint, that "time would tell".

Producers were asked to rank the three most important production problems they faced in order of importance. The first problem listed by each producer was given a score of three, the second a score of two and the third a score of one. The scores were totalled and ranked in order of importance (Table 7).

Table 7. The thirteen major production problems as perceived by peppermint producers in the Flathead valley.

Problem	Cumulative Score
Weeds	41
Insects	27
Weather	17
Water	5
Labor and management	4
Spray timing	3
Poor stand establishment	3
Diseases	2
Cultural practices	1
Nematodes	1
Money	1
Lack of good chemicals	1
Mint processing	1

Weeds were the most important problem followed by insects. Weather was third, and problems 4 through 13 were shared by very few of the growers.

Producers were then asked to list the two weeds they felt were most troublesome. The most troublesome weed listed by each producer was given a score of two, the second most troublesome weed listed by each producer was given a score of one. The scores were totalled and ranked in order of importance (Table 8). Two of the seventeen producers reported they had no "troublesome" weeds. They felt their control practices were working adequately, or that the "most troublesome" weed did not reduce oil yield.

It is worth noting that all of the "most troublesome" weeds are quite visible in a field. Short-statured plants such as Kentucky bluegrass (*Poa pratensis* L.) and scouringrush (*Equisetum hyemale* L.), which are less visible are not usually perceived as troublesome, even though they were often found in very high densities. Common groundsel and catchweed bedstraw were the number one and number two weeds, respectively, listed by producers.

Producers were asked to list their crop rotations for a three-year period before peppermint was planted and what crops they planned to plant after peppermint was taken out of production. The results show clearly that the pre- and post-peppermint rotations vary greatly (Table 9).

Table 8. The thirteen weed species perceived to be the most troublesome by peppermint producers in the Flathead valley.

Number	Weed Species	Latin Name	Cumulative Score
1	common groundsel	*Senecio vulgaris* L.	12
2	catchweed bedstraw	*Galium aparine* L.	10
3	Canada thistle	*Cirsium arvense* L.	7
4	annual and perennial grasses	*Agropyron* and *Poa* spp.	6
5	wild oat	*Avena fatua* L.	5
6	wild buckwheat	*Polygonum convolvulus* L.	5
7	pigweed spp.	*Amaranthus* spp.	3
8	Russian thistle	*Salsola iberica* S&P	2
9	field bindweed	*Convolvulus arvensis* L.	2
10	common mullein	*Verbascum thapsus* L.	2
11	blue mustard	*Chorispora tenella* (Pall.) DC.	2
12	pansy	*Viola pedatifida* G. Don.	2
13	henbit	*Lamium amplexicaule* L.	1

Producers were then asked to describe the cultural practices used in each field during peppermint production (Table 10). Similar answers were grouped together and summed. Producers implemented cultural practices, if used, after the peppermint rows began to fill in, either in late fall or early spring, after the second year of production. five of the producers used a combination of the cultural practices listed, depending on the age of the stand. The older the stand, the more aggressive was the treatment.

The final question asked was: how was your seedbed prepared before planting peppermint root pieces? Similar answers were grouped and summed (Table 11). The results indicate that most of the growers thoroughly prepare their seedbeds prior to planting.

After each peppermint producer was interviewed, fields were surveyed as described previously. Forty weed species were found in 34 peppermint fields in 1991 with an average of 7 weed species per field and a density of 6.6 weeds per m^2. The heaviest infestation recorded in an individual field was 51 weeds per m^2. The lowest infestation recorded in an individual field was 2.9 weed species per m^2.

All producers used herbicides. All but one producer hand-rogued his fields at least once during the growing season. Most hand-roguing occurred after the peppermint was too tall to get spray equipment into the field without sustaining crop damage from wheels.

The five most common weed species occurring in all 34 peppermint fields were, in order of frequency, wild oat, quackgrass, common groundsel, catchweed bedstraw and Canada thistle (Table 12). Wild oat and common groundsel each occurred with a frequency of 55.9%. Wild oat had a field uniformity of 18.8% and common groundsel had a field uniformity of 10.1%. Wild oat and common groundsel occurred in 42.7% and 23.0% of all sampling locations, respectively.

The five most common weed species occurring in the nine first year peppermint fields surveyed were, in order of frequency, wild oat, barley, quackgrass, Canada thistle, and wheat (Table 13). Wild oat, barley and Canada thistle each occurred with a frequency of 67.0%, 78.0%, and 67.0%, respectively. Wild oat had a field uniformity of 36.7%, barley had a field uniformity of 19.4%, and Canada thistle had a field uniformity of 13.3%. Wild oat, barley, and Canada thistle each had an occurrence field uniformity of 61.2%, 48.5%, and 22.2% respectively, in peppermint fields in their first year of production.

In the eight second year peppermint fields surveyed, wild oat, catchweed bedstraw, Russian thistle, common groundsel, and meadow salsify were the most frequently occurring weed species (Table 14). Wild oat and catchweed bedstraw each occurred with a frequency of 75.0%. Wild oat had a field uniformity of 21.9%, catchweed bedstraw had a field uniformity of 13.7%.

Table 9. Crop rotations before and after peppermint production.

