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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An educational program was designed for both weed seedling identification and crop staging. Each educational program was designed to be easily transportable. The weed seedling identification and crop staging workshops each included "hands-on" learning experiences which help adults learn difficult concepts.

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

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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**
	00	Dry Seed
	01	Start of imbibition
	02	
	03	Imbibition complete
	04	
	05	Radicle emerged from caryopsis
	06	
	07	Coleoptile emerged from caryopsis
	08	
	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
	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	
	39	Flag leaf ligule just visible
4		**Booting**
	40	
	41	Flag leaf sheath extending
	42	
	43	Boots just visibly swollen
	44	
	45	Boots swollen
	46	
	47	Flag leaf sheath opening
	48	
	49	First awns visible
5		**Inflorescence**
	50	
	51	First inflorescence just visible
	52	
	53	¼ of inflorescence emerged
	54	
	55	½ of inflorescence emerged
	56	
	57	¾ of inflorescence emerged
	58	Inflorescence fully emerged
	59	
6		**Anthesis (flowering)**
	60	
	61	Beginning of anthesis
	62	
	63	
	64	
	65	Anthesis half-way
	66	
	67	
	68	
	69	
7		**Milk development**
	70	
	71	Caryopsis water ripe
	72	
	73	Early milk
	74	
	75	Medium milk
	76	
	77	Hard dough
	78	
	79	
8		**Dough development**
	80	
	81	
	82	
	83	Early dough
	84	
	85	Soft dough
	86	
	87	Hard dough
	88	
	89	
9		**Ripening**
	90	
	91	Caryopsis hard (hard to divide)
	92	Caryopsis hard (not dented)
	93	Caryopsis loosening in daytime
	94	Over-ripe, straw dead, decaying
	95	Seed dormant
	96	Viable seed 50% germination
	97	Seed not dormant
	98	Secondary dormancy induced
	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**
	00	Dry seed
	01	Start of imbibition
	02	
	03	Imbibition complete
	04	
	05	Radicle emerged from seed
	06	
	07	Coleoptile emerged from seed
	08	
	09	Leaf at tip of coleoptile
1		**Vegetative development**
	10	First leaf through coleoptile
	11	Apex with 1 leaf primordium
	12	Apex with 2 leaf primordium
	13	Apex with 3 leaf primordium
	14	Apex with 4 leaf primordium
	15	Apex with 5 leaf primordium
	16	Apex with 6 leaf primordium
	17	Apex with 7 leaf primordium
	18	Apex with 8 leaf primordium
	19	Apex with 9 or more leaf primordium
2		**Branch formation (1st-order branches only)**
	20	Main axis only
	21	1 branch initial detectable
	22	2 branch initials detectable
	23	3 branch initials detectable
	24	4 branch initials detectable
	25	5 branch initials detectable
	26	6 branch initials detectable
	27	7 branch initials detectable
	28	8 branch initials detectable
	29	9 or more branch initials detectable
3		**Transition period**
	30	Ear at 1 cm
	31	
	32	2nd-order branches initiated
	33	3rd-order branches initiated
	34	4th-order branches initiated
	35	5th-order branches initiated
	36	6th-order branches initiated
	37	7th-order branches initiated
	38	8th-order branches initiated
	39	9th-order branches initiated
4		**Spikelet differentiation**
	40	Tip of main axis undifferentiated
	41	Spikelet primordium just visible on main axis
	42	
	43	
	44	
	45	Glume primordium stage: two ridges appear at right angles to the plane of 1st-order branches
	46	
	47	
	48	
	49	Lemma primordium stage: prominent ridges between glumes visible
5		**Floret differentiation**
	50	
	51	Floret primordium stage: round meristematic dome above lemma initials visible
	52	
	53	Stamen primordium stage: three bulges on the floret meristem visible
	54	
	55	Stamen division stage: four compartments clearly distinctive
	56	
	57	
	58	
	59	
6		**Anthesis**
	60	
	61	Beginning of anthesis
	62	
	63	
	64	
	65	50% anthesis
	66	
	67	
	68	
	69	Anthesis complete
7		**Milk development**
	70	
	71	Seed watery ripe
	72	
	73	Early milk
	74	
	75	Medium milk
	76	
	77	Late milk
	78	
	79	
8		**Dough development**
	80	
	81	
	82	
	83	Early dough
	84	
	85	Soft dough
	86	
	87	Hard dough
	88	
	89	
9		**Ripening**
	90	
	91	Seed hard (difficult to divide)
	92	Seed hard (dented by thumbnail)
	93	Seed loosening
	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

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.