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Title: FOLIAGE APPLICATIONS OF TERBACIL TO PEPPERMINT (Mentha piperita) AND SEVERAL WEED SPECIES

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Several studies were conducted to determine the feasibility of using terbacil (3-tert-butyl-5-chloro-6-methyluracil) postemergence to weeds and peppermint (Mentha piperita L.). Three nonionic surfactants, four nonphytotoxic oils, and a liquid fertilizer were each combined with 0.5 lb ai/A terbacil in 35 gallons of water per acre. Weed species tested include: redroot pigweed (Amaranthus retroflexus L.), lambsquarters (Chenopodium album L.), common mustard (Brassica campestris L.), barnyardgrass (Echinochloa crusgalli (L.) Beauv.), and green foxtail (Setaria viridis (L.) Beauv.).

Broadleaf weeds were more susceptible to foliage applications of terbacil than grass species. However, excellent control of both broadleaf weeds and grasses was obtained when applications were made within seven days after weed seedling emergence. Less grass control always resulted when treatments were made two or three weeks after emergence.

The addition of nonphytotoxic oils or surfactants to the spray solution was beneficial to terbacil activity at later stages of weed growth. Nonphytotoxic oils were usually more effective than surfactants. Solution 32, a liquid nitrogen solution, in combination with terbacil did not improve herbicidal activity. None of the terbacil treatments with or without spray solution additives, significantly reduced peppermint hay production.

Bioassay of core samples to determine the amount of herbicide remaining in soil from preemergence and split applications of terbacil indicated that lower levels of herbicide remained in soils treated by split application. Foliage interception and subsequent rapid detoxification of terbacil by the peppermint plant may explain this observed decrease of herbicide in the soil.

Foliage Applications of Terbacil to Peppermint (*Mentha piperita*) and Several Weed Species

by

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INTRODUCTION

Terbacil (3-tert-butyl-5-chloro-6-methyluracil) is a soil-active herbicide belonging to the substituted uracil family. It has been found to selectively control many broadleaf and grass weeds in peppermint (*Mentha piperita*) at the currently recommended rates of .8 to 1.6 pounds of active material per acre. However, at these rates of chemical, carryover in the soil may injure susceptible crops planted the following year.

Preemergence applications of terbacil give adequate weed control only when followed by .75 to 3.0 inches per acre of rainfall or sprinkler irrigation. The need for water would not be as critical for herbicidal activity if terbacil could be applied postemergence and absorbed by the leaf foliage. A foliage application of terbacil might also be of benefit in areas where peppermint is grown on muck soils and preemergence treatments are much less effective.

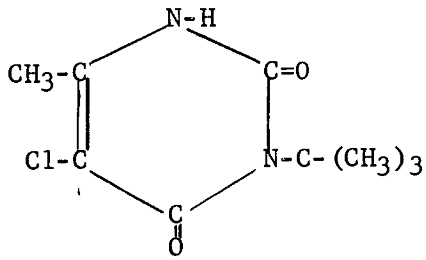
Furthermore, foliage applications of herbicides in combination with various solvents, surfactants, oils and other adjuvants have been shown by numerous investigators to increase the activity of herbicides. Such postemergence applications of terbacil might permit reduction in herbicide rate while providing acceptable weed control.

This study was conducted to determine the phytotoxicity of foliage applications of terbacil in combination with various spray solution additives to peppermint and several weed species. Three surfactants, four nonphytotoxic oils, and a liquid fertilizer were each combined with terbacil in 35 gallons of water per acre. Weeds treated were barnyardgrass (*Echinochloa crusgalli*), green foxtail (*Setaria viridis*), redroot pigweed (*Amaranthus retroflexus*), lambsquarters (*Chenopodium album*), and common mustard (*Brassica campestris*).

LITERATURE REVIEW

Properties of Terbacil

Terbacil is a new member of the substituted uracil class of herbicides. The commercial product used in these studies, Sinbar, contains 80% 3-tert-butyl-5-chloro-6-methyluracil and is formulated as a wettable powder. The structural formula is:



The pure chemical is a white crystalline solid which melts at 175-177°C. It is temperature stable up to the melting point and is only slightly soluble in water, aqueous bases, or common organic solvents.at room temperature. Water solubility is 710 ppm. at 25°C and the compound is subject to microbial decomposition under moist conditions in the soil (E. I. duPont deNemours & Company, 1967).

The LD_{50} has been found to be between 5000 and 7500 mg/kg of body weight for male white rats. When tebacil was introduced into rabbits' eyes the reactions were no greater than those which would result from the introduction of an inert material. Exposing the skin of both rabbits and guinea pigs to the compound produced no skin irritations or signs of toxicity through skin absorption (Weed, 1966).

Interference with the photosynthetic process may be the major mode through which terbacil controls plant growth. Hilton, Monaco, Moreland, and Gentner (1964) observed that substituted uracil compounds applied to isolated chloroplasts effectively inhibited the Hill reaction of photosynthesis. They further stated that this inhibitory action of the substituted uracils may be due to hydrogen bonding of the imino nitrogen in the number one position of the ring and the carbonyl oxygen of the carbon atom in the number two position with appropriate unknown receptors in the active site of the chloroplast.

Terbacil has been used successfully in peppermint, spearmint, deciduous and citrus orchards, and caneberries for control of many annual broadleaf and grass weeds such as pigweed (*Amaranthus retroflexus*), lambsquarters (*Chenopodium album*), green foxtail (*Setaria viridis*), and barnyardgrass (*Echinochloa crusgalli*). This material has also been effective against many perennial weeds such as quackgrass (*Agropyron repens* (L.) Beauv. , bermudagrass (*Cynodon dactylon* L.), johnsongrass (*Sorghum halepense* (L.)Pers.), and yellow nutsedge (*Cyperus esculentus* L.) (Weed, 1966).

Weed control is best when the chemical is applied preemergence or shortly after weed germination. Rainfall or sprinkler irrigation is necessary to move the herbicide into the germination zone of the weed seeds (Appleby, 1969).

Field studies at Oregon State University compared preemergence treatments of terbacil to postemergence applications of terbacil with and without surfactant or nonphytotoxic oil added to the spray solution. In areas where rainfall was lacking and furrow irrigation was necessary, foliage applications of terbacil with either surfactant or oil added to the spray solution were superior to applications of terbacil alone, and as effective as preemergence applications.[1] Barrentine and Warren (1969) observed an eighteenfold increase in herbicidal activity when terbacil was applied in an isoparafinic oil carrier to giant foxtail (Setaria faberii). They attributed this enhancement of herbicidal activity to increased penetration of the herbicide into the foliage of the plant. Migchelbrink (1969) also noted necrotic areas similar to the phytotoxic effects of a contact herbicide 24 hours after high rates of surfactant plus terbacil were applied to oat plants (Avena sativa). Oat plants treated with high rates of surfactant without terbacil did not exhibit this injury.

Surfactants

It has long been recognized that surfactants (surface-active agents) increase penetration of herbicides and other pesticides into plants (Currier, 1954; Currier and Dybing, 1959; Foy, 1958; 1961a; 1962a,b,d; 1963; Freed and Montgomery, 1958; Hughes and Freed, 1961; Jansen, Gentner, and Shaw, 1961; and Skogley, 1954). The mechanisms by which surfactants increase herbicidal action are often obscure and sometimes controversial. However, of great interest is the fact that herbicide entry into plants is aided by surfactants and the phytotoxic response obtained from a given herbicide is usually increased. This discussion will consider evidence of increased herbicidal activity by the addition of surfactant to a spray mixture and will also review

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1 Annual Report 1967-1968 Weed Control Research, Farm Crops Department, Project 41 and 732, pp 184-196.

modes of surfactant action.

Surfactants were defined by Parr and Norman (1965) as substances that can alter the energy relationships at interfaces, thereby causing a reduction of surface tension (gas-liquid interfaces) and interfacial tensions (liquid-liquid and solid-liquid interfaces). Their surface-active nature or ability to orient at an interface is a result of both a lipophilic (oil-soluble) and hydrophilic (water-soluble) group within the same molecule. Behrens (1964) graphically presents this concept in Figure 1. Two chemical groups have been joined into a single molecule as designated H and L. In this representation, the H is the one that is predominately hydrophilic in nature or attracted to water. Conversely, the L group is predominantly lipophilic in nature and attracted to oil (Behrens, 1964).

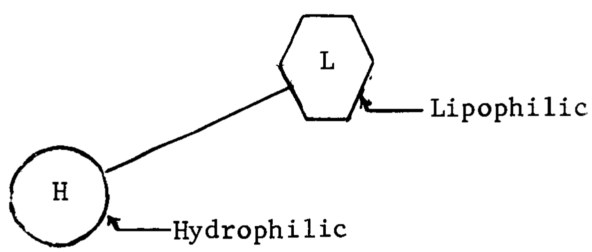


Figure 1. Diagram of a surfactant molecule containing both hydrophilic and lipophilic groups (Behrens, 1964).

Surfactants are commonly classified as anionic, cationic, or nonionic depending upon the nature of electrical charge, or absence of ionization on the hydrophilic portion of the molecule (Parr and Norman, 1965). Anionic surfactants contain negatively charged groups and are commonly used as cleaning agents or home laundry detergents. The cationic types contain positive groups, their major use being for various germicidal preparations. Nonionic surfactants are neutral. These molecules obtain surface-active properties without forming ions. The lipophilic group is balanced by such nonionized hydrophilic groups as polymerized ethylene oxide and polyhydric alcohols. Because neither positive nor negative ions are produced, these surfactants have advantages over both cationic and anionic surfactants. Most nonionic surfactants are not subject to hydrolysis by aqueous alkaline or acidic solutions. They do not form salts with metal ions, so they are effective in both hard and soft water. Because of these advantages, nonionic surfactants have received major emphasis in herbicide-surfactant research (Schweizer and McWhorter, 1965).

Behrens (1964) noted that in the nonionic category the proper choice of the hydrophilic and lipophilic groups provides varying degrees of lipophilic and hydrophilic tendencies, and the hydrophilic-lipophilic balance (HLB) in a molecule controls the character of the surfactant. This balance of tendencies can be expressed as an arbitrary number and used in classification. Materials with predominantly lipophilic character (low HLB) tend to promote water-in-oil emulsions (Behrens, 1964). Within a family of surfactants of varying HLB's, one member will have an optimum emulsifying efficiency for a particular herbicide-solvent system. Behrens (1964) illustrates this behavior in Figure 2. Anionic and cationic surfactants can also have either high or low HLB's and can easily be mixed with the nonionic type but not together.

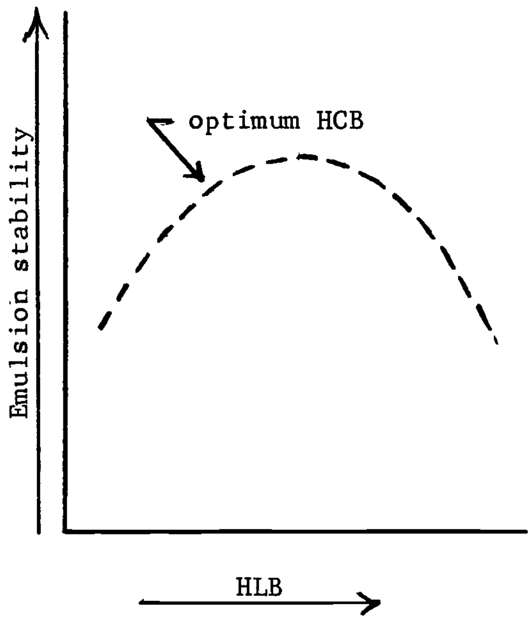


Figure 2. Example of emulsion efficiency varying with HLB (Behrens, 1964).

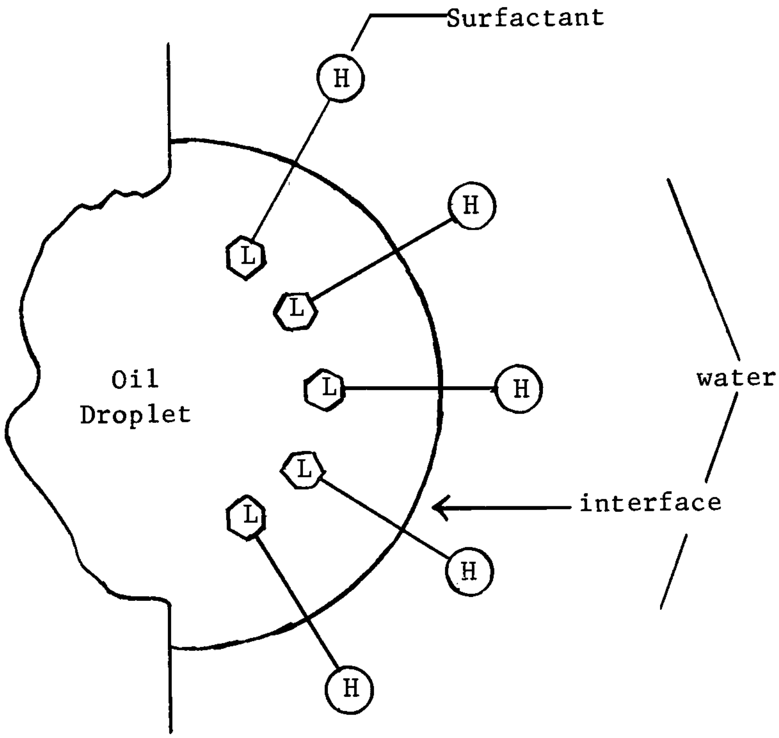


Figure 3. Diagram of surfactant molecules oriented between the oil-water surfaces reducing interfacial tensions (Behrens, 1964).

In oil-in-water emulsions and suspensions the water tends to be repelled by the oil or the solid forming the suspension. This produces surface or interfacial tensions. Surfactant molecules orient themselves between the two surfaces, thus modifying the surface (interfacial) forces and providing a more intimate coupling (Klingman, 1961). Behrens (1964) has graphically depicted this concept in Figure 3.

Another important consideration on some emulsion systems is electrical charge. Behrens (1964) explains this point by using an emulsion stabilized with an anionic compound as an example. In this case the molecules of the surfactant are concentrated at the interface with the lipophilic faction dissolved in the oil and the ionic heads attracted toward the water phase, causing the surface of the oil droplet to be studded with charged molecules. This produces a surface charge which hinders coalescence, since like charges repel one another.

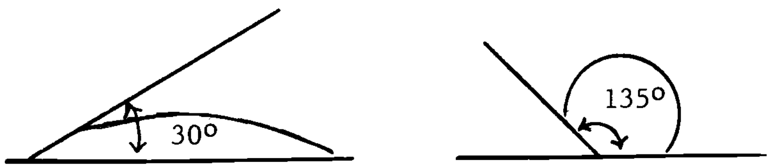
Several workers have reported considerable evidence that surfactants exhibit one of three types of action on herbicidal activity: progressive enhancement with increasing surfactant concentration, progressive suppression, or no effect (Currier, 1954; Jansen et al., 1961; Foy, 1962; Foy, Whitworth, Muzik, and Currier, 1967). The concentration and nature of both herbicide and surfactant, the plant species and stage of growth, humidity, temperature, and light have all been suggested as factors which contribute to the variation in phytotoxicity.

Currier and Dybing (1959) reported nine factors to which the response to surfactants may be due: a) improving coverage, b) removing air films between spray and leaf surfaces, c) reducing interfacial tensions between polar and apolar submicroscopic regions of the cuticle, d) inducing stomatal entry, e) increasing the permeability of the plasma membrane by stimulation or incipient toxicity, f) facilitating cell wall movement in the region of the wall-cytoplasm interface, g) acting as cosolvents, h) interacting with the herbicide in some manner, and i) acting as hemectants secondarily.

Klingman (1961) stated that surface-active agents generally intensify the action of herbicides by: a) creating uniform spreading of the spray, or uniform wetting of the plant, b) increasing spray retention, c) bringing the spray and the plant surface into more intimate contact, d) solubilizing nonpolar plant substances, and e) causing denaturation of enzymes by detergent action. Dallyn and Sweet (1951) and van Overbeek and Blondeau (1954) suggested that hydrocarbons and surfactants solubilize the lipo-proteic complex of the plasma membrane and upset the osmotic equilibrium of the cell.

A surfactant added to a spray solution promotes coverage of the leaf surface. The effectiveness increases as the herbicide mixture spreads over the surface of the foliage. This spread over the surface area determines the contact angle of the liquid with the surface, as illustrated in Figure 4 (Klingman, 1961). The addition of the wetting agent causes the spray droplet to spread uniformly over the surface while the chemical without surfactant remains as droplets, burning small holes in the leaf (Klingman, 1961).

Several workers have suggested that in addition to reduction in



waxy leaf; with surfactant   waxy leaf; no surfactant

Figure 4. Diagram of water droplets containing a surfactant spread in a thin film over a waxed surface. Pure water will stand as a droplet, with small area of contact with the waxed surface (Klingman, 1961).

surface tension, perhaps interactions between surfactant, herbicide, and plant are of equal, or more importance for absorption of herbicide-surfactant solutions into leaves (Freed and Montgomery, 1958; Jansen *et al*., 1961; Foy and Smith, 1965; Smith, Foy, and Bayer, 1966).

Freed and Montgomery (1958), working with several surfactants and a single herbicide, concluded that a specific intermolecular relationship between herbicide and surfactant was responsible for increased amitrole absorption, and that this interaction was probably more important than surfactant action on surface activity. Data presented by Jansen (1964) support their conclusion and extend the interaction to include the species also. Strong herbicide-surfactant-species interactions were evident for DNBP and amitrole on both soybeans (*Glycine max* L.) and corn (*Zea mays* L.) (Jansen, 1964).

Smith, Foy, and Bayer (1966) have proposed a theory for herbicide-surfactant entry into plant foliage. They state that when a spray droplet falls on a leaf it will spread and wet the leaf to an extent depending upon the leaf surface, surface tension, and interfacial tension of the spray solution. Evaporation of the water occurs and an equilibrium is reached between the air on the outside and the leaf surface on the inside of the spray deposit. There exists in this deposit a layer of material on the leaf surface which consists of herbicide, surfactant, and some water molecules.

The surface of the leaf contains many imperfections (cracks, insect punctures, and possibly hydrophilic and/or lipophilic areas) through which transpiration water escapes and wax precursors move to the leaf surface. It would seem reasonable that the surfactant molecules would diffuse from the liquid spray droplet into these areas along the lipophilic cuticle waxes and cutin, the molecules perhaps aligning themselves in monolayers. If true, this would result in the lipophilic end being in or on the cuticle waxes thus creating a hydrophilic layer or layers in these imperfections. Water molecules would then be attracted to these hydrophilic regions and channels would be formed, conceivably bringing about a slight swelling of the cuticle. Water soluble herbicides would be free to diffuse through these hydrophilic channels into the cell wall region of the plant cell and thence, either into the cytoplasm or via the apoplast into the transpiration stream (Smith, Foy, and Bayer, 1966).

Jansen (1965) was able to show that differences in phytotoxicity of herbicide-surfactant mixtures were associated with variations in both the hydrophilic and hydrophobic portions of the surfactant molecule. He also stated that the cuticle, as a barrier to absorption, is unquestionably involved in spray activity and that differences obtained in the activity of a given amount of a herbicide in mixtures with many surfactants indicate the cuticular absorption pathway, and possibly translocation channels, may have been modified by the surfactant. Alternate polar and apolar pathways have also been suggested by Crafts (1956a), Crafts and Robbins (1962), Klingman (1961), and Roberts, Southwick, and Palmiter (1948).