Respondent	Years Before Peppermint Production					Years in Peppermint	Years After Peppermint Production				
	5	4	3	2	1		1	2	3	4	5
1		Barley	Barley	Barley	Fallow	7	Small Grains	Small Grains	Small Grains	Small Grains	Small Grains
2	Barley	Winter Wheat	Alfalfa	Alfalfa	Winter Wheat	5	Small Grains	Small Grains	Mint		
3	Barley	Alfalfa	Alfalfa	Alfalfa	Alfalfa	6	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Barley
4	Barley	Barley	Alfalfa	Alfalfa	Alfalfa	5-6	Small Grains	Small Grains	Small Grains	Alfalfa	Alfalfa
5			Winter Wheat	Fallow	Barley	4-5	Barley	Barley	Barley	Barley	Mint
6			Barley	Barley	Barley	5-6	Barley	Barley	Barley	Barley	
7	Pasture	Pasture	Barley	Barley	Barley	7	Unknown				
8			Small Grains	Small Grains	Small Grains	5-6	Small Grains	Small Grains	Small Grains	Small Grains	Fallow
9			Fallow	Winter Wheat	Barley	5-6	Barley	Barley	Legume or Wheat	Mint	
10			Spring Wheat	Spring Wheat	Spring Wheat	7	Winter Wheat	Barley	Fallow	Mint	
11			Barley	Spring Wheat	Fallow	5-6	Small Grains	Small Grains	Small Grains	Small Grains	
12				Barley	Barley	5	Barley	Barley	Mint		

(Continued)

Table 9. Crop rotations before and after peppermint production.(Continued)

Respondent	Years Before Peppermint Production 5	4	3	2	1	Years in Peppermint	Years After Peppermint Production 1	2	3	4	5
13			Alfalfa	Alfalfa	Alfalfa	15	Mint				
14			Spring Wheat	Lentils	Spring Wheat	4-5	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Alfalfa
15			Spring Wheat	Spring Wheat	Spring Wheat	6-8	Small Grains	Small Grains	Small Grains		
16			Barley	Barley	Barley	6	Alfalfa	Alfalfa	Alfalfa	Alfalfa	
17			Barley	Barley	Barley	6	Spring Wheat	Spring Wheat	Spring Wheat		

Table 10. Cultural practices used during peppermint production.

Cultural Practices Used During Peppermint Production	Number of Producers
Disced lightly	9
No cultural practices used	5
Harrowing or field cultivation	3
Fall corrugation	3
Shallow moldboard plowing	1

Table 11. Seedbed preparation practices used before planting peppermint.

Seedbed Preparation Practice	Number of Producers
Plow, cultivate, pack, plant, harrow, cultipack	11
Chisel plow, disc, harrow	3
Plow, pack, spray with glyphosate, plant, pack	2
Burn, cultivate, plant, harrow	2
Plant into fallow, pack	1
Disc stubble, plant	1

Field uniformity of wild oat and catchweed bedstraw was 54.7%, and 34.3% respectively, in peppermint fields in their second year of production.

The five most common weed species in five third year peppermint fields were, in order of frequency, quackgrass, wild oat, Canada thistle, meadow salsify, and catchweed bedstraw (Table 15). Quackgrass, Canada thistle, and meadow salsify each occurred with a frequency of 60.0%, however, the relative abundance ratings varied greatly. Even though each specie had the same frequency of occurrence, the densities varied greatly as indicated by field uniformities of 3.2%, 2.0%, and 1.4%, respectively.

The most abundant five weed species in seven fourth year peppermint fields were, in order of frequency, common groundsel, wild oat, quackgrass, meadow salsify, and catchweed bedstraw (Table 16). Common groundsel and meadow salsify each occurred with a frequency of 71.4%, but meadow salsify had a relative abundance approximately one-half that of common groundsel. The field uniformity for common groundsel was 15.0% while meadow salsify only had a field uniformity of 5.7%.

In five peppermint fields that were six years old or older, common groundsel, meadow salsify, dandelion, Kentucky bluegrass and prostrate pigweed, were the most frequent weeds found (Table 17). Common groundsel and meadow salsify each had a frequency of occurrence of 100.0% and 80.0%, respectively. Common groundsel was found in all sampling locations.

Four herbicides were used in the fields surveyed in 1991 (Table 18). The most frequently used herbicides were, in order, Sinbar (terbacil), Gramoxone (paraquat), Basagran (bentazon), and Stinger (clopyralid). All peppermint fields were irrigated frequently to maintain soil moisture in the top 14 cm of soil. Soil types where peppermint was grown ranged from sandy loams to heavy clay loams. All fields were planted to the same variety, 'Black Mitcham', originally planted in rows 49-53 cm apart.

Plants eventually grew and filled in between plants and rows so a solid stand was obtained by the fourth year of production. Solid stands required mechanical renovation to disrupt rhizomes to provide rejuvenation. Expected yields ranged from 50 pounds of oil per acre from first year peppermint fields, to 120 pounds of oil per acre from two to three year old stands.

CHAPTER 5

SUMMARY

Since many agricultural producers in Montana have difficulty identifying weed seedlings and staging small grains for herbicide application, portable workshops were developed to teach these concepts. The workshops were highly portable using a standard pick-up truck and contained live plant material that allowed for hands-on activities that often help adults learn. Many participants expressed that they felt they had learned a great deal from these workshops and would feel more confident identifying weed seedlings and staging small grain crops in their own fields.

Peppermint producers in the Flathead valley of Montana were interested in identifying what weed species were occurring in peppermint fields throughout the valley. Producers were asked to fill out a simple survey about their production practices. After the survey was completed, 34 of the 58 peppermint fields were surveyed to determine weed species and density per m^2.

Table 12. Frequency, occurrence, density, and relative abundance of 40 weed species common to peppermint fields surveyed in 1991.