Currier and Dybing and many others have pointed out that herbicides must penetrate the leaf surface to be effective and that this is a diffusion mechanism. Therefore, in order for penetration to occur, the herbicide must be in solution. Temple and Hilton

(1963), assuming a diffusion mechanism for foliage penetration, indicate that the amount of herbicide which would penetrate a leaf surface would depend on a) the concentration of the herbicide in solution and b) the length of time the herbicide solution is in contact with the leaf. They further suggest that if a surfactant and herbicide solution is applied as a foliage spray, the surfactant increases the amount of herbicide dissolved in the initial spray solution. If the spray solution contains excess undissolved herbicide some of it will dissolve as the water evaporates from the leaf, resulting in increased concentration. This concentration increase is due to greater herbicide solubility in pure surfactant.

Petroleum Oils

Petroleum oil factions have been used successfully in the production of many horticultural and agronomic crops. The weed-killing ability of petroleum oils has been known since near the beginning of the petroleum industry. Oils did not become important commercially until the early 1940's, and their early use was preceded only by early inorganic herbicides such as sodium chlorate and such organics as the dinitro compounds. They have been used to selectively kill weeds in carrots and other umbellifereae (Sweet, Kunkel, and Raleigh, 1944; Lachman, 1946), in lawns (Loomis, 1938 and 1956), in qualulue nurseries (Robbins, Grigsby, and Churchill, 1947), as well as for nonselective total vegetation control. In addition, certain grades of oil have been used as both insecticides and insecticide carriers where it is important to minimize plant injury. Recent investigations by

Wright (1966) and Barrentine and Warren (1968) suggest that certain oils might also be used selectively as spray solution additives to increase the foliage activity of several herbicides. Due to the importance that petroleum hydrocarbons have assumed in the use of herbicides, a consideration of their action in plants merits discussion.

Naturally-occurring crude petroleum is largely composed of hydrocarbons (compounds consisting of hydrogen and carbon), plus other organic compounds containing oxygen, nitrogen, and sulfur. The crude petroleum, by means of distillation, can be separated into the following factions because of differences in boiling points: gas, gasoline, kerosene, gas-oil, and asphalt residue (Minshall, 1949). These factions are usually further treated by chemicals or a cracking process to produce the desired finished product. Since petroleum products may greatly differ because of refining processes and geological area, oils used in pest control clearly are not single compounds but complex mixtures of individual hydrocarbons. According to Minshall (1949), most petroleum oils used as herbicides are members of the gasoline or kerosene factions. Herbicidal oils are low in viscosity and surface tension and have an affinity for the waxy cuticle found on the surface of plants. All oils used in pest control readily wet plant surfaces and tend to spread as a thin film.

Several workers have suggested that oil toxicity is generally associated with the amount of unsaturates (compounds containing double carbon to carbon bonds) in the oil (Gray and deOng, 1926; Green, 1932; Crafts, 1947; Chapman and Pearce, 1947; Crafts and Rieber, 1948). The basis for this point of view is that sulfonatable residues of oil fractions are found to be more phytotoxic than the unsulfonatable portion. Thus, Gray and deOng (1926), after treating several oils with concentrated sulfuric acid, observed that oils having an unsulfonated residue (U. R.) of only 50 to 60 percent were extremely phytotoxic, but those oils with an unsulfonatable residue of 90 percent or more were nonphytotoxic.

Chapman and Pearce (1947) learned by working with insecticidal oils that the safety of an oil application to plant leaves was related to the aromatic content of the oil. This view has also been substantiated by studies in the herbicidal field. Sweet et al. (1946) and Lachman (1946), while testing several factions of oil for selective weed control in carrots, found a strong correlation between aromatic content of the oil and phytotoxicity. Both aromatic and cycloparaffin hydrocarbons were found to be highly toxic to plants by Crafts and Rieber (1948), but straight chained paraffins were not toxic. As side chains are added to the aromatic group the toxicity to plant tissue has been found to increase until the molecular weight of the side chains equals the aromatic portion.

The structural formulas of examples of the hydrocarbons discussed are illustrated in Figure 5.

Paraffins or Alkanes (Nonphytotoxic)

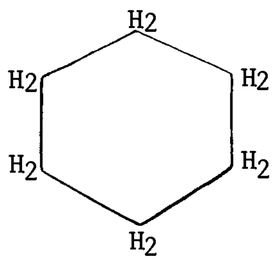
$CH_3-CH_2-CH_2-CH_2-CH_2-CH_3$

n-hexane

$$\begin{array}{l} CH_3-\underset{\displaystyle CH_3}{\underset{|}{C}H}-CH_2-CH\ -\underset{\displaystyle CH_3}{\underset{|}{C}H}-CH_3 \end{array}$$

2,5,dimethylhexane

Cycloparaffins (Phytotoxic)



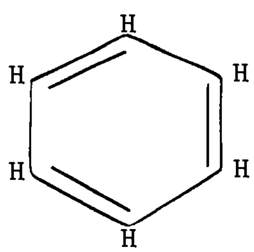
cyclohexane

Olefins or Alkenes (Phytotoxic)

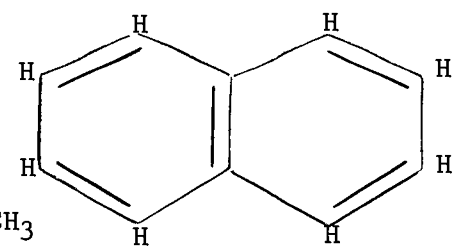
$CH_3-CH=CH-CH_2-CH_2-CH_3$

n-hexene

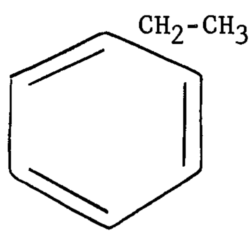
Aromatic (Phytotoxic)



benzene



naphthalene



ethyl benzene

Figure 5. Structural formulas of examples of phytotoxic and non-phytotoxic hydrocarbons.

Oils can penetrate into plants through stomates, thin cuticle, and bark. Knight, Chamberlin, and Samuels, (1929) believe that the resistance to leaf penetration of oils is due principally to the epidermis. Leaves of stonecrop (Sedum sp.), a desert plant, showed no penetration of kerosene after exposure for eight hours, but penetration was extremely rapid when the epidermis was punctured. Turrell (1947) studied citrus leaf stomata structure, composition, and pore size. He arrived at the conclusion that stomata may be penetrated by oils. Stomatal penetration was also demonstrated by van Overbeek and Blondeau (1954). They sprayed an emulsion of light oil on seedling plants in the light when stomata were open and in the darkness when they were closed. The oil treatment in light killed the test species whereas no phytotoxicity resulted when the stomata were closed.

Penetration is not confined to the stomata, as oils can also penetrate the cuticle, especially if it is thin. Penetration of plant cuticle by organic compounds is related to its lipophilic properties. If an organic molecule is very polar (having a high affinity for water and other polar substances) it will not penetrate readily through the cuticle. Very nonpolar substances penetrate into the waxy cuticle quite easily but may accumulate in the wax and not pass through into the inner leaf. These accumulations of oil have been shown by van Overbeek and Blondeau (1954) to sometimes cause phytotoxicity. Viscosity and surface tension of the oil determine the rate of penetration of the leaf surface (Knight and Cleveland, 1934). After penetration, the oil is believed to move into the intercellular spaces of the leaf. It is this displacement of air which gives oil-treated leaves a "water soaked" appearance.

It seems possible for several things to happen to oils after they have penetrated the plant leaf. They may remain in the cuticular portion of the leaf for an indefinite time, evaporate, or be translocated into other plant parts. Minshall (1949) states that evaporation of insecticidal oils from leaves is considered to be negligible and that with certain oils at least a portion remains within the leaf throughout the growing season. Rohrbaugh (1934) found that less than 1/3 of the insecticidal emulsions applied to orange leaves remained three months after treatment. Young (1935), working with potato plants, also reported that lubrication oils would remain for an entire growing season but that kerosene disappeared in one to twenty-four hours.

Considerable evidence has been presented indicating that oils will move from one part of the plant into other parts. Knight and Cleveland (1934) were of the opinion that this movement was via the vascular system--the oil ultimately being moved into storage tissue. Most workers believe, however, that oils move primarily through intercellular spaces with little translocation in the vascular system. Young (1935) has proposed an oil-mass theory of hydrocarbon penetration into cell protoplasm but Rohrbaugh (1934) found no indications that oils entered living cells. Van Overbeek and Blondeau (1954) have proposed that once oil is inside the leaf it solubilizes the lipoids (fat-like substances) of the cell membrane. The semipermeable membrane thus becomes more permeable, cell sap leaks out into intercellular spaces, and the cell finally collapses.

Minshall (1949) has demonstrated that oil is indeed transported through intercellular spaces. In a study of kerosene-like oils applied to dandelion, carrot, and parsnip and by using an indicator dye dissolved in the oil, the following was observed: when oil was applied to cut roots, movement was toward the leaves but when it was applied to the leaves, movement was toward the roots. He also determined that movement of the oil was in no way associated with xylem vessels, sieve tube elements, or the latex system, and that diffusion of the oil within the root was not confined to a single direction.

DeOng, Knight, and Chamberlin (1927), working with citrus foliage, pointed out that oils may have two rather distinct types of toxicity: acute, caused by low boiling oils, and chronic, caused by high boiling fractions. Acute toxicity produces rapid burning of the leaf tissue and is often fatal within 48 hours. Chronic toxicity, on the other hand, produces a slow yellowing of the leaves and defoliation within several days. It was also noted that oils which are chronically toxic to grasses often cause a shift from negative to positive geotropism. Similar toxic symptoms result from the use of herbicidal oils as reported by Crafts and Rieber (1948).

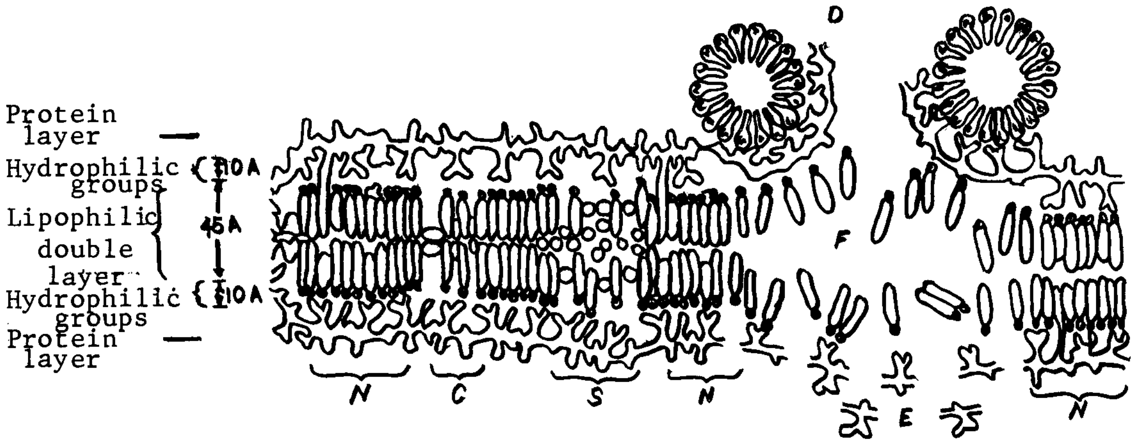
Several theories have been proposed to explain the mode of action of oils within the plant. Petroleum oils are nonpolar substances with low surface tension. Therefore, oils tend to spread easily on the foliage surface forming a thin film over the cuticle and providing an area of wide diffusion. Havis (1950), observing this factor, indicated that some phytotoxicity could be attributed to oils creating mechanical interference with the normal functions of the stomates. A strong reduction in the gas interchange was observed.

Dallyn and Sweet (1951) also attempted to explain the mode of action of petroleum hydrocarbons. They suggested that in sensitive plants, oils pass through plasmic membranes and upset the osmotic equilibrium. In plant species such as carrot, which are resistant to herbicidal oils, the oil has been found to remain in the intercellular spaces. This implies a strong resistance by the plasma membrane in umbelliferous crops. Van Overbeek and Blondeau (1954) agree with the preceding theory and explain the phenomenon of selectivity based on the solubilization of the lipo-proteic complex of the plasma membrane.

Other theories have been proposed to explain the mode of action of oils as a method of chlorophyll destruction in plants. Minshall (1949) studied the time course of photosynthesis and respiration for leaves of carrot, parsnip, common mustard, lambsquarters, and common chickweed following the application of petroleum naphtha (boiling range 300-400 degrees F.). Readings using infrared absorption were made after application of the oil and in all cases photosynthesis ceased abruptly after the oil application. With parsnips, photosynthesis started to recover within 30 minutes and after 48 hours had nearly returned to normal. Photosynthesis was never resumed by the weed species tested. The disruption of photosynthesis following the application of oil is apparently temporary in nature for carrots and parsnips but permanent as far as such weeds as mustard and lambsquarters are concerned. Parsnips and carrots are thus able to survive the oil application while the weeds are killed (Minshall, 1949).

It is also possible that oils are responsible for a great increase in respiration rate, as reported by Kelly (1930) and also Oberle, Pearce, Chapman, and Avens (1944). Both investigations indicated that respiration rate of apple leaves and twigs increase following an application of insecticidal oil emulsion.

The use of oils as spray solution additives for various organic herbicides represents a relatively recent development. These oils are termed nonphytotoxic, having unsulfonated residue ratings above



N--normal membrane consists of a double layer of fatty molecules stabilized by protein layers. Cell sap is kept inside cell by fatty portion of plasma membrane.

C--fatty molecules being pushed apart by polycyclic hydrocarbons. The large molecules penetrate slowly.

S--xylene solubilized into the fatty layers; penetration is rapid.

D--detergent micells are pulling away the protein layer, rendering the fatty layer (F) unstable.

E--disruption of the protein layer is brought about by agents which liquify the protein. Solubilization of the plasma membrane causes leaks, permitting the cell sap to move into the intercellular spaces.

Figure 6. The plasma membrane as affected by various toxic molecules (van Overbeek and Blondeau, 1954).

95 percent and are used as carriers for herbicides where better foliage wetting and penetration by the herbicide is desired. These oils have been extensively used as carriers of atrazine for weed control in corn and sorghum (Wright, 1966; Weise and Owen, 1967). Attempts are now underway to find new uses with other herbicides for use in other crops.

The role of nonphytotoxic oils as postemergence carriers of herbicides is to facilitate maximum entry of the herbicide into the leaf tissue of weeds without injury to the crops. The foliage of the plants is generally nonpolar (water repellent) and therefore oil attracting. The oil coats the leaves of the weeds which allows greater retention of the herbicide to the foliage. This allows greater penetration of the herbicide into the plant tissue.

Petroleum hydrocarbons used for pest control can be classed into three broad categories based on their phytotoxic effects. First are the nonselective oils used for total vegetation control. These oils are usually aromatic in nature, are relatively high boiling and low in viscosity. The next group is the selective herbicidal oils used for weed control in carrots and other umbelliferous crops. These oils have controlled phytotoxicity because boiling points are lower and aromatic compounds are limited (usually 12-24%). The third class of oils is termed nonphytotoxic and members are used as insecticides and insecticide or herbicide spray additives. These oils have high unsulfonated residue and viscosity ratings but low boiling ranges.

Phytotoxicity of petroleum oils can be affected by oil composition, which can influence penetration and translocation to other plant parts. Workers have disagreed on mechanisms of plant damage from applications of oil. However, effects on permeability of plasma membrane, photosynthesis, and respiration can be cited as reasons for phytotoxic action.

III. POSTEMERGENCE APPLICATIONS OF TERBACIL TO ESTABLISHED PEPPERMINT

Materials and Methods

An experiment was established at the A. D. Belnap farm near Corvallis, Oregon on established peppermint (Mentha piperita) in the spring of 1969. The objective of the experiment was to determine selectivity to peppermint and weed control activity of terbacil when applied postemergence with various additives added to the spray solution.

Additives included surfactants, nonphytotoxic oils, and a liquid fertilizer. Tronic, X-77, and Activate-Plus were the surfactants tested and each was applied at 0.1%, 0.5%, and 1.0% of the final volume of sprayed solution. Nonphytotoxic oils were used at 10% of the final volume of sprayed solution. These were Savol Oil, Superior Spray Oil, Superior Spray Emulsion, and 3408 Spray Oil. Solution 32, a liquid fertilizer containing 32% nitrogen, was tested at 5%, 10%, and 20% of the final volume of solution sprayed.

The experiment was arranged as a randomized block design with four replications. Individual plots were 8 x 20 feet. Treatments included additives alone, additives plus terbacil, terbacil alone, and neither additives nor terbacil. Applications of terbacil both with and without spray additives were made at 0.5 lb ai/A. At the time of application, June 4, 1969, the peppermint was five to seven inches in height and weeds including pigweed (Amaranthus retroflexus) and lambsquarters (Chenopodium album) ranged from just emerging to two inches in height. Irrigation of the experiment was by sprinkler.

Percent visual weed control and percent visual peppermint injury were independently evaluated by two workers on July 30, 1969, 46 days after application. Samples from selected plots were taken six days later on August 6, 1969. Sampling was accomplished by harvesting the peppermint within a 9 sq. ft. area of each plot and putting the gathered material into large burlap bags. The samples were subsequently dried at a temperature of 180° F and yields of dry weight of peppermint were determined.

Results

All treatments of terbacil with or without an additive were effective in controlling the weed species in the experiment. There were no statistically significant differences in weed control between the type of additive used or the rate of additive, when more than one rate was applied. Treatments of terbacil alone or with an additive always resulted in excellent control of pigweed and lambsquarters. Peppermint yields and visual observations of peppermint injury indicate that no significant yield reduction resulted from any of the treatments. Results of this experiment are summarized in Table 1. Additional data are included in Table 1 of the Appendix.

Table 1. Summary of the effects of terbacil applied postemergence with and without spray solution additives to peppermint and two weed species.

Treatment	Rate lb/A	Rate %/vol	Avg. % control of pigweed	Avg. % control of lambs-quarters	Avg. weight of peppermint gm/9 sq. ft.
terbacil + X-77	1/2	0.1	100	100	
terbacil + X-77	1/2	0.5	100	100	566
terbacil + X-77	1/2	1.0	100	100	593
X-77		0.1	0	0	
X-77		0.5	0	0	608
X-77		1.0	0	0	550
terbacil + Activate-Plus	1/2	0.1	100	100	
terbacil + Activate-Plus	1/2	0.5	100	100	535
terbacil + Activate-Plus	1/2	1.0	100	100	568
Activate-Plus		0.1	0	0	
Activate-Plus		0.5	0	0	598
Activate-Plus		1.0	0	0	588
terbacil + Tronic	1/2	0.1	100	100	
terbacil + Tronic	1/2	0.5	100	100	592
terbacil + Tronic	1/2	1.0	100	99	511
Tronic		0.1	0	0	
Tronic		0.5	0	0	501
Tronic		1.0	0	0	644
terbacil + 3408 Spray Oil	1/2	10.0	100	100	698
3408 Spray Oil		10.0	0	0	621
terbacil + Savol Oil	1/2	10.0	100	100	699
Savol Oil		10.0	0	0	571
terbacil + Superior Spray Oil	1/2	10.0	100	100	575
Superior Spray Oil		10.0	0	0	560
terbacil + Superior Spray Emulsion	1/2	10.0	100	100	651
Superior Spray Emulsion		10.0	0	0	531

(cont'd)

Table 1. Continued

Treatment	Rate lb/A	Rate %/vol	Avg. % control of pigweed	Avg. % control of lambs-quarters	Avg. weight of peppermint gm/9 sq. ft.
terbacil + Solution 32	1/2	5.0	100	100	
terbacil + Solution 32	1/2	10.0	100	100	
terbacil + Solution 32	1/2	20.0	100	100	567
Solution 32		5.0	0	0	
Solution 32		10.0	0	0	
Solution 32		20.0	0	0	578
terbacil	1/2		100	100	561
Control			0	0	685

IV. FOLIAGE APPLICATIONS OF TERBACIL ON FIVE WEED SPECIES

Materials and Methods

In the summer of 1969 an experiment was established at the Hyslop Agronomy Farm on four species of weeds. The objectives of this experiment were as follows:

(1) to determine the effectiveness of postemergence treatments of terbacil when applied to several weed species,

(2) to evaluate the effect of various additives (surfactants, nonphytotoxic crop oils, and liquid fertilizer) when added to the spray solution, and

(3) to compare the effectiveness of postemergence treatments of terbacil when various rates of surfactants were added to the spray solution.

A split block design with three replications was used with treatments as the main blocks and species as the sub-plots. Individual main plots were 6 x 36 feet and sub-plots were 6 x 9 feet.

Additives included surfactants, nonphytotoxic crop oils, and a liquid fertilizer. Tronic, X-77, and Activate-Plus were used as the surfactants and were applied at 0.1%, 0.5%, and 1.0% of the final volume of the sprayed solution. Four crop oils were also tested at 10% of the final volume of the solution sprayed. These were Savol Oil, Superior Spray Oil, Superior Oil Emulsion, and 3408 Spray Oil. Solution 32, a liquid fertilizer containing 32% nitrogen, was tested at 5%, 10%, and 20% of the final volume of sprayed solution.

Pigweed, lambsquarters, barnyardgrass (Echinochloa crusgalli), and green foxtail (Setaria viridis) were seeded into a pre-irrigated seedbed on June 26, 1969 and emergence of all species was noted on July 2, 1969. Common mustard (Brassica campestris) was a contaminate of the green foxtail seed and it also emerged at that time. Treatments, including additives only, terbacil plus additives, terbacil only, and neither terbacil nor additives, were applied on July 23, 1969. At that time, the stage of growth of each species was noted as follows:

Pigweed - 2 to 4 inches in height

Lambsquarters - approximately 6 inches in height

Green foxtail - 3 to 5 inches in height, 4 to 6-leaf stage

Barnyardgrass - 4 to 5 inches in height, 4-leaf stage

Common mustard - Approximately 6 inches in height

Applications of terbacil both with and without additives were made at 0.5 lb/A. of active ingredient. All treatments were applied to a moist soil in 35 gallons of water per acre. Irrigation was by sprinkler and a total of 6.5 inches were applied.

Percent visual weed control was independently evaluated by two workers on July 30, 1969.and August 14, 1969. The stand of lambsquarters was found to be highly variable and therefore was not evaluated at the later date.

Results

Foliage applications of terbacil plus surfactant at any of the three rates tested were effective to some degree in controlling pigweed, lambsquarters, and common mustard. Barnyardgrass and green foxtail were not controlled by similar treatments. Applications of terbacil without a surfactant were usually about as effective as those with surfactant added to the spray solution. Treatments of surfactant without terbacil resulted in lack of weed control for all species tested. Table 2 illustrates the effect of different terbacil-surfactant combinations on the several weed species in the experiment. Additional data are presented in Appendix Table 2.

Table 2. Summary of the effect of foliage applications of terbacil with and without surfactants to pigweed, green foxtail, barnyardgrass, and common mustard.

	Rate		Average % control of			
Treatment	lb/A	%/vol	pigweed	green foxtail	barnyard-grass	common mustard
terbacil + X-77	1/2	0.1	81	7	13	88
terbacil + X-77	1/2	0.5	83	10	18	90
terbacil + X-77	1/2	1.0	80	8	13	88
X-77		0.1	0	0	0	0
X-77		0.5	0	0	0	0
X-77		1.0	0	0	0	0
terbacil + Activate-Plus	1/2	0.1	83	8	23	80
terbacil + Activate-Plus	1/2	0.5	91	14	31	75
terbacil + Activate-Plus	1/2	1.0	83	8	10	78
Activate-Plus		0.1	0	0	0	0
Activate-Plus		0.5	0	0	0	0
Activate-Plus		1.0	0	0	0	0
terbacil + Tronic		0.1	93	11	16	85
terbacil + Tronic		0.5	90	13	20	88
terbacil + Tronic		1.0	77	8	21	50
Tronic		0.1	0	0	0	0
Tronic		0.5	0	0	0	0
Tronic		1.0	0	0	0	0
terbacil	1/2		87	13	14	83
Control			0	0	0	0

Applications of terbacil plus nonphytotoxic crop oils gave more effective control of pigweed, lambsquarters, and common mustard than either of the grass species. Treatments of terbacil alone were usually about as effective as treatments of terbacil plus crop oil. Data in Table 3 and Appendix Table 3 illustrate these points. Treatments of terbacil plus crop oils, except 3408 Spray Oil, were significantly more effective than terbacil alone when applied to lambsquarters.

Table 3. Summary of the effect of foliage applications of terbacil with and without nonphytotoxic oils to pigweed, green foxtail, barnyardgrass, and common mustard.

	Rate		Average % control of			
Treatment	lb/A	%/vol	pigweed	green foxtail	barnyard-grass	common mustard
terbacil + 3408 Spray Oil	1/2	10.0	74	9	13	80
3408 Spray Oil		10.0	0	0	0	0
terbacil + Savol Oil	1/2	10.0	91	10	13	85
Savol Oil		10.0	0	0	0	0
terbacil + Superior Spray Oil	1/2	10.0	83	13	13	88
Superior Spray Oil		10.0	0	0	0	0
terbacil + Superior Spray Emulsion	1/2	10.0	87	10	16	78
Superior Spray Emulsion		10.0	0	0	0	0
terbacil	1/2		87	13	14	83
Control			0	0	0	0

Terbacil plus Solution 32 was effective against pigweed and lambsquarters at the three rates tested. Control of common mustard was fair while grass control was poor. The 20% rate of Solution 32 when combined with terbacil usually gave the best results of the three rates tested. Terbacil alone was usually as effective as the terbacil-Solution 32 combination. No injury or growth stimulation to weeds from the addition of liquid fertilizer was noted in those plots where Solution 32 was applied without terbacil.

In summary, terbacil at 0.5 lb/A gave reasonable control of small pigweed, lambsquarters, and common mustard but control of grasses after they reached three inches tall was very poor. Additives were sometimes helpful, but no additive was markedly superior to any other.

There appeared to be no advantage of the 0.5% rate over the 0.1% rate of surfactant. In several cases, however, the 1.0% rate was excessive and actually reduced control.

V. FOLIAGE APPLICATIONS OF TERBACIL TO FOUR WEED POPULATIONS AT SEVERAL STAGES OF GROWTH

Materials and Methods

Based on the results of a preliminary experiment (Foliage Applications of Terbacil on Five Weed Species), four experiments were established at Hyslop Agronomy Farm during the summer of 1969. The purpose of this study was to determine the best combination of terbacil, additive, and stage of plant growth that would give acceptable weed control when applied to the foliage of several weed species.

A split block design with four replications was used with stage of plant growth as the main blocks and herbicide treatments as the sub-plots. Individual sub-plots were $3^{1}/3$ x 20 feet and main plots were $3^{1}/3$ x 80 feet. The experiment was conducted on three populations of weed species; pigweed, barnyardgrass, and green foxtail. The treatments also were applied to a mixed population of weeds which included the above species.

Additives used in combination with terbacil included surfactants, nonphytotoxic crop oils, and a liquid fertilizer. Tronic, X-77, and Activate-Plus were used as surfactants and applied at 0.5% of the final volume sprayed. Three nonphytotoxic oils were also tested at 10% of the final volume of solution sprayed. These were Savol Oil, Superior Spray Emulsion, and Superior Spray Oil. Solution 32, a liquid fertilizer containing 32% nitrogen, was tested at 20% of the final volume of sprayed solution.

The three weed populations and the mixed population were seeded at 75 pounds per acre into a pre-irrigated seedbed on August 12, 1969. Emergence of all weed populations was noted on August 16, 1969. Treatments of terbacil alone at 0.5 lb/A of active material were applied two days later. At that time about 20% emergence of the weed population was noted.

Treatments of additives only, terbacil plus additives, and terbacil alone were applied on August 23, August 30, and September 6, 1969. Control plots which received neither terbacil nor additives were included in this experiment. Applications of terbacil both with and without additives were made at 0.5 pounds of active ingredient per acre.

At each date of application the stage of growth of the weed species in each population was noted and is as follows:

Application date 1: (August 23, 1969)

pigweed - two-leaf stage

green foxtail - two-leaf stage

barnyardgrass - one true leaf present

Application date 2: (August 30, 1969)

pigweed - four-leaf stage

green foxtail - three- to four-leaf stage

barnyardgrass - three- to four-leaf stage

Application date 3: (September 6, 1969)

pigweed - 2 to 3 inches in height, seed heads present

green foxtail - 5 inches in height, 3- to 5-leaf stage

barnyardgrass - 3 to 4 inches in height, 3- to 5-leaf stage.

Treatments were applied to the foliage in 35 gallons of water per acre. The soil was moist at the times of application and all climatic conditions were favorable. Irrigation was by sprinkler and a total of five inches of water was applied plus an additional three inches of rainfall.

Percent visual weed control was independently evaluated by two workers 19 days after each date of application. In addition, all treatments were visually evaluated on September 26, 1969, 40 days after weed emergence was first noted. Samples of living plant tissue were taken from a 10 sq. ft. area within each sub-plot on the following dates:

barnyardgrass - September 25, 40 days after weed emergence

green foxtail - September 26, 41 days after weed emergence

pigweed - September 26, 41 days after weed emergence

mixed population - September 27, 42 days after weed emergence

Dead plant tissue was carefully excluded from the samples. The samples were subsequently dried at a temperature of 180° F. and dry weight of the weeds was determined. Common mustard (*Brassica campestris*) was found to contaminate the seed of green foxtail. Therefore, common mustard was removed from all samples of green foxtail at the time of harvest.

The purpose for evaluating 19 days after each application date was to determine at which stage of growth the weeds were most susceptible to the herbicide application. In this case, it was determined that no further death of the test species was likely to occur by later evaluation dates. Because of late weed emergence and regrowth, applications to young weeds often do not result in acceptable long-term control. Evaluations were made at 40 days after test species emergence to determine which treatments were most effective at a time later in the growing season of the weed population. Harvesting of the weed samples was done on the chosen dates to further substantiate the visual data taken at 40 days after emergence.

Results

Grass species were less susceptible to foliage applications of terbacil than pigweed. The stage of growth of the weed at the time of postemergence application was critical for adequate control. Good results were often obtained when weeds were one inch or smaller regardless of whether any additive was used or which additive was included. As the weeds became larger, control markedly decreased. Excellent control resulted when terbacil was applied at about 20% emergence of the weeds.

In general, the addition of nonphytotoxic oils or surfactants was beneficial to terbacil activity. Nonphytotoxic oils tended to be somewhat more effective than surfactants in improving terbacil activity. Solution 32, a liquid nitrogen solution, was least effective.

Because this experiment was conducted on four different populations of weeds, the data for each population will be considered separately. Dry weight of weeds, expressed as percent of control, are shown in Figures 7 through 10. Data in Appendix Tables 4 through 15 provide additional information.

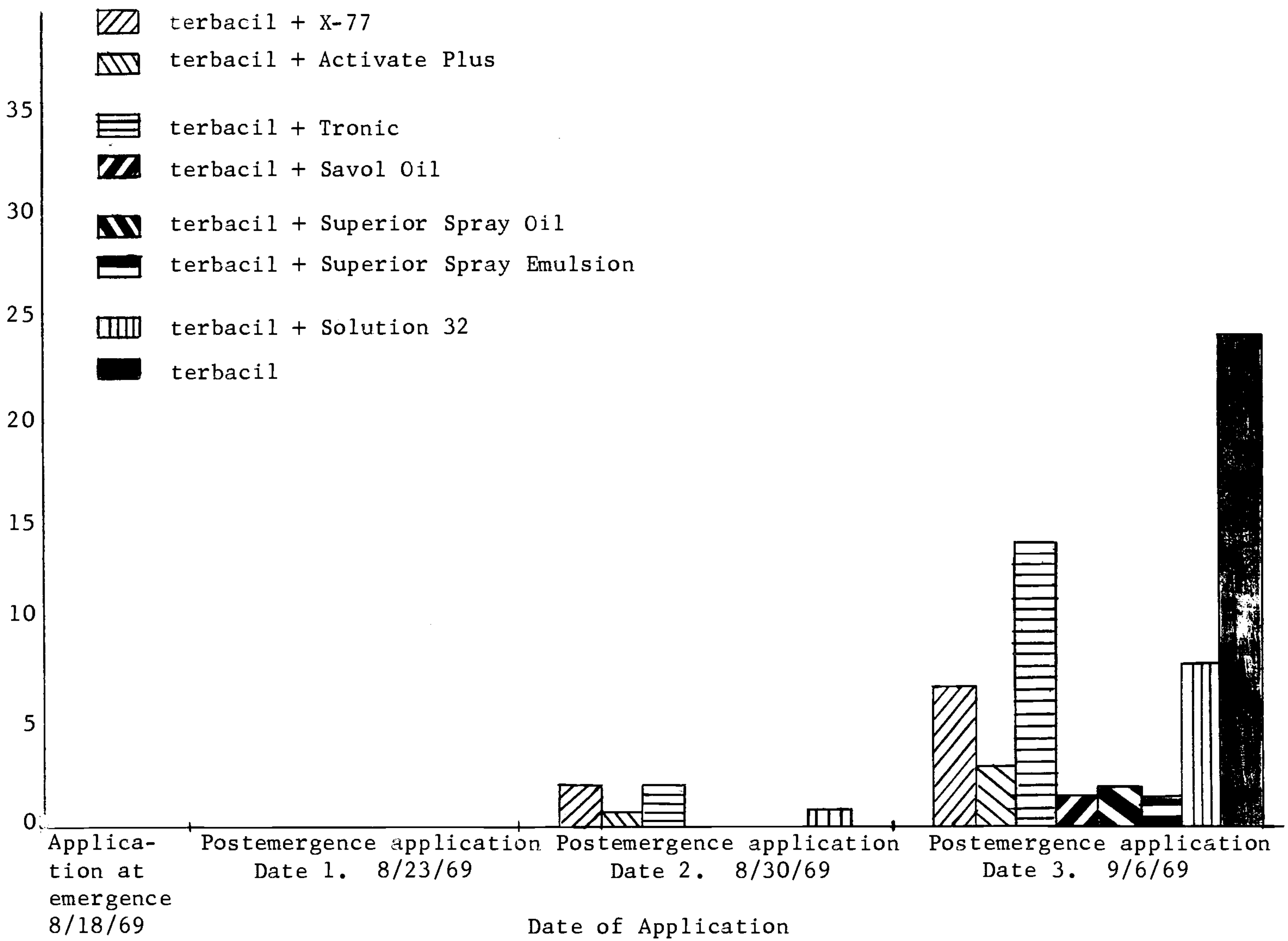


Figure 7. Percent of control of pigweed foliage harvested from 10 sq. ft. of plot area 41 days after weed emergence.

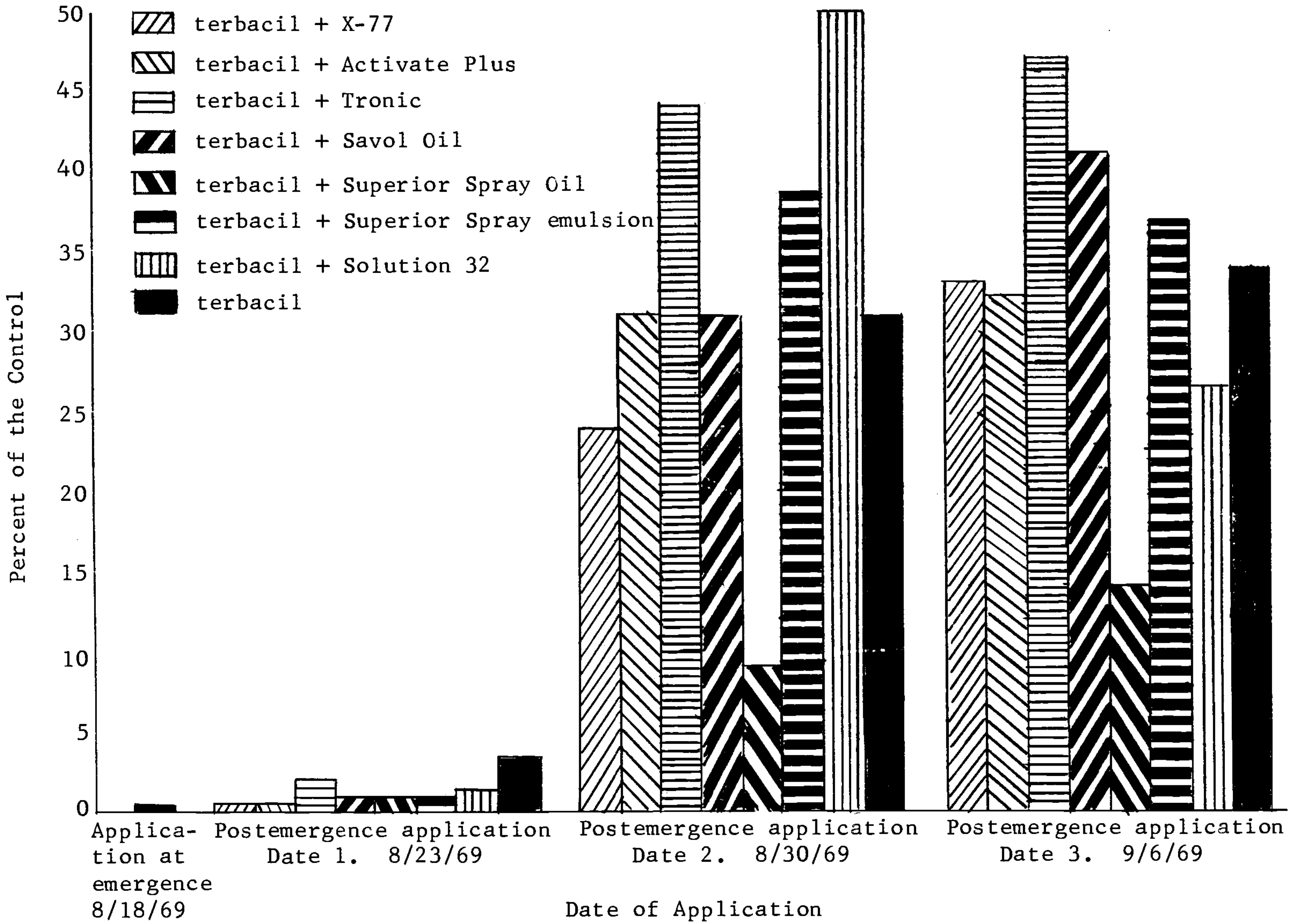


Figure 8. Percent of control of green foxtail foliage harvested from 10 sq. ft. of plot area 41 days after weed emergence.