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----)		
Wild Oat (*Avena fatua* L.)	55.9	18.8	42.7	2.4	4.4	47.5
Quackgrass (*Agropyron repens* L.)	44.1	11.9	21.3	0.5	1.2	28.3
Common Groundsel (*Senecio vulgaris* L.)	55.9	10.1	23.0	0.5	0.9	29.3
Catchweed Bedstraw (*Galium aparine* L.)	47.1	8.1	15.3	0.4	0.9	22.1
Dandelion (*Taraxacum officinale* W.)	35.3	6.5	10.0	0.1	0.3	19.9
Meadow Salsify (*Tragopogon pratensis* L.)	50.0	6.0	12.1	0.1	0.2	18.9
Canada Thistle (*Cirsium arvense* L.)	44.1	6.5	11.6	0.4	1.0	18.3

(Continued)

Table 12. Frequency, occurrence, density, and relative abundance of 40 weed species common to peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----)		
Barley (*Hordeum vulgare* L.)	35.3	6.8	10.5	0.2	0.5	16.7
Wild Buckwheat (*Polygonum convolvulus* L.)	32.4	4.1	6.1	0.1	0.3	11.5
Russian Thistle (*Salsola iberica* S&P)	23.5	4.1	5.4	0.4	1.5	9.9
Prostrate Knotweed (*Polygonum aviculare* L.)	26.5	3.7	5.0	0.1	0.3	9.8
Henbit (*Lamium amplexicaule* L.)	8.8	0.6	0.6	0.01	0.1	9.6
Scouringrush (*Equisetum hyemale* L.)	20.6	2.2	2.8	0.1	0.4	6.4
Prickly Lettuce (*Lactuca scariola* L.)	23.5	1.3	1.7	0.1	0.3	5.5

(Continued)

Table 12. Frequency, occurrence, density, and relative abundance of 40 weed species common to peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----)		
Kentucky Bluegrass (*Poa pratensis* L.)	14.7	2.1	2.4	0.2	1.5	5.3
Wheat (*Triticum aestivum* L.)	14.7	1.9	2.2	0.02	0.2	5.0
Field Bindweed (*Convolvulus arvensis* L.)	17.6	1.5	1.8	0.1	0.5	4.8
Green Foxtail (*Setaria viridis* L.)	5.9	2.4	2.5	0.2	3.2	4.3
Mouse-ear Chickweed (*Stellaria media* (L.) Vill.)	14.7	1.2	1.4	0.05	0.4	3.9
Blue-eyed Mary (*Collinsia parviflora* Lindl.)	11.8	1.3	1.5	0.1	0.6	3.7
Blue Mustard (*Chorispora tenella* (Pall.) DC.)	14.7	1.0	1.2	0.03	0.2	3.6

(Continued)

Table 12. Frequency, occurrence, density, and relative abundance of 40 weed species common to peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----)		
Prostrate Pigweed (*Amaranthus blitoides* L.)	8.8	1.3	1.5	0.3	3.7	3.3
Small Seeded Falseflax (*Camelina microcarpa* Andrz. ex DC.)	11.8	0.6	0.7	0.01	0.05	2.6
Night Flowering Catchfly (*Silene noctiflora* L.)	8.8	0.6	0.6	0.04	0.4	2.1
Field Pennycress (*Thlaspi arvense* L.)	8.8	0.5	0.6	0.01	0.1	2.0
Pineapple Weed (*Matricaria matricarioides* (Less.) Porter	2.9	1.0	1.1	0.05	1.8	1.9
Wild Mustard (*Brassica kaber* (DC) Wheeler)	5.9	0.6	0.6	0.01	0.1	1.6
Kochia (*Kochia scoparia* (L.) Schrad)	5.9	0.3	0.3	0.01	0.1	1.6

(Continued)

Table 12. Frequency, occurrence, density, and relative abundance of 40 weed species common to peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency (%)	Field Uniformity (%)	Occurrence Field Uniformity (%)	Mean Field Density (-----NUMBER/m^2-----)	Mean Occurrence Field Density	Relative Abundance
Alfalfa (*Medicago sativa* L.)	5.9	0.4	0.5	<0.01	0.1	1.5
Corn Gromwell (*Lithospermum arvense* L.)	2.9	0.7	0.8	0.01	0.4	1.4
Pinnate Tansy Mustard (*Descurainia pinnata* (Walt.) Britt)	5.9	0.3	0.3	<0.01	0.05	1.3
Cowcockle (*Vaccaria pyramidata* M.)	5.9	0.3	0.3	<0.01	0.05	1.3
Tumble Mustard (*Sisymbrium altissimum* L.)	5.9	0.3	0.3	<0.01	0.1	1.3
Pansy (*Viola pedatifida* G. Don.)	5.9	0.3	0.3	<0.01	0.05	1.3
Common Mullein (*Verbascum thapsus* L.)	2.9	0.3	0.3	<0.01	0.1	0.9

(Continued)

Table 12. Frequency, occurrence, density, and relative abundance of 40 weed species common to peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m²-----)		
Common Lambsquarters (*Chenopodium album* L.)	2.9	0.1	0.2	<0.01	0.5	0.6
Broadleaf Plantain (*Plantago major* L.)	2.9	0.1	0.2	<0.01	0.1	0.6
Cone Catchfly (*Silene conoidea* L.)	2.9	0.1	0.2	<0.01	0.05	0.6
Cheatgrass (Downy Brome) (*Bromus tectorum* L.)	2.9	0.1	0.2	<0.01	0.05	0.6
Yellow Toadflax (*Linaria vulgaris* Mill.)	2.9	0.1	0.2	<0.01	0.05	0.6

Table 13. Frequency, occurrence, density, and relative abundance of 40 weed species common to first-year peppermint fields surveyed in 1991.