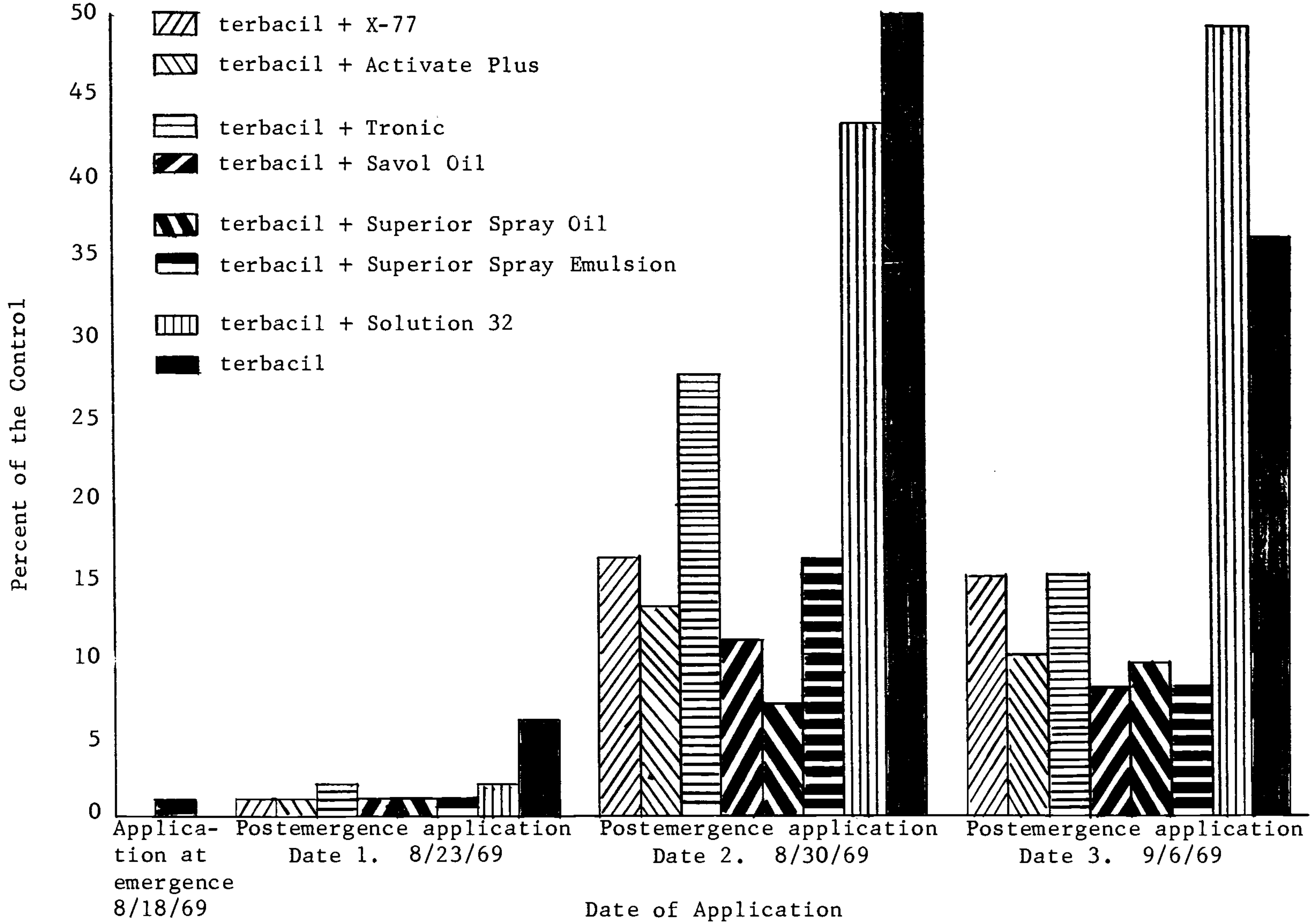


Figure 9. Percent of control of barnyardgrass foliage harvested from 10 sq. ft. of plot area 40 days after weed emergence.

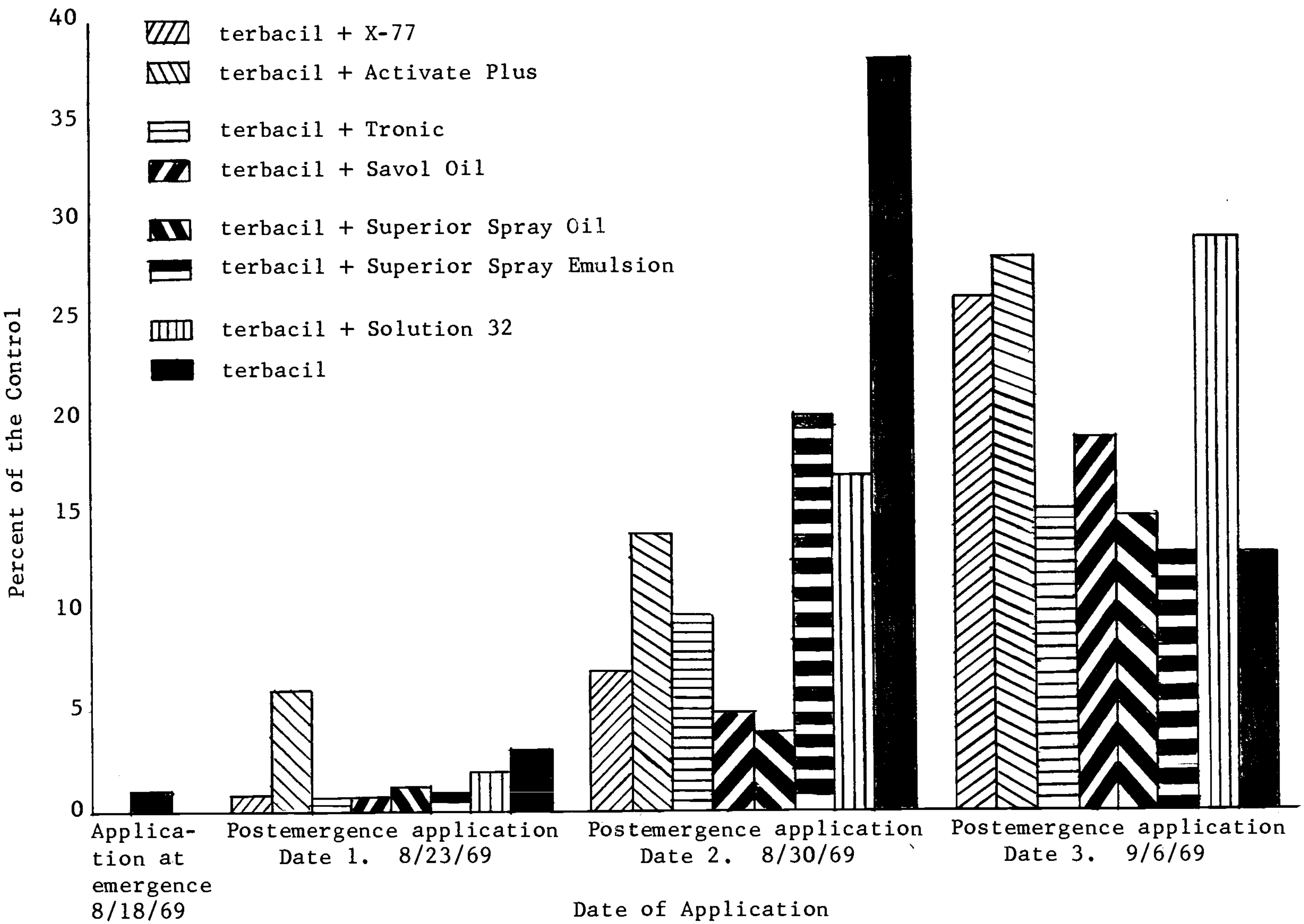


Figure 10. Percent of control of mixed weed population foliage harvested from 10 sq. ft. of plot area 42 days after weed emergence.

Pigweed

The foliage applications of terbacil plus surfactants at two of the three dates of application were effective in controlling pigweed. Terbacil with any of the three surfactants added to the spray solution gave best control at the earliest application date when the weeds were very young. Pigweed control was slightly less at the second application time and poorest at the third date of treatment. This suggests that timing of terbacil plus surfactant treatments may be important to get maximum control of a population of this species.

Treatments of terbacil without surfactants were generally as effective as those treatments using surfactants at the first two application dates. At the last time of application, when the weeds were two to three inches in height and with seed heads, better control was obtained when surfactants were added to the spray solution. At this stage of growth of the pigweed, terbacil plus Activate-Plus outperformed similar treatments of both Tronic and X-77. Surfactants applied without terbacil did not cause injury to the pigweed at any stage of growth.

Applications of terbacil plus nonphytotoxic crop oils were effective at each of the three dates of application. Pigweed control was slightly less when the treatments were applied to larger weeds at the last application date. Postemergence treatments of terbacil alone also gave excellent control at the two early application dates. However, the data obtained by dry weight determinations at the latest stage of growth would indicate a significant difference between all terbacil plus oil treatments and similar treatments of terbacil only. These data suggest that at early times of application the addition of oil to the spray solution may not be necessary for good control of pigweed but at later dates of application oil may be needed for maximum uptake by the plant.

Terbacil plus Solution 32 was somewhat effective against pigweed at every date of application. Based upon data obtained from dry weight determinations, least control of the test species was obtained at the latest time of application. Visual evaluations suggest significant differences in the treatment X stage of growth interaction when comparing the first and second application dates to the third time of application.

Treatments of terbacil alone when compared to similar treatments with Solution 32 added to the spray solution gave about equal control at the two earliest stages of growth. Terbacil without Solution 32 was less effective at the oldest stage of growth, indicating that addition of Solution 32 may aid pigweed control as the weeds become larger and more mature. Injury did not result from treatments of Solution 32 alone but increases in dry weight were observed.

Terbacil applied without additives when about 20% of the weed population had emerged gave excellent control of the test species, suggesting much root or hypocotyl uptake of terbacil by the plant. The data would also indicate the importance of proper timing of application; the most susceptible period being very early in the life of the weed.

Green foxtail

All postemergence applications of terbacil plus a surfactant were effective in controlling green foxtail at the earliest date of application. When treatments were applied at later stages of growth, i.e. on larger plants, weed control was greatly decreased. Treatments of terbacil without surfactants were slightly less effective than those treatments which included surfactants. The addition of a surfactant may be necessary if near perfect weed control is desired. Both Activate-Plus and X-77 when combined with terbacil gave better results than treatments of terbacil plus Tronic. It is interesting to note that treatments of terbacil plus Tronic combinations often did not perform as well as treatments of terbacil alone. Injury did not result from any treatments of surfactant without terbacil.

Treatments of terbacil plus nonphytotoxic crop oils were effective at the earliest stage of growth of the foxtail but control diminished as the grass became older and larger. In most cases applications of terbacil plus Superior Spray Oil showed greater activity than either terbacil alone or other terbacil-oil combinations. These data suggest that terbacil plus Superior Spray Oil may be an effective postemergence treatment with greatest control being obtained from applications made early in the life of this grass species. All treatments which were applied later than one week after emergence did not give satisfactory weed control. Nonphytotoxic oils applied without terbacil caused no injury to the test species.

Terbacil applied without additives was usually not as effective in foxtail control as treatments of terbacil plus Solution 32.

Young weeds were killed much more effectively by both treatments than older weeds. Data obtained by dry weight determinations would indicate significant increases in plant injury due to applications of Solution 32 alone when compared to a control. Visual observations do not support this observation, however.

When terbacil was applied at about 20% emergence of the foxtail population, excellent control resulted. These data suggest that early timing of terbacil applications is needed for satisfactory control of this grass.

Barnyardgrass

Results from foliage applications of terbacil in combination with each of the several surfactants were highly affected by stage of growth of the barnyardgrass. All terbacil plus surfactant treatments controlled the test species equally well at the first date of application. Delaying the application time until one week later when the weeds were larger, significantly decreased the effectiveness of each treatment.

When treatments of terbacil with and without surfactants were compared, the results vary according to the time of spraying (stage of plant growth). Generally, terbacil with surfactants were more effective than terbacil alone, especially as the weeds became larger. Because only small differences in performance existed at each stage of growth, no surfactant appeared to be superior to any other. Injury to barnyardgrass did not result from any treatment of surfactant without terbacil.

The effectiveness of all applications of terbacil plus nonphytotoxic oils were highly affected by the stage of growth of the barnyardgrass at the time applications were made. All treatments of terbacil plus oils adequately controlled the test species at the first application date. Applications made two and three weeks after emergence gave some weed control but were less effective than those treatments applied to the youngest weeds.

Treatments of terbacil plus oil were more effective in barnyardgrass control than terbacil alone. This indicates that adequate control of barnyardgrass is possible if time of application is watched closely and oils are used to increase herbicide activity. Phytotoxicity to barnyardgrass did not result from applications of nonphytotoxic crop oils without terbacil.

Control resulting from treatments of terbacil plus Solution 32 was also affected by stage of growth of the barnyardgrass. Greatest control was obtained at the first application date; this diminished as weeds became larger. No differences between treatments of terbacil with and without Solution 32 were observed and no injury or stimulation resulted from applications of Solution 32 alone.

Applications of terbacil at 20% emergence of the barnyardgrass population also gave excellent control indicating the necessity of early application for maximum control.

Mixed population

Weed populations under most field conditions do not exist as pure stands but are usually found in combination with a crop or other weeds.

For this reason the treatments were applied to a mixed population of weeds which consisted of pigweed, barnyardgrass, and green foxtail. In every case pigweed was controlled by treatments of terbacil with or without additive. The data, therefore, indicate only the effects caused by the grass species which survived the treatments.

The foliage applications of terbacil plus an additive at each of the three application dates were effective to some degree in controlling the weed species which made up this population. Terbacil in combination with any additive gave best control at the earliest application date, when the weeds were very young. When similar treatments were made at later dates of application, the amount of weed control diminished as the weeds became larger.

Foliage applications of terbacil alone gave acceptable results at the earliest time of application with control also diminishing as the weeds became large. As the weeds increased in size, however, treatments of terbacil plus an additive were usually more effective. Terbacil applied without additives when approximately 20% of the weed population had emerged gave excellent control of all weed species tested in the population.

VI. SOIL RESIDUAL STUDY

Materials and Methods

In areas of limited rainfall, water must be applied by either furrow or sprinkler irrigation to peppermint fields. Because of the lack of peppermint competition in the region around the furrow, weed control is more difficult under this type of irrigation than in fields which are sprinkler irrigated. Weed germination often occurs after each application of water. Preemergence treatments of terbacil up to 1.6 lb ai/A have sometimes failed to give adequate control of annual weeds in this region.

Postemergence applications of a reduced rate of terbacil plus a spray solution additive, if necessary, applied to each new population of weeds, should give sufficient control until the peppermint could adequately compete with the weeds in the furrow area. However, the terbacil residue in the soil would not be decreased to any extent, unless much of the terbacil-additive solution was absorbed by the leaves of the peppermint plants and detoxified or degraded into simple organic compounds. The purpose of this study was to determine if equal amounts of terbacil remained in the soil after similar rates of terbacil are applied as:

(1) a single preemergence treatment

(2) several postemergence treatments in combination with a spray solution additive.

The experiment was established in a commercial peppermint field in the spring of 1969. A randomized block design was used with three replications. Individual plots were 8 x 20 feet.

Five treatments were used: (1) terbacil at 3 lb ai/A applied preemergence, (2) terbacil at 1.5 lb ai/A applied preemergence, (3) terbacil applied postemergence as three 1 lb rates of active ingredient per acre plus X-77, (4) terbacil applied postemergence as three .5 lb treatments of active ingredient per acre plus X-77, and (5) an untreated control. All application dates and stage of peppermint growth at each time of application are given in Table 4.

Table 4. Application dates and peppermint stage of growth.

Date of application	Peppermint stage of growth
April 19, 1969	Preemergence
April 30, 1969	Emergence
June 14, 1969	5 to 7 inches in height
July 25, 1969	1.5 to 2.0 feet in height

The plots were sprayed by means of a compressed air bicycle plot sprayer. Sprinkler irrigation was applied according to the field schedule.

Core samples 1.0 inch in diameter and 6 inches deep were taken on November 12, 1969. Each sample was divided into two 3-inch segments. All samples from each depth, within each plot were bulked, air dried, ground with a soil grinder, and mixed thoroughly. Each bulked sample was then separated into three sub-samples, consisting of 25 grams of soil, and placed in 2.75 x 2.75 x 2.75 inch plastic pots for bioassay in the greenhouse. Eight oat seeds were planted .5 inches deep in each pot. Seedlings were later thinned to six plants per pot. Pots from each replication were randomized in watering trays and subirrigated. Temperature in the greenhouse ranged from 60°F. at night to 75-80°F. in the day. Supplemental lighting was provided. All oat plants were harvested six weeks after planting and dry weights were determined.

Results

Dry weights of oat plants grown in soil from 0-3 and 3-6 inches in depth are shown in Figure 11. (See also Tables 16 and 17 of the Appendix.) At the 0-3 inch depth, preemergence treatments of terbacil at 3 lb/A and the split application of terbacil consisting of three 1 lb/A treatments resulted in greatest oat injury when compared to a control treatment. It was noted that the single preemergence application of terbacil at 3 lb/A always resulted in most severe phytotoxicity to the oat plants, but no statistically significant difference could be determined between that treatment and the postemergence treatment of terbacil consisting of three 1 lb/A applications.

About equal control was obtained by both the preemergence applications of 1.5 lb/A of terbacil and the split application of terbacil consisting of three 1 lb/A treatments. Injury resulting from a postemergence application of three .5 lb/A rates of terbacil did not differ from that of the control at either soil depth. Only the preemergence treatment of terbacil at 3 lb/A was significantly different from the control at the 3-6 inch soil depth, indicating that less herbicide was able to leach to this soil level by all other treatments.

These data suggest that even though differences were not statistically significant more herbicide reached the soil as a result of a single preemergence treatment than when applied in split application of postemergence treatments.