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----)		
Wild Oat (*Avena fatua* L.)	67.0	36.7	61.2	8.1	0.9	55.4
Barley (*Hordeum vulgare* L.)	78.0	19.4	48.5	0.5	5.6	42.0
Quackgrass (*Agropyron repens* L.)	56.0	22.8	28.5	0.9	10.0	32.4
Canada Thistle (*Cirsium arvense* L.)	67.0	13.3	22.2	1.0	11.1	26.0
Wheat (*Triticum aestivum* L.)	44.0	13.9	13.9	0.1	1.1	19.6
Prostrate Knotweed (*Polygonum aviculare* L.)	44.0	10.0	10.0	0.3	0.3	15.8
Wild Buckwheat (*Polygonum convolvulus* L.)	44.0	8.9	8.9	0.3	3.3	14.8

(Continued)

Table 13. Frequency, occurrence, density, and relative abundance of 40 weed species common to first-year peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----)		
Dandelion (*Taraxacum officinale* W.)	33.0	8.9	7.4	0.1	1.1	13.3
Catchweed Bedstraw (*Galium aparine* L.)	33.0	8.3	6.9	0.4	4.4	12.1
Russian Thistle (*Salsola iberica* S&P)	33.0	6.7	5.6	1.1	12.2	10.7
Green Foxtail (*Setaria viridis* L.)	11.0	7.8	4.9	0.5	5.6	7.9
Mouse-ear Chickweed (*Stellaria media* (L.) Vill.)	33.0	3.3	2.8	0.2	2.2	7.6
Prickly Lettuce (*Lactuca scariola* L.)	22.0	4.4	3.1	0.1	1.1	6.8
Wild Mustard (*Brassica kaber* (DC) Wheeler)	22.0	2.2	1.6	0.02	0.2	5.0

(Continued)

Table 13. Frequency, occurrence, density, and relative abundance of 40 weed species common to first-year peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m²-----	-----)	
Pineapple Weed (*Matricaria matricarioides* (Less.) Porter	11.0	3.9	2.4	0.2	2.2	4.6
Field Bindweed (*Convolvulus arvensis* L.)	22.0	1.1	0.8	0.02	0.2	4.0
Common Groundsel (*Senecio vulgaris* L.)	11.0	2.8	1.8	0.01	0.07	3.8
Corn Gromwell (*Lithospermum arvense* L.)	11.0	2.8	1.8	0.04	0.4	3.8
Alfalfa (*Medicago sativa* L.)	11.0	1.1	0.7	0.1	0.1	2.4
Night Flowering Catchfly (*Silene noctiflora* L.)	11.0	1.1	0.7	0.01	0.1	2.4
Henbit (*Lamium amplexicaule* L.)	11.0	0.6	0.4	0.01	0.07	2.0

(Continued)

Table 13. Frequency, occurrence, density, and relative abundance of 40 weed species common to first-year peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----)		
Kochia (*Kochia scoparia* (L.) Schrad)	11.0	0.5	0.3	0.01	0.07	1.9
Pinnate Tansy Mustard (*Descurainia pinnata* (Walt.) Britt)	11.0	0.6	0.4	0.01	0.07	2.0
Kentucky Bluegrass (*Poa pratensis* L.)	11.0	0.6	0.4	0.01	0.1	2.0
Cowcockle (*Vaccaria pyramidata* M.)	11.0	0.6	0.4	0.01	0.1	2.0

Table 14. Frequency, occurrence, density, and relative abundance of 40 weed species common to second-year peppermint fields surveyed in 1991.

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----)		
Wild Oat (*Avena fatua* L.)	75.0	21.9	54.7	0.7	0.1	74.5
Catchweed Bedstraw (*Galium aparine* L.)	75.0	13.7	34.3	1.1	0.1	50.7
Common Groundsel (*Senecio vulgaris* L.)	62.5	8.1	13.5	0.1	0.01	27.9
Meadow Salsify (*Tragopogon pratensis* L.)	50.0	5.0	6.2	0.07	0.01	17.4
Russian Thistle (*Salsola iberica* S&P)	25.0	7.5	6.2	0.2	0.03	16.9
Canada Thistle (*Cirsium arvense* L.)	50.0	3.7	4.6	0.2	0.03	14.7
Wild Buckwheat (*Polygonum convolvulus* L.)	37.5	4.4	4.4	0.1	0.01	13.7

(Continued)

Table 14. Frequency, occurrence, density, and relative abundance of 40 weed species common to second-year peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency (%)	Field Uniformity (%)	Occurrence Field Uniformity (%)	Mean Field Density (-----NUMBER/m²-----)	Mean Occurrence Field Density	Relative Abundance
Quackgrass (*Agropyron repens* L.)	37.5	4.4	4.4	0.1	0.01	13.7
Scouringrush (*Equisetum hyemale* L.)	37.5	3.1	3.1	0.08	0.01	11.2
Dandelion (*Taraxacum officinale* W.)	25.0	3.7	3.1	0.05	0.01	10.1
Field Bindweed (*Convolvulus arvensis* L.)	25.0	3.1	2.6	0.3	0.04	9.1
Prickly Lettuce (*Lactuca scariola* L.)	37.5	1.9	1.9	0.06	0.01	9.0
Prostrate Knotweed (*Polygonum aviculare* L.)	25.0	1.2	1.0	0.01	<0.01	5.7
Barley (*Hordeum vulgare* L.)	25.0	1.2	1.0	0.01	<0.01	5.7

(Continued)

Table 14. Frequency, occurrence, density, and relative abundance of 40 weed species common to second-year peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----)		
Kentucky Bluegrass (*Poa pratensis* L.)	12.5	1.2	0.9	0.03	<0.01	3.8
Green Foxtail (*Setaria viridis* L.)	12.5	1.2	0.8	0.2	0.03	3.7
Kochia (*Kochia scoparia* (L.) Schrad	12.5	0.6	0.4	0.01	<0.01	2.8
Alfalfa (*Medicago sativa* L.)	12.5	0.6	0.4	0.01	<0.01	2.8
Common Lambsquarters (*Chenopodium album* L.)	12.5	0.6	0.4	0.01	<0.01	2.8
Broadleaf Plantain (*Plantago major* L.)	12.5	0.6	0.4	0.01	<0.01	2.8
Small Seeded Falseflax (*Camelina microcarpa* Andrz. ex DC.)	12.5	0.6	0.4	0.01	<0.01	2.8

(Continued)

Table 14. Frequency, occurrence, density, and relative abundance of 40 weed species common to second-year peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----	-----)	
Blue Mustard (*Chorispora tenella* (Pall.) DC.)	12.5	0.6	0.4	0.01	<0.01	2.8
Cone Catchfly (*Silene conoidea* L.)	12.5	0.6	0.4	0.01	<0.01	2.8

Table 15. Frequency, occurrence, density, and relative abundance of 40 weed species common to third-year peppermint fields surveyed in 1991.

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----	-----)	
Quackgrass (*Agropyron repens* L.)	60.0	3.2	8.0	0.9	0.2	56.7
Wild Oat (*Avena fatua* L.)	40.0	2.2	3.7	0.2	0.04	32.8
Canada Thistle (*Cirsium arvense* L.)	60.0	2.0	5.0	0.7	0.14	39.1
Meadow Salsify (*Tragopogon pratensis* L.)	60.0	1.4	1.5	0.1	0.02	23.6
Catchweed Bedstraw (*Galium aparine* L.)	40.0	1.2	2.0	0.1	0.02	20.8
Barley (*Hordeum vulgare* L.)	40.0	1.2	2.0	0.1	0.02	20.8
Common Groundsel (*Senecio vulgaris* L.)	60.0	0.8	1.5	0.3	0.06	19.8

(Continued)

Table 15. Frequency, occurrence, density, and relative abundance of 40 weed species common to third-year peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----)		
Dandelion (*Taraxacum officinale* W.)	40.0	0.6	1.0	0.03	<0.01	13.7
Henbit (*Lamium amplexicaule* L.)	40.0	0.6	1.0	0.04	<0.01	13.7
Blue-eyed Mary (*Collinsia parviflora* Lindl.)	20.0	0.8	1.0	0.08	0.02	11.6
Field Pennycress (*Thlaspi arvense* L.)	20.0	0.6	0.8	0.03	<0.01	9.7
Prickly Lettuce (*Lactuca scariola* L.)	20.0	0.2	0.3	0.01	<0.01	5.5
Scouringrush (*Equisetum hyemale* L.)	20.0	0.2	0.3	0.03	<0.01	5.5
Kentucky Bluegrass (*Poa pratensis* L.)	20.0	0.2	0.3	0.01	<0.01	5.5

(Continued)

Table 15. Frequency, occurrence, density, and relative abundance of 40 weed species common to third-year peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----)		
Mouse-ear Chickweed (*Stellaria media* (L.) Vill.)	20.0	0.2	0.3	0.01	<0.01	5.5
Prostrate Pigweed (*Amaranthus blitoides* L.)	20.0	0.2	0.3	0.01	<0.01	5.5
Cheatgrass (Downy Brome) (*Bromus tectorum* L.)	20.0	0.2	0.3	0.01	<0.01	5.5
Tumble Mustard (*Sisymbrium altissimum* L.)	20.0	0.2	0.3	0.01	<0.01	5.5

Table 16. Frequency, occurrence, density, and relative abundance of 40 weed species common to fourth-year peppermint fields surveyed in 1991.

Plant Species	Frequency (%)	Field Uniformity (%)	Occurrence Field Uniformity (%)	Mean Field Density (-----NUMBER/m²-----)	Mean Occurrence Field Density	Relative Abundance
Common Groundsel (*Senecio vulgaris* L.)	71.4	15.0	37.5	1.1	0.2	64.5
Wild Oat (*Avena fatua* L.)	57.1	10.0	16.7	0.5	0.1	37.4
Meadow Salsify (*Tragopogon pratensis* L.)	71.4	5.7	14.3	0.06	0.01	32.2
Quackgrass (*Agropyron repens* L.)	12.8	11.4	14.3	0.3	0.05	29.7
Catchweed Bedstraw (*Galium aparine* L.)	42.8	6.4	8.0	0.2	0.03	22.7
Scouringrush (*Equisetum hyemale* L.)	28.6	5.0	5.0	0.2	0.03	15.8
Wild Buckwheat (*Polygonum convolvulus* L.)	42.8	2.1	2.6	0.05	0.01	12.3

(Continued)

Table 16. Frequency, occurrence, density, and relative abundance of 40 weed species common to fourth-year peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency (%)	Field Uniformity (%)	Occurrence Field Uniformity (%)	Mean Field Density (-----NUMBER/m²-----)	Mean Occurrence Field Density (-----NUMBER/m²-----)	Relative Abundance
Kentucky Bluegrass (*Poa pratensis* L.)	14.3	4.3	3.6	0.2	0.02	11.2
Dandelion (*Taraxacum officinale* W.)	28.6	2.1	2.1	0.06	0.01	9.5
Blue Mustard (*Chorispora tenella* (Pall.) DC.)	28.6	1.4	1.4	0.01	<0.01	8.0
Barley (*Hordeum vulgare* L.)	14.3	2.1	1.8	0.04	0.01	6.8
Prostrate Pigweed (*Amaranthus blitoides* L.)	14.3	2.1	1.8	0.14	0.02	6.8
Field Bindweed (*Convolvulus arvensis* L.)	14.3	1.4	1.2	0.05	0.01	5.3
Common Mullein (*Verbascum thapsus* L.)	14.3	1.4	1.2	0.01	<0.01	5.3

(Continued)