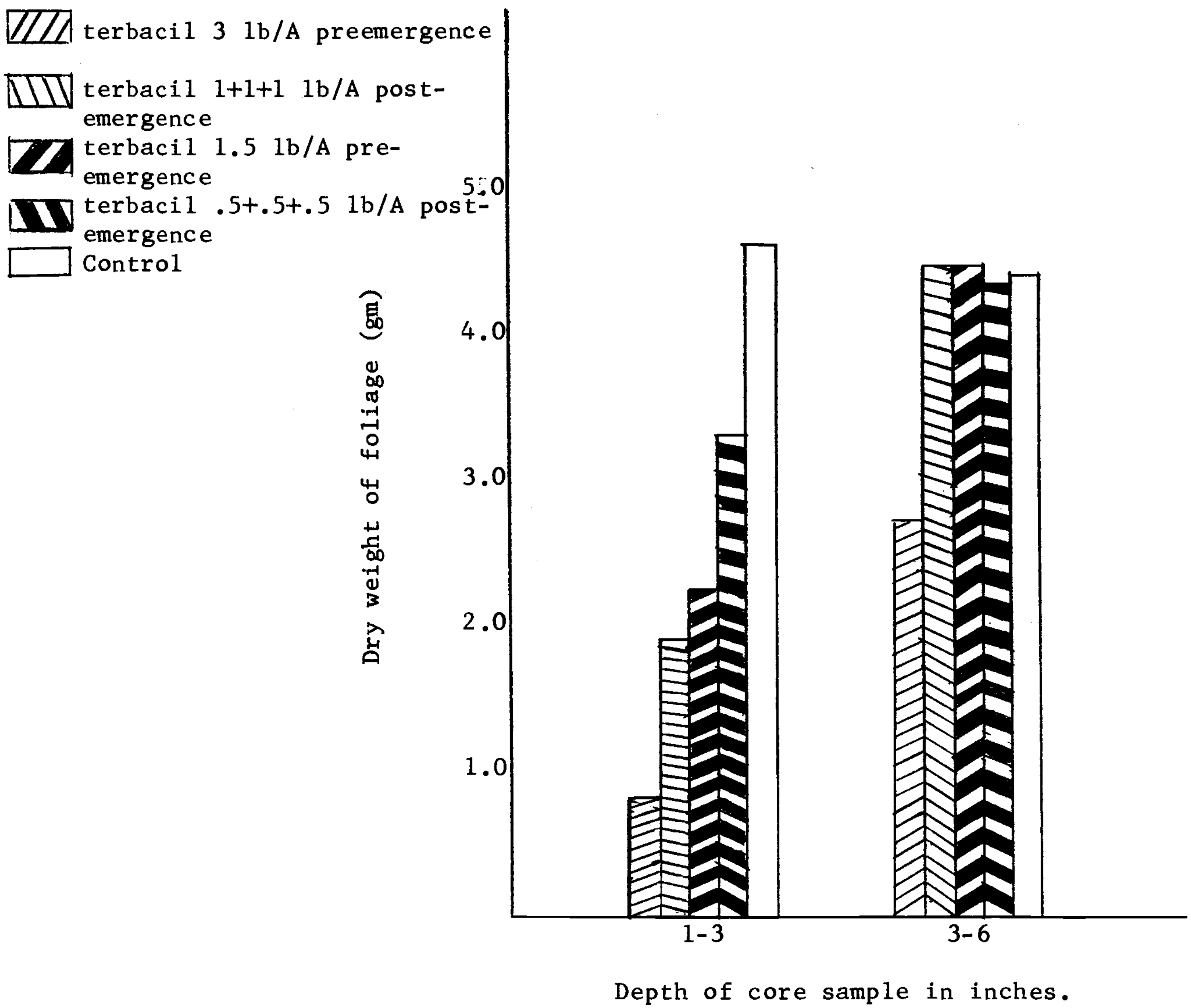


Figure 11. Dry weight of oat foliage harvested from core samples taken from an established peppermint trial. Core samples were taken November 12, 1969.

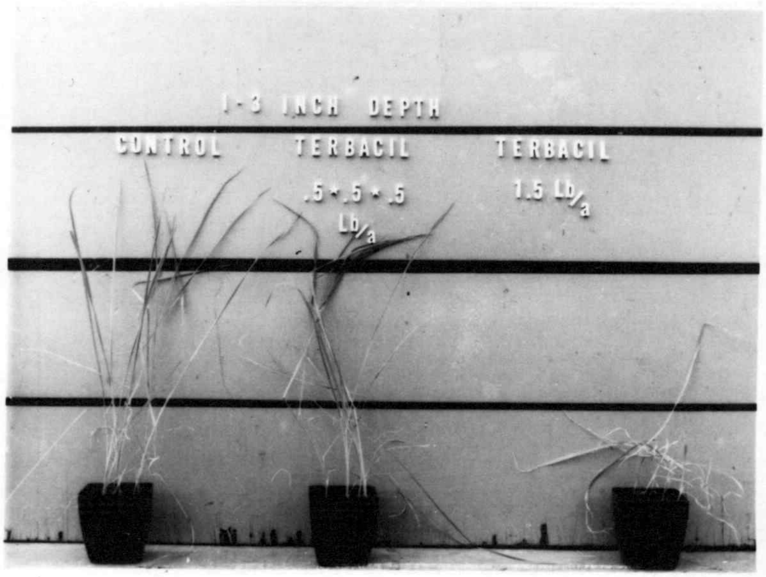


Figure 12. Oats grown in core samples taken from established peppermint trial. Samples were taken on November 12, 1969.

DISCUSSION AND CONCLUSIONS

Studies were conducted to investigate the feasibility of applying terbacil postemergence to weeds and peppermint. A review of literature indicated that surfactants and nonphytotoxic oils increase herbicide penetration into plant foliage. When spray solution additives were combined with low rates of terbacil, foliage applications resulted in good weed control. The results varied, however, with weed species involved, stage of weed growth, and type of additive used.

The stage of growth of the weed at the time of herbicide application was critical in determining the extent of weed control. Best results were obtained when treatments were applied to very young plants, i.e. within one week after emergence. When terbacil was applied at about 20% weed emergence, excellent control resulted. The time of application was more critical for adequate control of barnyardgrass and green foxtail than redroot pigweed. At the youngest stage of weed growth, differences between treatments of terbacil were usually insignificant. As weeds, especially grasses, became larger control was always inferior.

The cuticle is the waxy leaf surface which acts as a major barrier to foliage absorption of herbicides by plants. Currier and Dybing (1959) describe it as an inert semipolar layer which is readily wetted by oil but not by water, and is only slightly permeable to both. The work of Knight, Chamberlin, and Samuels (1929), Cook and Boyton (1952), and Hull (1959) indicate that a direct relationship exists between cuticle thickness and the amount of herbicide or other material penetrated. The thickness and nature of the cuticle varies according to species, age of the plant (young leaves have thinner cuticle than older leaves), and environmental conditions. The absorption and uptake of postemergence applications of terbacil seem to be highly sensitive to these cuticle differences.

The addition of nonphytotoxic oils or surfactants to the spray solution was beneficial to terbacil activity at later stages of weed growth. Nonphytotoxic oils were usually more effective than surfactants. Solution 32, a liquid nitrogen solution, in combination with terbacil did not appreciably improve herbicidal activity.

The role of oils and surfactants as postemergence carriers is to facilitate entry of the herbicide into the leaf tissue. Currier and Dybing (1959) and Klingman (1961) have stated several ways in which surface active agents may intensify herbicidal action. These include improving coverage by creating uniform spreading of the spray solution, causing more intimate contact between spray and plant surfaces, increasing spray retention, and solubilizing nonpolar plant substances. Dallyn and Sweet (1951) and van Overbeek and Blondeau (1954) have suggested that oils and surfactants solubilize the lipoproteic complex of the plasma membrane and upset the osmotic balance of the cell. If such mechanisms exist, the use of oils or surfactants in combination with terbacil would allow increased penetration of the herbicide into leaves and would enable greater inhibition of the photosynthetizing portions of the plant.

Freed and Montgomery (1959) concluded that a specific intramolecular relationship between herbicide and surfactant was responsible for increased absorption of amitrole. Such an interaction could also exist for certain terbacil-surfactant combinations. However, no consistent nor significant differences could be determined between the three wetting agents studied. Results on the rate of surfactant added to the spray solution were somewhat inconclusive. The 0.1% rate usually gave as effective weed control as the .5% rate. Higher rates were generally no more effective and sometimes less effective than either the 0.1% or 0.5% rates of surfactant.

These results suggested that reduction in interfacial tension between the spray droplet and the leaf surface could be a primary factor by which surfactants aid penetration and absorption of terbacil into leaf tissue. A specific relationship of surfactant to herbicide molecules was not indicated.

Peppermint yields were not significantly reduced by any treatment of terbacil in the study. Van Staalduine (1968) has demonstrated physiological resistance of peppermint to terbacil. Peppermint photosynthesis was completely restored within 12 hours after roots of exposed plants were removed from a 2×10^{-5}M solution of terbacil.

In the present study, core sample bioassays were used to determine the amount of herbicide remaining in soil from preemergence and split applications of terbacil. Lower herbicide levels existed in soil treated by split application. Foliage interception and subsequent rapid detoxification by the peppermint plant could explain this observed decrease in soil "carryover".

Postemergence applications of terbacil may be of benefit where peppermint is grown on muck soils or where rainfall or overhead irrigation is not readily available. The data presented in this thesis would indicate that weeds, especially grasses, should be quite small when foliage applications are made. Nonphytotoxic oils or surfactants intensify the activity of terbacil when applied to older weeds.

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APPENDIX

Appendix Table 1. The Effect of Terbacil Applied Postemergence with and without Various Spray Solution Additives + Peppermint and Two Weed Species.*

Treatment	Terbacil lbs/A	Additive %/vol	Pigweed									Lambsquarter									Peppermint gm/9 ft²				
			I		II		III		IV		Avg	I		II		III		IV		Avg	I	II	III	IV	Avg
Terbacil + X-77	1/2	.1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100					
Terbacil + X-77	1/2	.5	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	525	720	365	613	556
Terbacil + X-77	1/2	1.0	100	100	100	100	100	100	100	100	100	99	99	100	100	100	100	100	100	100	680	593	600	497	593
X-77		.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
X-77		.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	661	769	520	483	608
X-77		1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	460	606	570	565	550
Terbacil + Activate Plus	1/2	.1	99	99	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100					
Terbacil + Activate Plus	1/2	.5	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	626	632	365	518	535
Terbacil + Activate Plus	1/2	1.0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	660	588	405	620	568
Activate Plus		.1	0	0	0	0	0	0	-	-	0	0	0	0	0	0	0	0	0	0					
Activate Plus		.5	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	625	613	580	575	598
Activate Plus		1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	615	454	660	620	588
Terbacil + Tronic	1/2	.1	100	100	100	100	100	100	100	100	100	100	100	100	95	100	100	100	100	99					
Terbacil + Tronic	1/2	.5	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	564	550	733	520	592
Terbacil + Tronic	1/2	1.0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	457	487	415	684	511
Tronic		.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
Tronic		.5	-	-	0	0	0	0	0	0	0	0	0	-	-	0	0	0	0	0	680	610	325	390	501
Tronic		1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	695	507	850	525	644
Terbacil + 3408 Spray Oil	1/2	10.0	95	97	100	100	100	100	100	100	99	100	99	100	100	100	100	100	100	100	670	670	725	725	698
3408 Spray Oil		10.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	670	625	665	524	621
Terbacil + Savol Oil	1/2	10.0	99	99	100	100	100	100	100	100	100	100	100	97	95	100	100	100	100	74	975	525	575	600	669
Savol Oil		10.0	50	50	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	560	626	550	547	571
Terbacil + Superior Spray Oil	1/2	10.0	100	100	100	100	100	100	100	100	100	-	-	100	100	100	100	100	100	100	610	580	545	565	575
Superior Spray Oil		10.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	705	573	425	536	560
Terbacil + Superior Spray Emulsion	1/2	10.0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	632	540	653	777	651
Superior Spray Emulsion		10.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	370	587	690	475	531
Terbacil + Solution 32	1/2	5.0	100	100	100	100	100	100	100	100	100	100	100	100	100	95	95	100	100	99					
Terbacil + Solution 32	1/2	10.0	100	100	99	95	100	100	100	100	99	99	99	98	95	100	100	100	100	99					
Terbacil + Solution 32	1/2	20.0	100	100	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	555	691	503	520	567
Solution 32		5.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
Solution 32		10.0	0	0	0	0	0	0	0	0	0	-	-	0	0	0	0	0	0	0					
Solution 32		20.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	605	545	475	685	578
Terbacil	1/2		100	100	100	100	90	90	100	100	98	100	100	100	100	100	100	100	100	100	566	584	377	715	561
Control			-	-	0	0	0	0	0	0	0	x	x	0	0	0	0	0	0	0	720	741	630	650	685

*Weed control rating: 100 = perfect control
0 = no control

Analysis of Variance Table for Peppermint Yields in Appendix Table 1.

Source of variation	d.f.	SS	MS	F
Treatments	23	246,704	10,726	.902 ns
Replications	3	64,785	21,595	
Error	69	820,375	11,889	

C.V. = 18.5%

Table 2. The Effect of Foliage Applications of Terbacil, With and Without Spray Solution Additives to Pigweed, Lambsquarters, Green Foxtail, Barnyardgrass, and Common Mustard. Treatments evaluated 7 days after application.

Treatment	Terbacil lbs/A	Additives %/Vol	Pigweed I		Pigweed II		Pigweed III		Pigweed Avg	Lambsquarter I		Lambsquarter II		Lambsquarter III		Lambsquarter Avg	Foxtail I		Foxtail II		Foxtail III		Foxtail Avg	Barnyardgrass I		Barnyardgrass II		Barnyardgrass III		Barnyardgrass Avg	Mustard I		Mustard II		Mustard III		Mustard Avg
Terbacil + X-77	1/2	.1	95	90	90	90	92	90	91	95	90	95	90	87	90	91	30	25	20	20	10	15	20	30	30	5	10	10	15	17	65	50	90	40	40	40	54
Terbacil + X-77	1/2	.5	95	95	90	90	95	95	93	95	90	80	85	87	90	88	30	25	10	15	25	25	22	30	30	15	20	25	20	23	65	50	50	50	50	50	53
Terbacil + X-77	1/2	1.0	96	90	88	90	86	90	90	95	90	92	90	87	90	91	40	20	20	20	20	20	23	35	25	10	15	10	15	18	50	45	45	50	40	45	46
X-77		.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X-77		.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X-77		1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil + Activate Plus	1/2	.1	90	90	88	90	95	95	91	95	95	92	90	95	90	93	30	20	15	10	25	25	21	40	30	25	20	40	30	31	55	50	40	40	60	50	50
Terbacil + Activate Plus	1/2	.5	98	95	97	95	97	95	96	99	95	95	90	95	90	94	40	35	40	35	30	30	35	70	60	50	45	30	35	48	75	65	55	50	50	50	58
Terbacil + Activate Plus	1/2	1.0	95	95	93	85	92	95	93	90	90	95	90	95	90	92	25	15	15	15	30	30	22	45	35	15	15	30	20	27	55	50	40	50	50	50	49
Activate Plus		.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Activate Plus		.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Activate Plus		1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil + Tronic	1/2	.1	94	90	95	95	95	95	94	93	90	95	95	88	90	92	35	30	20	15	25	20	24	35	35	15	20	20	25	25	50	50	55	50	45	45	49
Terbacil + Tronic	1/2	.5	95	90	95	90	95	95	93	90	90	96	95	95	90	93	40	30	20	15	25	30	27	45	40	20	20	30	35	32	50	50	50	45	50	55	50
Terbacil + Tronic	1/2	1.0	95	90	92	90	96	90	92	90	95	88	85	93	90	90	25	20	25	20	25	20	23	35	25	35	25	30	40	32	60	50	50	40	45	40	48
Tronic		.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tronic		.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tronic	.	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil + 3408 Spray Oil	1/2	10	60	65	90	90	90	85	80	65	60	87	90	90	80	79	20	15	15	10	25	20	18	25	20	20	10	25	20	20	45	50	55	50	50	40	48
3408 Spray Oil		10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil + Savol Oil	1/2	10	97	98	90	85	95	95	93	95	95	88	85	95	90	91	25	15	10	10	20	10	15	25	25	10	10	35	25	22	50	50	50	35	55	50	48
Savol Oil		10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil + Superior Spray Oil	1/2	10	93	95	95	95	85	90	92	88	90	98	95	90	90	92	25	15	25	25	20	20	15	45	35	25	30	20	30	31	55	50	50	50	50	50	51
Superior Spray Oil		10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil + Superior Spray Emulsion	1/2	10	99	95	88	90	93	85	93	99	95	92	90	95	90	94	35	25	15	10	25	20	22	40	30	20	15	15	20	23	45	50	40	45	50	55	48
Superior Spray Emulsion		10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil + Solution 32	1/2	5	75	85	80	80	90	95	84	70	70	80	75	92	85	79	15	15	10	10	15	15	13	20	20	20	15	30	20	21	50	50	45	40	45	45	46
Terbacil + Solution 32	1/2	10	80	85	93	95	93	95	90	75	75	95	95	90	90	87	25	15	20	15	25	20	20	25	20	25	20	15	20	21	50	40	45	50	55	50	48
Terbacil + Solution 32	1/2	20	97	95	85	85	98	95	93	95	90	88	80	95	90	90	55	45	30	25	15	10	30	70	65	10	15	40	40	40	80	70	50	50	65	60	63
Solution 32		5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solution 32		10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solution 32		20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil	1/2		85	85	85	95	93	90	89	80	80	80	90	85	75	82	15	10	25	30	30	25	23	25	25	20	30	10	15	21	35	30	50	50	50	45	43
Control			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 3. The Effects of Foliage Applications of Terbacil with and without Spray Solution Additives to Pigweed, Green Foxtail, Barnyardgrass, and Common Mustard. Treatments Evaluated 21 days after Application.

Treatment	Terbacil lbs/A	Additive % vol	Pigweed I		Pigweed II		Pigweed III		Pigweed Avg	Foxtail I		Foxtail II		Foxtail III		Foxtail Avg	Barnyardgrass I		Barnyardgrass II		Barnyardgrass III		Barnyardgrass Avg	Mustard I		Mustard II		Mustard III		Mustard Avg
Terbacil + X-77	1/2	.1	70	65	85	80	95	90	81	10	10	5	5	5	5	7	10	15	5	5	25	20	13	85	90	80	90	85	90	87
Terbacil + X-77	1/2	.5	80	80	85	75	90	90	83	10	15	5	5	10	15	10.0	10	20	10	20	20	25	18	85	80	80	90	85	95	85
Terbacil + X-77	1/2	1.0	85	95	75	75	80	70	80	15	20	5	5	5	0	8.3	15	20	10	10	15	5	13	85	90	90	90	85	90	88
X-77		.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X-77		.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X-77		1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil + Activate Plus	1/2	.1	65	75	90	85	90	93	83	5	10	5	5	10	10	8	10	15	20	15	35	40	23	90	90	90	85	80	80	86
Terbacil + Activate Plus	1/2	.5	90	95	95	95	85	88	91	15	15	20	15	10	10	14	40	30	35	45	20	15	31	75	85	90	95	75	75	83
Terbacil + Activate Plus	1/2	1.0	90	85	75	70	90	90	83	10	5	10	5	10	10	8	20	15	10	5	5	5	10	80	90	60	75	75	80	77
Activate Plus		.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Activate Plus		.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Activate Plus		1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil + Tronic	1/2	.1	90	90	95	90	95	95	93	15	10	5	5	10	20	11	20	15	10	10	25	15	16	85	90	85	90	80	90	87
Terbacil + Tronic	1/2	.5	90	80	90	90	95	95	90.0	15	20	10	5	10	15	13	25	25	20	15	20	15	20	70	80	60	70	85	90	76
Terbacil + Tronic	1/2	1.0	70	60	85	90	75	80	77	5	5	10	5	10	10	8	15	20	20	30	20	20	21	80	85	85	90	50	50	73
Tronic		.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tronic		.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tronic		1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil + 3408 Spray Oil	1/2	10.0	60	50	85	90	80	80	74	10	15	5	5	10	10	9	10	10	5	10	20	20	13	50	80	80	90	80	80	77
3408 Spray Oil		10.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil + Savol Oil	1/2	10.0	90	90	90	95	90	93	91	10	10	10	20	0	10	10	10	10	10	10	15	20	13	80	85	80	85	80	90	83
Savol Oil		10.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil + Superior Oil Spray	1/2	10.0	95	95	90	85	70	60	83	10	10	20	15	15	10	13	20	15	10	10	10	15	13	80	90	75	85	85	90	84
Superior Spray Oil		10.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil + Superior Spray Emulsion	1/2	10.0	85	90	95	95	80	75	87	10	10	15	5	10	10	10	30	25	10	10	10	10	16	75	85	80	85	75	80	80
Superior Spray Emulsion		10.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil + Solution 32	1/2	5.0	70	60	85	90	75	75	77	10	10	5	5	10	10	8	10	10	10	20	25	20	16	80	90	85	90	75	85	84
Terbacil + Solution 32	1/2	10.0	65	75	90	85	90	90	83	5	5	10	10	15	20	11	10	20	15	10	20	10	14	75	90	95	85	90	95	88
Terbacil + Solution 32	1/2	20.0	90	80	75	70	85	90	83	20	30	10	10	5	0	13	40	50	15	10	50	50	36	90	95	90	90	75	80	87
Solution 32		5.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solution 32		10.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solution 32		20.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terbacil	1/2	-	80	70	95	95	90	90	87.7	5	0	20	25	10	20	13	10	10	20	20	15	10	14	80	90	85	95	80	85	86
Control			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix Table 4. The effect of foliage applications of terbacil with and without spray solution additives to pigweed at several application dates.

Treatments evaluated 19 days after application.

Treatments	Rate		Application Date #1								
	lb/A	% additive/vol	I		II		III		IV		Avg.
terbacil + X-77	1/2	0.5	100	100	99	99	100	100	100	100	100
X-77		0.5	0	0	0	0	0	0	0	0	0
terbacil + Activate Plus	1/2	0.5	100	100	100	99	100	99	100	100	100
Activate Plus		0.5	0	0	0	0	0	0	0	0	0
terbacil + Tronic	1/2	0.5	97	99	100	100	100	99	100	100	99
Tronic		0.5	0	0	0	0	0	0	0	0	0
terbacil + Savol Oil	1/2	10	100	100	99	100	100	100	98	99	99
Savol Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Oil	1/2	10	100	100	100	100	100	99	100	100	100
Superior Spray Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Emulsion	1/2	10	100	100	100	100	100	100	100	100	100
Superior Spray Emulsion		10	0	0	0	0	0	0	0	0	0
terbacil + Solution 32	1/2	20	99	100	97	100	100	100	99	100	99
Solution 32		20	0	0	0	0	0	0	0	0	0
terbacil (postemergence)	1/2		98	99	99	99	96	99	100	99	98
terbacil (at emergence)	1/2		100	99	100	100	100	100	100	100	100
Control	-	--	0	0	0	0	0	0	0	0	0
Date of application means											53

(cont'd)

Appendix Table 4. (cont'd)

Treatments	Rate		Application Date #2								
	lb/A	% additive/vol	I		II		III		IV		Avg.
terbacil + X-77	1/2	0.5	90	95	90	92	90	90	95	90	91
X-77		0.5	0	0	0	0	0	0	0	0	0
terbacil + Activate Plus	1/2	0.5	97	98	88	92	95	95	95	96	94
Activate Plus		0.5	0	0	0	0	0	0	0	0	0
terbacil + Tronic	1/2	0.5	75	85	90	98	99	98	99	98	93
Tronic		0.5	0	0	0	0	0	0	0	0	0
terbacil + Savol Oil	1/2	10	98	97	99	99	100	100	99	97	99
Savol Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Oil	1/2	10	100	99	100	98	99	98	98	97	98
Superior Spray Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Emulsion	1/2	10	100	100	98	98	100	100	99	100	99
Superior Spray Emulsion		10	0	0	0	0	0	0	0	0	0
terbacil + Solution 32	1/2	20	80	85	98	99	98	97	100	99	94
Solution 32		20	0	0	0	0	0	0	0	0	0
terbacil (postemergence)	1/2		98	98	97	97	98	99	99	98	98
terbacil (at emergence)	1/2		100	100	100	99	100	100	100	100	100
Control	-	--	0	0	0	0	0	0	0	0	0
Date of application means											51

(cont'd)

Appendix Table 4. (cont'd)

Treatments	Rate lb/A	Rate % additive/vol	Application Date #3 I		II		III		IV		Avg.	Treatment means
terbacil + X-77	1/2	0.5	60	50	75	70	75	75	75	65	68	86
X-77		0.5	0	0	0	0	0	0	0	0	0	0
terbacil + Activate Plus	1/2	0.5	75	75	75	70	75	70	75	75	74	89
Activate Plus		0.5	0	0	0	0	0	0	0	0	0	0
terbacil + Tronic	1/2	0.5	55	60	50	60	80	80	80	80	68	87
Tronic		0.5	0	0	0	0	0	0	0	0	0	0
terbacil + Savol Oil	1/2	10	70	85	85	80	90	90	80	80	82	93
Savol Oil		10	0	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Oil	1/2	10	95	95	80	75	70	70	85	85	80	93
Superior Spray Oil		10	0	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Emulsion	1/2	10	95	95	90	90	75	80	90	85	87	96
Superior Spray Emulsion		10	0	0	0	0	0	0	0	0	0	0
terbacil + Solution 32	1/2	20	45	50	85	85	93	95	85	80	77	90
Solution 32		20	0	0	0	0	0	0	0	0	0	0
terbacil (postemergence)	1/2		50	50	50	50	60	70	75	70	59	85
terbacil (at emergence)	1/2		100	100	99	99	100	100	100	100	100	100
Control	-	--	0	0	0	0	0	0	0	0	0	0
Date of application means											41	

Analysis of Variance Table for Date in Appendix Table 4.

Source of variation	d.f.	SS	MS	F
Replications	3	147.58	49.19	2.74
Treatment	16	423491.67	26468.22	827.0 **
Error (a)	48	1580.83	32.93	1.83
Replication	3	147.58	49.19	2.74
Date of application	2	5486.65	2743.32	156.7 **
Error (b)	6	105.22	17.53	.97
Replication	3	147.58	49.19	2.74
Treatment x date of application	32	7600.17	237.50	13.16**
Error (c)	96	1724.60	17.96	
Total	203	440136.75		

** Significant at .1% level
C.V.=8.76

Date LSD at .05 level = 7.2% at .01 level = 10.9%
Treatment LSD at .05 level = 8.0% at .01 level = 10.5%
Date x treatment LSD at .05 level = 5.9% at .01 level = 7.7%

Appendix Table 5. The effect of foliage applications of terbacil with and without spray solution additives to pigweed at several application dates.

Treatments evaluated 40 days after weed emergence.

Treatment	Rate lb/A	Rate % additive/vol	Application Date #1 I		II		III		IV		Avg.
terbacil + X-77	1/2	0.5	100	100	100	99	100	99	100	99	99
X-77		0.5	0	0	0	0	0	0	0	0	0
terbacil + Activate Plus	1/2	0.5	100	99	99	100	99	98	100	100	99
Activate Plus		0.5	0	0	0	0	0	0	0	0	0
terbacil + Tronic	1/2	0.5	99	98	100	100	98	100	100	100	99
Tronic		0.5	0	0	0	0	0	0	0	0	0
terbacil + Savol Oil	1/2	10	100	99	99	98	100	99	99	98	99
Savol Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Oil	1/2	10	100	100	98	99	100	100	100	99	99
Superior Spray Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Emulsion	1/2	10	99	99	99	99	100	100	100	100	99
Superior Spray Emulsion		10	0	0	0	0	0	0	0	0	0
terbacil + Solution 32	1/2	20	100	100	99	97	99	100	100	100	99
Solution 32		20	0	0	0	0	0	0	0	0	0
terbacil (postemergence)	1/2		99	98	97	98	99	95	99	99	98
terbacil (at emergence)	1/2		99	100	100	100	100	100	100	100	100
Control	-	--	0	0	0	0	0	0	0	0	0
Date of application means											53

(cont'd)

Appendix Table 5. (cont'd)

Treatment	Rate lb/A	Rate % additive/vol	Application Date #2 I		II		III		IV		Avg.
terbacil + X-77	1/2	0.5	95	95	95	95	90	95	99	96	95
X-77		0.5	0	0	0	0	0	0	0	0	0
terbacil + Activate Plus	1/2	0.5	96	95	95	99	97	90	98	99	96
Activate Plus		0.5	0	0	0	0	0	0	0	0	0
terbacil + Tronic	1/2	0.5	95	90	93	94	99	100	100	99	96
Tronic		0.5	0	0	0	0	0	0	0	0	0
terbacil + Savol Oil	1/2	10	99	99	100	99	100	100	100	99	99
Savol Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Oil	1/2	10	100	100	99	100	100	100	100	98	99
Superior Spray Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Emulsion	1/2	10	100	100	99	97	100	100	100	100	99
Superior Spray Emulsion		10	0	0	0	0	0	0	0	0	0
terbacil + Solution 32	1/2	20	95	90	99	98	98	99	100	100	97
Solution 32		20	0	0	0	0	0	0	0	0	0
terbacil (postemergence)	1/2		98	97	98	99	100	99	99	100	99
terbacil (at emergence)	1/2		100	100	100	100	100	100	100	100	100
Control	-	--	0	0	0	0	0	0	0	0	0
Date of application means											52

(cont'd)

Appendix Table 5. (cont'd)

Treatment	Rate		Application Date #3									Treatment means
	lb/A	% additive/vol	I		II		III		IV		Avg.	
terbacil + X-77	1/2	0.5	50	60	70	75	75	75	65	75	95	88
X-77		0.5	0	0	0	0	0	0	0	0	0	0
terbacil + Activate Plus	1/2	0.5	75	75	75	70	75	75	75	75	74	90
Activate Plus		0.5	0	0	0	0	0	0	0	0	0	0
terbacil + Tronic	1/2	0.5	60	65	50	60	80	80	80	80	69	88
Tronic		0.5	0	0	0	0	0	0	0	0	0	0
terbacil + Savol Oil	1/2	10	80	80	85	70	80	85	90	90	82	94
Savol Oil		10	0	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Oil	1/2	10	95	95	80	75	70	70	85	85	82	94
Superior Spray Oil		10	0	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Emulsion	1/2	10	95	95	90	90	75	80	85	90	87	95
Superior Spray Emulsion		10	0	0	0	0	0	0	0	0	0	0
terbacil + Solution 32	1/2	20	80	85	50	45	85	85	93	95	77	91
Solution 32		20	0	0	0	0	0	0	0	0	0	0
terbacil (postemergence)	1/2		50	50	50	50	70	60	75	70	59	85
terbacil (at emergence)	1/2		100	99	99	100	100	100	100	100	100	100
Control	-	--	0	0	0	0	0	0	0	0	0	0
Date of application means											41	

Analysis of Variance Table for Data in Appendix Table 5.

Source of variation	d.f.	SS	MS	F
Replications	3	168.99	56.33	3.16
Treatment	16	429218.51	26826.15	1277. **
Error (a)	48	1027.75	21.41	1.20
Replication	3	168.99	56.33	3.16
Date of application	2	5484.91	2742.45	85.6 **
Error (b)	6	192.10	32.01	1.80
Replication	3	168.99	56.33	3.16
Treatment x date of application	32	7571.92	236.62	13.16**
Error (c)	96	1710.39	17.81	
Total	203	445374.60		

** Significant at 1% level
C.V. = 8.72

Date LSD at .05 = 9.8%, at .01 = 14.8%
Treatment LSD at .05 = 6.3%, at .01 = 8.2%
Date x treatment LSD at .05 = 17.3%, at .01 = 22.9%

Appendix Table 6. The effect of foliage applications of terbacil with and without spray solution additives to pigweed at several application dates.

Dry weights determined 41 days after weed emergence.

Treatment	Rate		Application Date 1					Application Date 2					Application Date 3				
	lb/A	%/volume	I	II	III	IV	Avg.	I	II	III	IV	Avg.	I	II	III	IV	Avg.
terbacil + X-77	1/2	0.5	0	0	0	0	0	3	3	6	1	3	15	10	8	7	10
X-77		0.5	205	161	158	143	167	147	127	251	162	172	180	181	103	111	144
terbacil + Activate Plus	1/2	0.5	0	0	0	0	0	0	4	0	0	1	3	1	6	8	4
Activate Plus		0.5	205	160	125	172	165	198	212	166	172	187	170	178	136	132	154
terbacil + Tronic	1/2	0.5	0	0	0	0	0	9	4	0	0	3	25	37	7	10	20
Tronic		0.5	135	158	103	109	126	169	165	151	120	151	85	164	141	132	130
terbacil + Savol Oil	1/2	10	0	0	0	0	0	0	0	0	0	0	0	0	2	6	2
Savol Oil		10	157	206	173	140	169	143	183	140	180	161	145	120	165	220	162
terbacil + Superior Spray Oil	1/2	10	0	0	0	0	0	0	0	0	0	0	0	0	9	3	3
Superior Spray Oil		10	217	204	153	186	190	186	160	174	129	162	169	147	156	156	157
terbacil + Superior Spray Emulsion	1/2	10	0	0	0	0	0	0	0	0	0	0	0	0	4	5	2
Superior Spray Emulsion		10	242	193	177	141	186	185	124	120	164	148	204	143	90	168	151
terbacil + Solution 32	1/2	20	0	0	0	0	0	5	0	0	0	1	40	0	0	3	11
Solution 32		20	216	162	215	203	199	173	150	179	134	159	126	164	186	160	159
terbacil (postemergence)	1/2		0	1	0	0	0	0	0	0	0	0	37	44	48	8	34
terbacil (at emergence)	1/2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Control	-	--	206	163	148	155	168	117	180	171	127	124	206	99	145	127	144
Date of application means							80					75					75

Analysis of Variance Table for Data in Appendix Table 6.

Source of variation	d.f.	SS	MS	F
Replications	3	4509.19	1503.06	3.33
Treatment	16	1257466.82	78591.67	127.8 **
Error (a)	48	29536.39	615.34	1.36
Replication	3	4509.19	1503.06	3.33
Date of application	2	1280.36	640.18	1.45
Error (b)	6	2641.32	440.22	.97
Replication	3	4509.19	1503.06	3.33
Treatment x Date of application	32	23071.97	720.99	1.60 *
Error (c)	96	43290.34	450.94	
Total	203	1361796.40		

* Significant at 5% level
** Significant at 1% level
C.V. = 27.4%

Date LSD at .05 level = 36.1 gms., at .01 level = 54.7 gms.
Treatment LSD at .05 level = 34.3 gms., at .01 level = 45.0 gms.
Date x treatment LSD at .05 level = 29.4 gms., at .01 level = 38.5 gms.

Appendix Table 7. The effects of foliage applications of terbacil with and without spray solution additives to foxtail at several application dates.

Treatments evaluated 19 days after application.

Treatment	Rate lb/A	Rate % additive/vol	Application Date #1 I		II		III		IV		Avg.
terbacil + X-77	1/2	0.5	98	99	99	99	97	98	96	99	98
X-77		0.5	0	0	0	0	0	0	0	0	0
terbacil + Activate Plus	1/2	0.5	97	98	97	95	99	99	99	99	98
Activate Plus		0.5	0	0	0	0	0	0	0	0	0
terbacil + Tronic	1/2	0.5	97	99	97	95	99	99	90	90	96
Tronic		0.5	0	0	0	0	0	0	0	0	0
terbacil + Savol Oil	1/2	10	97	98	99	97	97	98	98	99	98
Savol Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Oil	1/2	10	95	97	99	98	99	99	98	99	98
Superior Spray Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Emulsion	1/2	10	98	99	98	98	98	99	98	99	98
Superior Spray Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Solution 32	1/2	20	96	99	96	95	99	99	93	95	96
Solution 32		20	0	0	0	0	0	0	0	0	0
terbacil (postemergence)	1/2		88	90	95	97	90	92	95	98	93
terbacil (at emergence)	1/2		98	98	97	97	97	98	95	97	97
Control	-	--	0	0	0	0	0	0	0	0	0
Date of application means											51

(cont'd)

Appendix Table 7. (cont'd

Treatment	Rate lb/A	Rate % additive/vol	Application Date #2 I	II	III	IV	Avg.
terbacil + X-77	1/2	0.5	60 50	70 60	65 60	50 50	58
X-77		0.5	0 0	0 0	0 0	0 0	0
terbacil + Activate Plus	1/2	0.5	45 30	50 65	65 60	70 55	55
Activate Plus		0.5	0 0	0 0	0 0	0 0	0
terbacil + Tronic	1/2	0.5	30 40	35 25	40 35	40 30	34
Tronic		0.5	0 0	0 0	0 0	0 0	0
terbacil + Savol Oil	1/2	10	50 40	75 70	75 80	60 50	62
Savol Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Oil	1/2	10	80 80	90 85	80 80	80 70	80
Superior Spray Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Emulsion	1/2	10	60 60	35 25	25 20	75 60	45
Superior Spray Emulsion		10	0 0	0 0	0 0	0 0	0
terbacil + Solution 32	1/2	20	40 40	20 20	70 60	30 25	38
Solution 32		20	0 0	0 0	0 0	0 0	0
terbacil (postemergence)	1/2		60 65	50 50	60 75	40 35	54
terbacil (at emergence)	1/2		97 98	95 96	95 97	93 95	96
Control	-	--	0 0	0 0	0 0	0 0	0
Date of application means							31

(cont'd)

Appendix Table 7. (cont'd)

Treatment	Rate lb/A	Rate % additive/vol	Application Date #3 I	II	III	IV	Avg.	Treatment means
terbacil + X-77	1/2	0.5	30 30	15 10	50 50	50 60	37	64
X-77		0.5	0 0	0 0	0 0	0 0	0	0
terbacil + Activate Plus	1/2	0.5	20 25	60 55	40 30	45 40	39	64
Activate Plus		0.5	0 0	0 0	0 0	0 0	0	0
terbacil + Tronic	1/2	0.5	25 25	5 10	25 30	15 35	21	50
Tronic		0.5	0 0	0 0	0 0	0 0	0	0
terbacil + Savol Oil	1/2	10	20 20	40 50	40 30	20 30	31	64
Savol Oil		10	0 0	0 0	0 0	0 0	0	0
terbacil + Superior Spray Oil	1/2	10	60 70	75 70	70 75	45 60	67	82
Superior Spray Oil		10	0 0	0 0	0 0	0 0	0	0
terbacil + Superior Spray Emulsion	1/2	10	30 40	10 15	15 20	50 50	29	57
Superior Spray Emulsion		10	0 0	0 0	0 0	0 0	0	0
terbacil + Solution 32	1/2	20	70 60	30 20	60 70	35 30	47	60
Solution 32		20	0 0	0 0	0 0	0 0	0	0
terbacil (postemergence)	1/2		20 30	20 15	30 20	15 20	21	56
terbacil (at emergence)	1/2		97 98	95 90	95 90	95 90	94	95
Control	-	--	0 0	0 0	0 0	0 0	0	0
Date of application means							23	

Analysis of Variance Table for Data in Appendix Table 7.