Table 16. Frequency, occurrence, density, and relative abundance of 40 weed species common to fourth-year peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m²-----)		
Canada Thistle (*Circsium arvense* L.)	14.3	0.7	0.6	0.06	0.01	3.8
Prostrate Knotweed (*Polygonum aviculare* L.)	14.3	0.7	0.6	0.01	<0.01	3.8
Russian Thistle (*Salsola iberica* S&P)	14.3	0.7	0.6	0.01	<0.01	3.8
Field Pennycress (*Thlaspi arvense* L.)	14.3	0.7	0.6	0.01	<0.01	3.8
Pinnate Tansy Mustard (*Descurainia pinnata* (Walt.) Britt)	14.3	0.7	0.6	0.01	<0.01	3.8
Small Seeded Falseflax (*Camelina microcarpa* Andrz. ex DC.)	14.3	0.7	0.6	0.01	<0.01	3.8
Mouse-ear Chickweed (*Stellaria media* (L.) Vill.)	14.3	0.7	0.6	0.01	<0.01	3.8

Table 17. Frequency, occurrence, density, and relative abundance of 40 weed species common to six-year and older peppermint fields surveyed in 1991.

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----)		
Common Groundsel (*Senecio vulgaris* L.)	100.0	30.0	150.0	1.2	0.2	77.7
Meadow Salsify (*Tragopogon pratensis* L.)	80.0	18.0	90.0	0.3	0.1	49.2
Dandelion (*Taraxacum officinale* W.)	60.0	16.0	40.0	0.3	0.1	31.3
Kentucky Bluegrass (*Poa pratensis* L.)	40.0	10.0	16.7	1.3	0.3	17.7
Prickly Lettuce (*Lactuca scariola* L.)	40.0	5.0	8.3	0.1	0.03	11.3
Catchweed Bedstraw (*Galium aparine* L.)	40.0	4.0	6.7	0.1	0.02	10.0
Blue-eyed Mary (*Collinsia parviflora* Lindl.)	40.0	4.0	6.7	0.4	0.1	10.0

(Continued)

Table 17. Frequency, occurrence, density, and relative abundance of 40 weed species common to six year and older peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----)		
Blue Mustard (*Chorispora tenella* (Pall.) DC.)	40.0	4.0	6.7	0.2	0.04	10.0
Russian Thistle (*Salsola iberica* S&P)	40.0	3.0	5.0	0.1	0.02	8.8
Prostrate Pigweed (*Amaranthus blitoides* L.)	20.0	5.0	6.3	2.0	0.4	8.2
Prostrate Knotweed (*Polygonum aviculare* L.)	20.0	5.0	6.3	0.01	0.00	8.2
Quackgrass (*Agropyron repens* L.)	40.0	2.0	3.3	0.2	0.04	7.4
Wild Buckwheat (*Polygonum convolvulus* L.)	20.0	2.0	2.5	0.02	0.00	4.7
Wild Oat (*Avena fatua* L.)	20.0	2.0	2.5	0.05	0.01	4.7

(Continued)

Table 17. Frequency, occurrence, density, and relative abundance of 40 weed species common to six-year and older peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency	Field Uniformity	Occurrence Field Uniformity	Mean Field Density	Mean Occurrence Field Density	Relative Abundance
	(%)	(%)	(%)	(-----NUMBER/m^2-----)		
Canada Thistle (*Cirsium arvense* L.)	20.0	2.0	2.5	0.04	0.01	4.7
Scouringrush (*Equisetum hyemale* L.)	20.0	1.0	1.3	0.03	0.01	3.6
Wheat (*Triticum aestivum* L.)	20.0	1.0	1.3	0.01	<0.01	3.6
Field Bindweed (*Convolvulus arvensis* L.)	20.0	1.0	1.3	0.1	0.02	3.6
Small Seeded Falseflax (*Camelina microcarpa* Andrz. ex DC.)	20.0	1.0	1.3	0.01	<0.01	3.6
Night Flowering Catchfly (*Silene noctiflora* L.)	20.0	1.0	1.3	0.05	0.01	3.6
Mouse-ear Chickweed (*Stellaria media* (L.) Vill.)	20.0	1.0	1.3	0.05	0.01	3.6

(Continued)

Table 17. Frequency, occurrence, density, and relative abundance of 40 weed species common to six-year and older peppermint fields surveyed in 1991.(Continued)

Plant Species	Frequency (%)	Field Uniformity (%)	Occurrence Field Uniformity (%)	Mean Field Density (-----NUMBER/m^2-----)	Mean Occurrence Field Density (-----NUMBER/m^2-----)	Relative Abundance
Cheatgrass (Downy Brome) (*Bromus tectorum* L.)	20.0	1.0	1.3	0.01	<0.01	3.6
Tumble Mustard (*Sisymbrium altissimum* L.)	20.0	1.0	1.3	0.02	<0.01	3.6
Yellow Toadflax (*Linaria vulgaris* Mill.)	20.0	1.0	1.3	0.01	<0.01	3.6
Pansy (*Viola pedatifida* G. Don.)	20.0	1.0	1.3	0.03	<0.01	3.6

Table 18. Field age, weed density, number of species, and weed control practices used in 34 peppermint fields surveyed in 1991.