Source of variation	d.f.	SS	MS	F
Replications	3	231.46	77.15	1.73
Treatment	16	239989.16	14999.32	144.2 **
Error (a)	48	5001.61	104.20	2.3
Replication	3	231.46	77.15	1.73
Date of application	2	29615.80	14807.90	616.9 **
Error (b)	6	149.60	24.93	.56
Replication	3	231.46	77.15	1.73
Treatment x date of application	32	37933.55	1185.41	26.93**
Error (c)	96	4280.55	44.58	
Total	203	317201.58		

** Significant at 1% level
C.V. = 15.4%

Date LSD at .05 level = 6.1%, at .01 level = 9.2%
Treatment LSD at .05 level = 14.1%, at .01 level = 18.5%
Date x treatment LSD .05 level = 9.2%, at .01 level = 12.1%

Appendix Table 8. The effects of foliage application of terbacil with and without spray solution additives to foxtail at several application dates.

Treatments evaluated 40 days after weed emergence.

Treatment	Rate		Application Date #1				
	lb/A	% additive/vol	I	II	III	IV	Avg.
terbacil + X-77	1/2	0.5	99 99	97 95	95 95	95 97	96
X-77		0.5	0 0	0 0	0 0	0 0	0
terbacil + Activate Plus	1/2	0.5	95 95	90 95	98 99	95 98	95
Activate Plus		0.5	0 0	0 0	0 0	0 0	0
terbacil + Tronic	1/2	0.5	93 95	90 95	97 98	90 93	94
Tronic		0.5	0 0	0 0	0 0	0 0	0
terbacil + Savol Oil	1/2	10	95 95	95 95	90 95	98 98	95
Savol Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Oil	1/2	10	90 88	96 95	97 98	90 95	94
Superior Spray Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Emulsion	1/2	10	95 98	95 90	95 95	95 95	95
Superior Spray Emulsion		10	0 0	0 0	0 0	0 0	0
terbacil + Solution 32	1/2	20	98 95	95 90	96 95	95 95	95
Solution 32		20	0 0	0 0	0 0	0 0	0
terbacil (postemergence)	1/2		90 90	90 90	85 85	95 93	90
terbacil (at emergence)	1/2		95 90	90 95	90 95	97 95	93
Control	-	--	0 0	0 0	0 0	0 0	0
Date of application means							50

(cont'd)

Appendix Table 8. (cont'd)

Treatment	Rate lb/A	Rate % additive/vol	Application Date #2 I		II		III		IV		Avg.
terbacil + X-77	1/2	0.5	60	50	50	50	50	50	40	30	47
X-77		0.5	0	0	0	0	0	0	0	0	0
terbacil + Activate Plus	1/2	0.5	20	20	50	50	50	40	75	75	47
Activate Plus		0.5	0	0	0	0	0	0	0	0	0
terbacil + Tronic	1/2	0.5	15	20	20	10	10	20	30	20	18
Tronic		0.5	0	0	0	0	0	0	0	0	0
terbacil + Savol Oil	1/2	10	40	30	70	75	75	65	50	40	56
Savol Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Oil	1/2	10	85	75	88	85	70	75	75	60	76
Superior Spray Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Emulsion	1/2	10	40	50	10	20	20	15	55	75	36
Superior Spray Emulsion		10	0	0	0	0	0	0	0	0	0
terbacil + Solution 32	1/2	20	20	10	10	5	50	50	5	5	19
Solution 32		20	0	0	0	0	0	0	0	0	0
terbacil (postemergence)	1/2		55	50	20	20	50	60	25	20	37
terbacil (at emergence)	1/2		95	90	90	95	90	95	96	90	93
Control	-	--	0	0	0	0	0	0	0	0	0
Date of application means											25

(cont'd)

Appendix Table 8. (cont'd)

Treatment	Rate lb/A	Rate % additive/vol	Application Date #3 I	II	III	IV	Avg.	Treatment means
terbacil + X-77	1/2	0.5	30 30	15 10	50 50	60 50	37	60
X-77		0.5	0 0	0 0	0 0	0 0	0	0
terbacil + Activate Plus	1/2	0.5	20 25	55 60	40 30	40 45	39	61
Activate Plus		0.5	0 0	0 0	0 0	0 0	0	0
terbacil + Tronic	1/2	0.5	25 25	10 5	25 30	35 15	21	44
Tronic		0.5	0 0	0 0	0 0	0 0	0	0
terbacil + Savol Oil	1/2	10	20 20	40 50	30 40	30 20	31	61
Savol Oil		10	0 0	0 0	0 0	0 0	0	0
terbacil + Superior Spray Oil	1/2	10	70 60	75 70	70 75	60 45	66	78
Superior Spray Oil		10	0 0	0 0	0 0	0 0	0	0
terbacil + Superior Spray Emulsion	1/2	10	30 40	10 15	20 15	50 50	29	53
Superior Spray Emulsion		10	0 0	0 0	0 0	0 0	0	0
terbacil + Solution 32	1/2	20	60 70	30 20	60 70	30 35	47	54
Solution 32		20	0 0	0 0	0 0	0 0	0	0
terbacil (postemergence)	1/2		30 20	15 20	30 20	20 15	21	50
terbacil (at emergence)	1/2		98 90	90 95	90 95	95 90	93	93
Control	-	--	0 0	0 0	0 0	0 0	0	0
Date of application means							23	

Analysis of Variance Table for Data in Appendix Table 8.

Source of variation	d.f.	SS	MS	F
Replications	3	215.54	71.84	1.18
Treatment	16	214927.98	13432.99	104.94**
Error (a)	48	6147.03	128.06	2.10
Replication	3	215.54	71.84	1.18
Date of application	2	30632.12	15316.06	1021. **
Error (b)	6	91.55	15.25	.25
Replication	3	215.54	71.84	1.18
Treatment x date of application	32	41811.10	1306.62	21.41**
Error (c)	96	5859.10	61.03	
Total	203	299685.10		

** Significant at 1% level
C. V. = 24%

Date LSD at .05 level = 6.7%, at .01 level = 10.2%
Treatment LSD at .05 level = 15.7%, at .01 level = 20.6%
Date x treatment LSD at .05 level = 10.9%, at .01 level = 14.3%

Appendix Table 9. The effects of foliage applications of terbacil with and without spray solution additives to foxtail at several application dates.

Dry weights determined 41 days after weed emergence.

	Rate		Application Date 1					Application Date 2				
Treatment	lb/A	% additive/vol	I	II	III	IV	Avg.	I	II	III	IV	Avg.
terbacil + X-77	1/2	0.5	1	1	1	1	1	19	56	42	54	43
X-77		0.5	138	150	108	95	123	127	120	109	100	114
terbacil + Activate Plus	1/2	0.5	1	1	1	1	1	80	53	48	37	54
Activate Plus		0.5	218	145	74	218	164	184	128	88	205	176
terbacil + Tronic	1/2	0.5	3	4	1	6	3	79	85	97	55	79
Tronic		0.5	114	145	180	111	137	100	89	205	108	125
terbacil + Savol Oil	1/2	10	2	1	2	1	1	99	22	27	73	55
Savol Oil		10	98	132	108	188	131	120	176	90	204	147
terbacil + Superior Spray Oil	1/2	10	2	1	1	1	1	22	3	14	26	16
Superior Spray Oil		10	167	145	112	109	133	148	172	126	83	132
terbacil + Superior Spray Emulsion	1/2	10	1	1	1	1	1	65	111	81	26	71
Superior Spray Emulsion		10	207	129	100	125	140	195	98	122	119	133
terbacil + Solution 32	1/2	20	1	3	1	2	2	84	110	49	113	89
Solution 32		20	85	132	103	158	119	143	121	183	166	153
terbacil (postemergence)	1/2		10	5	6	3	6	39	84	35	65	56
terbacil (at emergence)	1/2		1	2	1	1	1	1	4	2	2	2
Control	-	--	219	116	126	242	176	197	126	145	256	181
Date of application means							93					82

(cont'd)

Appendix Table 9. (cont'd)

Treatment	Rate lb/A	Rate % additive/vol	Application date #3 I	II	III	IV	Avg.	Treatment means
terbacil + X-77	1/2	0.5	50	95	39	35	55	33
X-77		0.5	165	96	134	147	135	124
terbacil + Activate Plus	1/2	0.5	65	62	45	40	53	36
Activate Plus		0.5	155	128	101	215	150	163
terbacil + Tronic	1/2	0.5	75	109	75	58	79	54
Tronic		0.5	134	151	177	106	142	135
terbacil + Savol Oil	1/2	10	106	38	46	85	69	42
Savol Oil		10	109	116	100	136	115	131
terbacil + Superior Spray Oil	1/2	10	25	21	14	30	22	13
Superior Spray Oil		10	165	176	138	159	159	142
terbacil + Superior Spray Emulsion	1/2	10	85	74	60	26	61	44
Superior Spray Emulsion		10	195	80	123	80	119	131
terbacil + Solution 32	1/2	20	37	73	20	45	44	45
Solution 32		20	120	150	116	165	138	137
terbacil (postemergence)	1/2		50	65	60	57	57	39
terbacil (at emergence)	1/2		1	3	1	2	2	2
Control	-	--	165	137	122	246	167	175
Date of application means							76	

Analysis of Variance Table for Data in Appendix Table 9.

Source of variation	d.f.	SS	MS	F
Replications	3	8274.60	2758.20	7.16
Treatment	16	644653.48	40290.84	18.87**
Error (a)	48	102458.48	2134.55	5.54
Replication	3	8274.60	2758.20	7.16
Date of application	2	33062.36	16531.18	34.50**
Error (b)	6	287.61	478.43	1.24
Replication	3	8274.60	2758.20	7.16
Treatment x date of application	32	50941.13	1591.91	4.13**
Error (c)	96	36998.54	385.40	
Total	203	879259.54		

** Significant at 1% level
C.V. = 23%

Date LSD at .05 level = 37.7 gms., at .01 level = 57.2 gms.
Treatment LSD at .05 level = 63.9 gms., at .01 level = 83.8 gms.
Date x treatment LSD at .05 level = 27.3 gms., at .01 level = 35.8 gms.

Appendix Table 10. The effects of foliage applications of terbacil with and without spray solution additives to barnyardgrass at several application dates.

Treatments evaluated 19 days after application.

Treatment	Rate		Application Date #1				
	lb/A	% additive/vol	I	II	III	IV	Avg.
terbacil + X-77	1/2	0.5	95 95	93 90	97 95	97 95	95
X-77		0.5	0 0	0 0	0 0	0 0	0
terbacil + Activate Plus	1/2	0.5	93 92	95 96	93 95	93 95	94
Activate Plus		0.5	0 0	0 0	0 0	0 0	0
terbacil + Tronic	1/2	0.5	85 90	88 85	88 90	93 90	89
Tronic		0.5	0 0	0 0	0 0	0 0	0
terbacil + Savol Oil	1/2	10	90 90	93 95	95 96	95 95	93
Savol Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Oil	1/2	10	93 97	90 90	95 95	97 98	94
Superior Spray Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Emulsion	1/2	10	93 93	95 95	97 90	95 95	94
Superior Spray Emulsion		10	0 0	0 0	0 0	0 0	0
terbacil + Solution 32	1/2	20	90 92	90 90	90 90	90 92	90
Solution 32		20	0 0	0 0	0 0	0 0	0
terbacil (postemergence)	1/2		75 80	85 85	80 80	70 80	79
terbacil (at emergence)	1/2		99 98	99 99	99 98	98 98	98
Control	-	--	0 0	0 0	0 0	0 0	0
Date of application means							49

(cont'd)

Appendix Table 10. (cont'd)

Treatment	Rate lb/A	Rate % additive/vol	Application #2 I	II	III	IV	Avg.
terbacil + X-77	1/2	0.5	75 80	50 50	40 55	50 50	56
X-77		0.5	0 0	0 0	0 0	0 0	0
terbacil + Activate Plus	1/2	0.5	25 30	60 60	70 70	65 60	54
Activate Plus		0.5	0 0	0 0	0 0	0 0	0
terbacil + Tronic	1/2	0.5	35 40	50 60	60 45	50 50	49
Tronic		0.5	0 0	0 0	0 0	0 0	0
terbacil + Savol Oil	1/2	10	50 65	70 60	60 60	70 65	62
Savol Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Oil	1/2	10	90 85	50 75	60 60	70 60	69
Superior Spray Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Emulsion	1/2	10	50 55	70 60	50 50	50 55	55
Superior Spray Emulsion		10	0 0	0 0	0 0	0 0	0
terbacil + Solution 32	1/2	20	25 30	35 35	45 45	35 40	36
Solution 32		20	0 0	0 0	0 0	0 0	0
terbacil (postemergence)	1/2		20 20	25 20	15 20	25 30	22
terbacil (at emergence)	1/2		98 98	99 98	98 99	98 98	98
Control	-	--	0 0	0 0	0 0	0 0	0
Date of application means							29

(cont'd)

Appendix Table 10 (cont'd)

Treatment	Rate lb/A	Rate % additive/vol	Application Date #3 I	II	III	IV	Avg.	Treatment means
terbacil + X-77	1/2	0.5	90 85	85 85	35 25	75 75	69	73
X-77		0.5	0 0	0 0	0 0	0 0	0	0
terbacil + Activate Plus	1/2	0.5	50 60	85 90	90 85	70 80	76	75
Activate Plus		0.5	0 0	0 0	0 0	0 0	0	0
terbacil + Tronic	1/2	0.5	75 80	75 70	55 60	65 55	67	68
Tronic		0.5	0 0	0 0	0 0	0 0	0	0
terbacil + Savol Oil	1/2	10	90 90	85 90	60 60	65 65	75	77
Savol Oil		10	0 0	0 0	0 0	0 0	0	0
terbacil + Superior Spray Oil	1/2	10	85 90	50 60	70 75	70 65	70	78
Superior Spray Oil		10	0 0	0 0	0 0	0 0	0	0
terbacil + Superior Spray Emulsion	1/2	10	85 85	80 85	70 65	75 75	77	75
Superior Spray Emulsion		10	0 0	0 0	0 0	0 0	0	0
terbacil + Solution 32	1/2	20	10 20	50 50	45 45	50 45	39	55
Solution 32		20	0 0	0 0	0 0	0 0	0	0
terbacil (postemergence)	1/2		65 70	5 5	50 60	50 40	43	48
terbacil (at emergence)	1/2		98 98	99 99	99 95	98 95	98	98
Control	-	--	0 0	0 0	0 0	0 0	0	0
Date of application means							36	

Analysis of Variance Table for Data in Appendix Table 10.

Source of variation	d.f.	SS	MS	F
Replications	3	51.93	17.31	.29
Treatment	16	283202.34	17700.14	192.4 **
Error (a)	48	4424.48	92.17	1.58
Replication	3	51.93	17.31	.29
Date of application	2	12900.79	6450.39	169.7 **
Error (b)	6	225.75	37.62	.64
Replication	3	51.93	17.31	.29
Treatment x date of application	32	17470.53	545.95	9.41**
Error (c)	96	5601.57	58.34	
Total	203	323877.42		

** Significant at 1% level
C.V. = 20%

Date LSD at .05 level = 10.6%, at .01 level = 16.0 %
Treatment LSD at .05 level = 13.3%, at .01 level = 16.5%
Date x treatment LSD at .05 level = 10.6%, at .01 level = 13.9%

Appendix Table 11. The effects of foliage applications of terbacil with and without spray solution additives to barnyardgrass at several application dates.

Treatments evaluated at 40 days after weed emergence.

Treatment	Rate		Application Date #1				
	lb/A	% additive/vol	I	II	III	IV	Avg.
terbacil + X-77	1/2	0.5	97 98	93 96	98 97	99 98	97
X-77		0.5	0 0	0 0	0 0	0 0	0
terbacil + Activate Plus	1/2	0.5	95 94	95 95	95 94	95 95	95
Activate Plus		0.5	0 0	0 0	0 0	0 0	0
terbacil + Tronic	1/2	0.5	90 90	90 85	95 95	97 98	92
Tronic		0.5	0 0	0 0	0 0	0 0	0
terbacil + Savol Oil	1/2	10	95 95	93 95	95 95	95 95	95
Savol Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Oil	1/2	10	95 95	95 95	95 90	98 99	95
Superior Spray Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Emulsion	1/2	10	95 98	95 96	98 98	95 97	96
Superior Spray Emulsion		10	0 0	0 0	0 0	0 0	0
terbacil + Solution 32	1/2	20	95 97	95 95	95 95	95 95	95
Solution 32		20	0 0	0 0	0 0	0 0	0
terbacil (postemergence)	1/2		85 93	85 85	85 90	90 93	88
terbacil (at emergence)	1/2		98 99	99 99	98 99	98 98	98
Control	-	--	0 0	0 0	0 0	0 0	0
Date of application means							50

(cont'd)

Appendix Table 11. (cont'd)

Treatment	Rate lb/A	Rate % additive/vol	Application Date #2 I	II	III	IV	Avg.
terbacil + X-77	1/2	0.5	90 85	50 70	60 60	50 60	65
X-77		0.5	0 0	0 0	0 0	0 0	0
terbacil + Activate Plus	1/2	0.5	20 10	70 70	90 85	60 60	58
Activate Plus		0.5	0 0	0 0	0 0	0 0	0
terbacil + Tronic	1/2	0.5	25 20	65 60	60 60	50 50	49
Tronic		0.5	0 0	0 0	0 0	0 0	0
terbacil + Savol Oil	1/2	10	70 60	70 70	60 60	65 65	65
Savol Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Oil	1/2	10	98 96	90 85	60 50	60 60	77
Superior Spray Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Emulsion	1/2	10	65 50	70 70	50 50	60 65	60
Superior Spray Emulsion		10	0 0	0 0	0 0	0 0	0
terbacil + Solution 32	1/2	20	20 10	50 40	40 40	50 50	37
Solution 32		20	0 0	0 0	0 0	0 0	0
terbacil (postemergence)	1/2		20 10	5 0	0 10	20 20	11
terbacil (at emergence)	1/2		98 99	99 99	98 99	99 99	99
Control	-	--	0 0	0 0	0 0	0 0	0
Date of application means							31

(cont'd)

Appendix Table 11. (cont'd)

Treatment	Rate lb/A	Rate % additive/vol	Application Date #3 I		II		III		IV		Avg.	Treatment means
terbacil + X-77	1/2	0.5	90	85	85	85	35	25	75	75	69	77
X-77		0.5	0	0	0	0	0	0	0	0	0	0
terbacil + Activate Plus	1/2	0.5	50	60	85	90	90	85	70	80	76	76
Activate Plus		0.5	0	0	0	0	0	0	0	0	0	0
terbacil + Tronic	1/2	0.5	70	80	75	70	55	60	65	55	65	69
Tronic		0.5	0	0	0	0	0	0	0	0	0	0
terbacil + Savol Oil	1/2	10	90	90	85	90	60	60	65	55	74	78
Savol Oil		10	0	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Oil	1/2	10	85	90	50	60	70	75	70	65	71	81
Superior Spray Oil		10	0	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Emulsion	1/2	10	85	85	80	85	70	65	75	75	78	78
Superior Spray Emulsion		10	0	0	0	0	0	0	0	0	0	0
terbacil + Solution 32	1/2	20	10	20	50	50	45	45	50	45	39	57
Solution 32		20	0	0	0	0	0	0	0	0	0	0
terbacil (postemergence)	1/2		65	70	5	5	50	60	50	40	43	47
terbacil (at emergence)	1/2		98	98	99	99	99	95	98	95	97	98
Control	-	--	0	0	0	0	0	0	0	0	0	0
Date of application means											36	

Analysis of Variance Table for Data in Appendix Table 11.