Field Number	Field Age Years	Weeds/ $20m^2$	Number of Weed Species	Herbicides	Application Rate
1	2	59	7	Sinbar	1 lb/A
2	1	82	4	Sinbar + Gramoxone Extra	1 lb/A + 1-1.5 pt/A
				Stinger	0.3 pt/A
				Basagran	1-2 pt/A
3	3	88	4	Same as field #2	
4	2	89	5	Same as field #2	
5	4	140	11	Sinbar + Paraquat	2/3 lb/A + 1 qt/A
				Basagran	1 pt/A
				Stinger	2/3 pt/A
6	3	37	5	Same as field #5	
7	2	165	10	Sinbar	0.8 lb/A
				Stinger	0.5 oz/A
				Basagran	1 pt/A
8	1	176	13	Sinbar	1 lb/A
				Basagran	Not Available
				Stinger	1 pt/A
9	2	47	8	Sinbar	0.7 lb/A
				Gramoxone	2 oz/A
				Basagran	Not Available
				Stinger	1 pt/A

(Continued)

Table 18. Field age, weed density, number of species, and weed control practices used in 34 peppermint fields surveyed in 1991.(Continued)

Field Number	Field Age Years	Weeds/ $20m^2$	Number of Weed Species	Herbicides	Application Rate
10	2	52	10	Sinbar	0.25 lb/A
				Gramoxone	8-12 oz/A
				Stinger	1 pt/A
11	3	32	53	Same as field #10	
12	2	28	6	Same as field #10	
13	1	111	8	Same as field #10	
14	1	276	5	Sinbar +	1 lb/A +
				Gramoxone	1 pt/A
				Stinger	0.5-0.7 pt/A
				Sinbar +	1 lb/A
				Basagran	1 pt/A
15	1	226	7	Same as field #14	
16	6	70	8	Same as field #14	
17	3	79	7	Sinbar	0.25-0.5 lb/A
				Gramoxone	1 qt/A
				Basagran	2 pt/A
				Stinger	0.25-0.5 pt/A
18	1	52	7	Same as field #17	
19	1	80	5	Same as field #17	
20	4	75	6	Sinbar	1 lb/A
				Paraquat	1 pt/A
				Basagran	2 pt/A
				Stinger	0.25-0.5 pt/A
21	2	113	9	Same as field #20	
22	1	1274	7	Same as field #20	

(Continued)

Table 18. Field age, weed density, number of species, and weed control practices used in 34 peppermint fields surveyed in 1991.(Continued)

Field Number	Field Age Years	Weeds/ 20m^2	Number of Weed Species	Herbicides	Application Rate
23	4	33	6	Sinbar	1 lb/A
				Gramoxone	< 0.25 pt/A
				Basagran	< 2 pt/A
				Stinger	1 pt/A
24	3	31	10	Same as field #23	
25	7	32	6	Sinbar	< 1 lb/A
				Gramoxone	< 1 pt/A
				Basagran	Not Available
				Stinger	Not Available
26	4	65	6	Same as field #25	
27	1	55	6	Same as field #25	
28	2	8	1	Sinbar	0.5-1 lb/A
				Basagran	Not Available
				Stinger	Not Available
29	8	107	11	Same as field #28	
30	4	25	4	Sinbar	1 lb/A
31	6	279	2	Sinbar	I lb/A
32	4	11	5	Sinbar	0.25 lb/A
				Paraquat	8-12 oz/A
				Stinger	< 1 qt/A
				Basagran	2 pt/A
33	15	177	12	Same as field #32	
34	1	300	6	Sinbar	1 lb/A
				Basagran	1 qt/A

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APPENDIX

APPENDIX

A Teaching Guide for Weed Seedling Identification

Slide 1: Basic plant parts - Cotyledons are the first to emerge from the soil. They are always opposite from each other on the stem, and may or may not be similar in form and shape to the later leaves. The first leaves can either have an entire (smooth) or toothed (lobed) leaf margin. The petiole is the plant structure that attaches leaves or cotyledons to the main stem. Leaves will either have pinnate (feather like) or palmate venation.

Slide 2: Cotyledon shape.

Slide 3: Linear, oblong, and lanceolate cotyledons. These cotyledons can be differentiated from others by their linear shape. They are approximately the same width the entire length of the cotyledon, and may or may not come to a point at the tip. The cotyledon begins abruptly at the petiole.

Slide 4: Ovate cotyledons. The cotyledon is wider at the base and always comes to a point at the tip. The cotyledon also begins abruptly at the petiole.

Slide 5: Oval, round, and spatulate cotyledons. These cotyledons are round. Oval cotyledons are slightly longer than wide, and never come to a point at the tip. Round cotyledons do not come to a point at the tip. Both begin abruptly at the petiole. Spatulate cotyledons are longer than they are wide, but do not begin abruptly at the petiole. They never come to a point at the tip. These cotyledons may have a slight indentation at the tip, similar to a kidney shaped cotyledon.

Slide 6: Kidney shaped cotyledons. These cotyledons have a kidney bean shape. The cotyledons begin abruptly at the petiole with a large dip at the tip which gives the appearance of a kidney bean or alfalfa seed.

Slide 7: Leaf.

Slide 8: Leaf arrangement on stem. Leaf arrangement can either be opposite or alternate. If they are opposite, leaves emerge from the growing point of the plant as a pair. this means there will be two leaves at the top of the plant that are the same size 180° apart from each other on the stem. If the leaves are alternate, leaves will emerge from the growing point of the plant one at a time. There will always be one leaf that is smaller than the previous leaf at the top of the plant. Often they are 90° apart from each other on the stem.

Slide 9: Leaf shape. Plants can either have lobed or unlobed leaves. If plants have a lobed leaves, the lobing can either be pinnate or palmate. Pinnate lobing is similar to a feather, with one main vein and the lobes deeply cut into the leaf, sometimes almost to the vein. Palmate lobing is similar to the palm of your hand, with lobes radiating from a central point. If leaves are not lobed, the leaf margin can either be entire (smooth) or toothed. A toothed leaf margin need not have lots of teeth (serrations). Often, there are only a few teeth. Lambsquarters serves as a good example.

Slide 10: Stem shape. Stems can either be square or round. Roll the seedling between your fingers. If it rolls easily, the stem is round, if it bumps or jerks as it rolls, the stem is square. You can also cut the stem and look at it in cross-section. If you see corners, the stem is square. If not, it's round.

After looking at the slides which describe how to use the key, pass out the keys so the participants can examine the key with you. If you pass out the keys prior to showing the slide set, the participants will examine the key and ignore you. After participants have a key, point out that all of the information presented in the slide set is found on the inner flaps of the key. Additional information including definitions and suggestions for collecting seedlings for identification are also found on the inner flaps of the key. Open the key and show the participants how to use it. Identify the cotyledon shape, and move across the key until a plant is identified. If the descriptions are not closelt matching the specimen, the wrong cotyledon group may have been selected, a common mistake for participants.

Seedling Slides:

Wild Mustard: The only plant on key with kidney shaped cotyledons. Easiest to key out. Do this plant first so participants have an initial success.

Cowcockle: Linear cotyledons, leaves not pinnately lobed, leaves sparsely hairy or without hair, leaves opposite, leaves not needle-like, leaves not mealy.

Catchweed Bedstraw: Oval cotyledons, stem is square above the cotyledons, leaves are whorled with 4 to 8 per node. Plant is sticky like velcro.

Russian Thistle: Linear cotyledons, leaves not pinnately lobed, leaves sparsely hairy or without hair, leaves are opposite, leaves are needle-like.

Henbit: Round cotyledons, stem is square above the cotyledons, leaves are opposite with two leaves per node. Mature plant has small purple flowers that occur in a whorl around the stem at the base of each set of leaves.

Eastern Black Nightshade: Ovate cotyledons, ovate-shaped leaves with pinnate venation, leaves sparsely hairy or without hair. It is important to notice where the hair is located. This nightshade has most of the hair on the stem, petiole, and leaf margins. There is a small amount of hair on the leaf surface, but most of the hair is located on the stem.

Redroot Pigweed: Linear cotyledons, leaves not pinnately lobed, leaves sparsely hairy or without hair, leaves are alternate, leaves are not arrowhead shaped, ovate-shaped leaves. Has an erect growth habit and also has a red stem.

Pinnate Tansy Mustard: Linear cotyledons, leaves are pinnately lobed, first two leaves are opposite, later leaves are alternate. Very difficult to tell when plants are small. It is easier to match the picture to the end of a leaflet. All these drawings are very close to what the actual plant looks like. This weed is often confused with flixweed.

Field Pennycress: Oval cotyledons, stem is round or absent (forms a basal rosette), Margin of second and later leaves is unevenly toothed or lobed, leaf margin teeth are not spine tipped, leaves without hair. This seedling is on the key twice due to the wide variation between seedlings. If the choice of margin of second and later leaves is entire or evenly toothed was made, continue through the key making the following choice - leaves without hair. A good diagnostic tool to use for this one is to rub a leaf and smell the unpleasant odor produced. This is a very distinct characteristic of field pennycress whick is called stink weed in some areas.

NOTE: If the margin of second and later leaves is to be evenly toothed or lobed, then the leaf margin teeth must be mirror images of the other side of the leaf. Teeth must occur at the same location on the leaf and be the same size and shape.

Wild Buckwheat: Linear cotyledons, leaves not pinnately lobed, leaves sparsely hairy or without hair, leaves are alternate, leaves are arrowhead shaped. This weed is often confused with field bindweed. There are some important differences: Wild buckwheat has linear cotyledons, is an annual with a single root, grows scattered around the field, flowers are small and green, and the seeds are black and triangular shaped. Field bindweed has kidney shaped cotyledons, is a perennial with a rhizomatous root system, grows in large patches, flowers are large trumpet shaped and can be different colors ranging from white, pink, and lavendar, seeds are round and grey.

Kochia: Linear cotyledons, leaves not pinnately lobed, leaves are very hairy. This weed tumbles and frequently gets caught in fence rows.

Corn Gromwell: Spatulate cotyledons (may have small dimple in end of cotyledon, but is not large enough to fit into the kidney shaped cotyledon category), stem is round, margin of second and later leaves is entire or evenly toothed, leaves are hairy, cotyledons are densely hairy. Many people will not read the key carefully and mistakenly call this one common sunflower. This mistake is made because of the hairiness of the cotyledons.

Common Lambsquarters: Linear cotyledons, leaves are not pinnately lobed (there may be leaf margin teeth, but leaves are not lobed), leaves are sparsely hairy or without hair, leaves are opposite, leaves are not needle-like, leaves are mealy. Mealy is listed in the definition list. May also be defined as having a frosty appearance, like a frosty window pane.

Common (Wild) Sunflower: Spatulate cotyledons, stem is round, margin of second and later leaves is entire or evenly toothed (leaf is hairy, but leaf margin is entire), leaves are hairy, cotyledons are sparsely hairy or without hair. Often confused with corn gromwell. Make sure participants read key carefully. May also rub a leaf and detect an odor characteristic of sunflowers.

Prickly Lettuce: Oval cotyledons, stem is round or absent (forms a basal rosette), margin of second and later leaves is unevenly toothed or lobed (leaf margins are not mirror images of each other), leaf margin teeth have soft spines at the tips. Spines are slightly larger than hairs and if they were stiff, would poke when touched (like a cactus).

Sheperdspurse: Oval cotyledons, stem is round or absent (forms a basal rosette), margin of second and later leaves is unevenly toothed or lobed, leaf margin teeth are not spine tipped, leaves are hairy. This weed, like tumble mustard (Jim Hill mustard, tall mustard) is very difficult to identify at this stage. Sheperdspurse leaves have a narrower shape than tumble mustard. Tumble mustard has longer, more obvious hairs on the leaf surface. The leaves also have a wider shape.

Prostrate Pigweed: Linear cotyledons, leaves not pinnately lobed, leaves sparsely hairy or without hair, leaves are alternate, leaves are not arrowhead shaped, leaves are spatulate-shaped (no abrupt beginning at the petiole). Prostrate growth habit, often confused with common purselane which has fleshy leaves, similar to jade plants.