Source of variation	d.f.	SS	MS	F
Replications	3	74.39	24.79	.33
Treatment	16	295815.51	18488.47	129.3 **
Error (a)	48	6857.77	142.87	1.92
Replication	3	74.39	24.79	.33
Date of application	2	13698.89	6849.44	85.6 **
Error (b)	6	483.34	80.55	1.09
Replication	3	74.39	24.79	.33
Treatment x date of application	32	21744.77	679.52	9.19**
Error (c)	96	7090.99	73.86	
Total	203	345765.68		

** Significant at 1% level
C.V. = 22.0%

Date LSD at .05 level = 15.5%, at .01 level = 23.5%
Treatment LSD at .05 level = 16.5%, at .01 level = 21.6%
Date x treatment LSD at .05 level = 11.9%, at .01 level = 15.6%

Appendix Table 12. The effects of foliage applications of terbacil with and without spray solution additives to barnyardgrass at several application dates.

Dry weight determined 42 days after weed emergence.

Treatment	Rate		Application date #1					Application date #2				
	lb/A	% additive/vol	I	II	III	IV	Avg.	I	II	III	IV	Avg.
terbacil + X-77	1/2	0.5	1	1	1	1	1	1	18	17	19	14
X-77		0.5	102	40	103	58	76	85	46	112	75	79
terbacil + Activate Plus	1/2	0.5	1	1	1	1	1	30	6	5	8	12
Activate Plus		0.5	125	87	64	90	91	121	93	80	91	96
terbacil + Tronic	1/2	0.5	2	3	1	1	2	49	13	13	29	26
Tronic		0.5	104	80	128	85	99	115	71	98	87	93
terbacil + Savol Oil	1/2	10	1	1	1	1	1	13	9	13	6	10
Savol Oil		10	120	113	75	100	102	121	135	88	98	110
terbacil + Superior Spray Oil	1/2	10	1	2	1	1	1	1	5	13	6	6
Superior Spray Oil		10	78	76	125	68	87	67	77	120	60	81
terbacil + Superior Spray Emulsion	1/2	10	1	1	1	1	1	13	8	28	9	14
Superior Spray Emulsion		10	92	89	84	62	82	104	114	80	92	97
terbacil + Solution 32	1/2	20	1	3	2	1	2	52	40	39	27	39
Solution 32		20	110	125	155	66	114	118	102	115	57	98
terbacil (postemergence)	1/2		8	8	3	3	5	40	46	56	37	45
terbacil (at emergence)	1/2		1	1	1	1	1	1	1	1	1	1
Control	-	--	101	79	83	107	92	105	80	57	112	88
Date of application means							45					54

(cont'd)

Appendix Table 12. (cont'd)

Treatment	Rate lb/A	Rate % additive/vol	Application date #3 I	II	III	IV	Avg.	Treatment means
terbacil + X-77	1/2	0.5	5	1	43	8	14	10
X-77		0.5	90	64	102	111	96	84
terbacil + Activate Plus	1/2	0.5	23	2	5	5	9	7
Activate Plus		0.5	135	149	79	108	118	102
terbacil + Tronic	1/2	0.5	14	8	13	22	14	14
Tronic		0.5	134	64	92	74	91	94
terbacil + Savol Oil	1/2	10	2	1	16	10	7	6
Savol Oil		10	102	126	92	85	101	105
terbacil + Superior Spray Oil	1/2	10	5	20	5	3	8	6
Superior Spray Oil		10	89	65	144	74	93	87
terbacil + Superior Spray Emulsion	1/2	10	1	2	23	3	7	8
Superior Spray Emulsion		10	100	108	85	92	96	92
terbacil + Solution 32	1/2	20	58	46	39	34	44	28
Solution 32		20	101	100	125	68	98	103
terbacil (postemergence)	1/2		25	67	22	20	33	28
terbacil (at emergence)	1/2		1	1	1	1	1	1
Control	-	--	118	88	80	94	95	92
Date of application means							55	

Analysis of Variance Table for Data in Appendix Table 12.

Source of variation	d.f.	SS	MS	F
Replications	3	4407.19	1469.06	14.4
Treatment	16	363804.01	22737.75	31.62**
Error (a)	48	34510.05	718.95	7.04
Replication	3	4407.19	1469.06	14.4
Date of application	2	4106.94	2053.47	64.15**
Error (b)	6	194.58	32.43	.32
Replication	3	4407.19	1469.06	14.4
Treatmenc x date of application	32	10569.89	330.30	3.23**
Error (c)	96	9811.91	102.20	
Total	203	427404.60		

** Significant at 1% level
C.V. = 19.7%

Date LSD at .05 level = 9.7 gms., at .01 level = 14.8 gms.
Treatment LSD at .05 level = 32.7 gms., at .01 level = 48.8 gms.
Date x treatment LSD at .05 level = 14.0 gms., at .01 level = 18.4 gms.

Appendix Table 13. The effects of foliage applications of terbacil with and without spray solution additives to a mixed population of weeds at several application dates.

Treatments evaluated 19 days after application.

Treatment	Rate lb/A	Rate % additive/vol	Application Date #1 I		II		III		IV		Avg.
terbacil + X-77	1/2	0.5	99	99	98	98	97	98	99	98	98
X-77		0.5	0	0	0	0	0	0	0	0	0
terbacil + Activate Plus	1/2	0.5	92	93	96	97	93	95	95	95	95
Activate Plus		0.5	0	0	0	0	0	0	0	0	0
terbacil + Tronic	1/2	0.5	99	99	98	97	99	99	99	97	98
Tronic		0.5	0	0	0	0	0	0	0	0	0
terbacil + Savol Oil	1/2	10	98	95	98	99	99	98	99	99	98
Savol Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Oil	1/2	10	98	97	96	95	95	97	98	97	96
Superior Spray Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Emulsion	1/2	10	99	98	97	96	97	99	98	98	98
Superior Spray Emulsion		10	0	0	0	0	0	0	0	0	0
terbacil + Solution 32	1/2	20	99	98	95	93	96	95	97	97	96
Solution 32		20	0	0	0	0	0	0	0	0	0
terbacil (postemergence)	1/2		96	97	90	88	94	90	90	90	92
terbacil (at emergence)	1/2		98	98	98	98	97	98	99	99	98
Control	-	--	0	0	0	0	0	0	0	0	0
Date of application means											51

(cont'd)

Appendix Table 13. (cont'd)

Treatment	Rate lb/A	Rate % additive/vol	Application Date #2 I	II	III	IV	Avg.
terbacil + X-77	1/2	0.5	85 75	35 35	75 65	80 93	68
X-77		0.5	0 0	0 0	0 0	0 0	0
terbacil + Activate Plus	1/2	0.5	30 40	60 45	65 65	75 87	58
Activate Plus		0.5	0 0	0 0	0 0	0 0	0
terbacil + Tronic	1/2	0.5	55 65	65 65	75 65	65 65	65
Tronic		0.5	0 0	0 0	0 0	0 0	0
terbacil + Savol Oil	1/2	10	75 75	85 75	85 85	65 70	77
Savol Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Oil	1/2	10	75 75	65 65	85 75	75 75	74
Superior Spray Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Emulsion	1/2	10	60 65	65 65	75 75	60 65	66
Superior Spray Emulsion		10	0 0	0 0	0 0	0 0	0
terbacil + Solution 32	1/2	20	60 65	40 45	75 70	60 55	59
Solution 32		20	0 0	0 0	0 0	0 0	0
terbacil (postemergence)	1/2		60 65	40 45	35 35	45 45	46
terbacil (at emergence)	1/2		98 97	97 97	97 97	98 97	97
Control	-	--	0 0	0 0	0 0	0 0	0
Date of application means							36

(cont'd)

Appendix Table 13. (cont'd)

Treatment	Rate lb/A	Rate % additive/vol	Application Date #3 I		II		III		IV		Avg.	Treatment means
terbacil + X-77	1/2	0.5	65	55	30	35	80	75	65	55	57	75
X-77		0.5	0	0	0	0	0	0	0	0	0	0
terbacil + Activate Plus	1/2	0.5	45	45	70	65	60	65	88	80	64	73
Activate Plus		0.5	0	0	0	0	0	0	0	0	0	0
terbacil + Tronic	1/2	0.5	65	60	40	75	80	80	65	65	66	76
Tronic		0.5	0	0	0	0	0	0	0	0	0	0
terbacil + Savol Oil	1/2	10	65	70	65	60	65	60	80	75	67	81
Savol Oil		10	0	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Oil	1/2	10	65	65	65	60	75	75	80	80	71	80
Superior Spray Oil		10	0	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Emulsion	1/2	10	70	65	80	80	85	80	70	60	74	79
Superior Spray Emulsion		10	0	0	0	0	0	0	0	0	0	0
terbacil + Solution 32	1/2	20	40	45	45	40	50	60	65	60	51	69
Solution 32		20	0	0	0	0	0	0	0	0	0	0
terbacil (postemergence)	1/2		85	85	60	65	80	80	60	65	72	70
terbacil (at emergence)	1/2		99	97	97	98	99	99	97	97	98	98
Control	-	--	0	0	0	0	0	0	0	0	0	0
Date of application means											37	

Analysis of Variance Table for Data in Appendix Table 13.

Source of variation	d.f.	SS	MS	F
Replications	3	556.98	158.66	6.18
Treatment	16	314815.05	19675.97	252.2 **
Error (a)	48	3742.18	77.96	2.00
Replication	3	556.98	158.66	6.18
Date of application	2	10174.27	5087.13	108.2 **
Error (b)	6	284.78	47.46	1.56
Replication	3	556.98	158.66	6.18
Treatment x date of application	32	14004.22	437.63	14.5 **
Error (c)	96	2922.04	30.43	
Total	203	346500.00		

** Significant at 1% level
C.V. = 13.3%

Date LSD at .05 level = 11.8%, at .01 level = 18.0%
Treatment LSD at .05 level = 12.2%, at .01 level = 16.0%
Date x treatment LSD at .05 level = 7.6%, at .01 level = 10.0%

Appendix Table 14. The effects of foliage applications of terbacil with and without spray solution additives to a mixed population of weeds at several application dates.

Treatments evaluated 40 days after weed emergence.

Treatment	Rate lb/A	Rate % additive/vol	Application Date #1 I		II		III		IV		Avg.
terbacil + X-77	1/2	0.5	99	99	99	99	97	94	99	97	98
X-77		0.5	0	0	0	0	0	0	0	0	0
terbacil + Activate Plus	1/2	0.5	93	93	97	96	93	97	97	93	95
Activate Plus		0.5	0	0	0	0	0	0	0	0	0
terbacil + Tronic	1/2	0.5	100	99	99	95	99	99	99	99	98
Tronic		0.5	0	0	0	0	0	0	0	0	0
terbacil + Savol Oil	1/2	10	97	97	99	99	97	97	99	97	98
Savol Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Oil	1/2	10	98	95	96	94	94	95	97	95	95
Superior Spray Oil		10	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Emulsion	1/2	10	98	98	97	97	99	97	99	97	98
Superior Spray Emulsion		10	0	0	0	0	0	0	0	0	0
terbacil + Solution 32	1/2	20	98	98	97	95	94	93	99	97	96
Solution 32		20	0	0	0	0	0	0	0	0	0
terbacil (postemergence)	1/2		93	95	97	88	96	93	97	96	94
terbacil (at emergence)	1/2		99	97	97	98	99	99	99	97	98
Control	-	--	0	0	0	0	0	0	0	0	0
Date of application means											51

(cont'd)

Appendix Table 14. (con'td)

Treatment	Rate lb/A	Rate % additive/vol	Application Date #2 I	II	III	IV	Avg.
terbacil + X-77	1/2	0.5	93 90	35 35	55 60	90 93	69
X-77		0.5	0 0	0 0	0 0	0 0	0
terbacil + Activate Plus	1/2	0.5	35 35	85 85	65 60	90 85	69
Activate Plus		0.5	0 0	0 0	0 0	0 0	0
terbacil + Tronic	1/2	0.5	80 75	85 85	90 80	85 80	83
Tronic		0.5	0 0	0 0	0 0	0 0	0
terbacil + Savol Oil	1/2	10	85 85	90 90	85 90	90 90	88
Savol Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Oil	1/2	10	85 85	90 85	85 85	90 90	87
Superior Spray Oil		10	0 0	0 0	0 0	0 0	0
terbacil + Superior Spray Emulsion	1/2	10	70 75	85 90	95 90	70 70	81
Superior Spray Emulsion		10	0 0	0 0	0 0	0 0	0
terbacil + Solution 32	1/2	20	65 65	65 55	80 75	75 80	70
Solution 32		20	0 0	0 0	0 0	0 0	0
terbacil (postemergence)	1/2		55 45	65 65	45 45	65 65	56
terbacil (at emergence)	1/2		97 99	97 98	99 99	99 97	98
Control	-	--	0 0	0 0	0 0	0 0	0
Date of application means							41

(cont'd)

Appendix Table 14. (cont'd)

Treatment	Rate lb/A	Rate % additive/vol	Application Date #3 I		II		III		IV		Avg.	Treatment means
terbacil + X-77	1/2	0.5	65	55	35	30	80	75	65	55	57	75
X-77		0.5	0	0	0	0	0	0	0	0	0	0
terbacil + Activate Plus	1/2	0.5	45	40	75	65	60	65	85	80	59	74
Activate Plus		0.5	0	0	0	0	0	0	0	0	0	0
terbacil + Tronic	1/2	0.5	65	60	70	70	80	80	65	65	69	84
Tronic		0.5	0	0	0	0	0	0	0	0	0	0
terbacil + Savol Oil	1/2	10	70	65	65	60	65	60	75	80	67	84
Savol Oil		10	0	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Oil	1/2	10	65	65	60	70	75	75	80	80	71	84
Superior Spray Oil		10	0	0	0	0	0	0	0	0	0	0
terbacil + Superior Spray Emulsion	1/2	10	65	70	80	80	80	80	80	65	75	84
Superior Spray Emulsion		10	0	0	0	0	0	0	0	0	0	0
terbacil + Solution 32	1/2	20	45	40	45	40	60	50	55	65	50	72
Solution 32		20	0	0	0	0	0	0	0	0	0	0
terbacil (postemergence)	1/2		85	85	65	60	45	65	60	65	66	72
terbacil (at emergence)	1/2		97	99	97	98	97	99	97	97	97	98
Control	-	--	0	0	0	0	0	0	0	0	0	0
Date of application means											36	

Analysis of Variance Table for Data in Appendix Table 14.

Source of variation	d.f.	SS	MS	F
Replications	3	242.45	80.81	2.08
Treatment	16	339484.16	21217.76	275.5 **
Error (a)	48	3690.38	76.88	1.97
Replication	3	242.45	80.81	2.08
Date of application	2	8080.74	4040.37	118.8 **
Error (b)	6	202.54	33.75	.86
Replication	3	242.45	80.81	2.08
Treatment x date of application	32	11522.42	360.07	9.23**
Error (c)	96	3737.61	38.93	
Total	203	366960.33		

** Significant at 1% level
C.V. = 14.6%

Date LSD at .05 level = 25.5%, at .01 level = 37.2%
Treatment LSD at .05 level = 12.1%, at .01 level = 15.9%
Date x treatment LSD at .05 level = 8.6%, at .01 level = 11.3%

Appendix Table 15. The effects of foliage applications of terbacil with and without spray solution additives to a mixed population of weeds at several application dates.

Dry weight determined 42 days after weed emergence.

Treatment	Rate		Application date #1					Application date #2				
	lb/A	% additive/vol	I	II	III	IV	Avg.	I	II	III	IV	Avg.
terbacil + X-77	1/2	0.5	1	1	2	1	1	10	14	9	10	11
X-77		0.5	241	150	200	287	219	276	209	200	257	235
terbacil + Activate Plus	1/2	0.5	27	2	6	1	9	23	12	53	4	23
Activate Plus		0.5	205	290	190	143	207	200	300	160	131	198
terbacil + Tronic	1/2	0.5	1	1	1	1	1	43	15	14	25	24
Tronic		0.5	143	174	157	170	161	165	135	141	155	149
terbacil + Savol Oil	1/2	10	1	1	1	1	1	14	10	4	5	8
Savol Oil		10	189	121	158	175	161	177	105	153	167	150
terbacil + Superior Spray Oil	1/2	10	1	4	2	1	2	10	5	5	7	7
Superior Spray Oil		10	230	154	125	200	177	180	177	130	176	161
terbacil + Superior Spray Emulsion	1/2	10	1	1	1	3	1	58	15	20	38	33
Superior Spray Emulsion		10	163	220	273	131	197	165	126	266	125	170
terbacil + Solution 32	1/2	20	1	3	6	1	3	24	35	33	21	28
Solution 32		20	191	171	173	173	177	206	177	133	165	170
terbacil (postemergence)	1/2		1	14	3	3	5	54	23	84	85	61
terbacil (at emergence)	1/2		1	1	4	1	2	1	1	3	1	1
Control	-	--	238	115	114	150	154	219	108	157	169	163
Date of application means							87					94

(cont'd)

Appendix Table 15. (cont'd)

Treatment	Rate lb/A	Rate % additive/vol	Application date #3 I	II	III	IV	Avg.	Treatment means
terbacil + X-77	1/2	0.5	35	85	13	34	42	18
X-77		0.5	265	185	200	251	225	227
terbacil + Activate Plus	1/2	0.5	50	55	63	10	44	25
Activate Plus		0.5	145	288	154	164	188	197
terbacil + Tronic	1/2	0.5	43	15	14	25	24	14
Tronic		0.5	175	140	139	188	160	157
terbacil + Savol Oil	1/2	10.	20	38	45	19	30	13
Savol Oil		10	150	140	175	173	159	157
terbacil + Superior Spray Oil	1/2	10	13	32	28	22	24	11
Superior Spray Oil		10	131	185	138	185	160	168
terbacil + Superior Spray Emulsion	1/2	10	28	9	7	38	20	18
Superior Spray Emulsion		10	133	153	255	165	176	181
terbacil + Solution 32	1/2	20	48	55	46	38	47	26
Solution 32		20	183	150	167	183	171	173
terbacil (postemergence)	1/2		11	23	12	36	20	29
terbacil (at emergence)	1/2		1	1	1	1	1	1
Control	-	--	228	101	188	165	170	163
Date of application means							94	

Analysis of Variance Table for Data in Appendix Table 15.

Source of variation	d.f.	SS	MS	F
Replications	3	3566.84	1188.94	4.06
Treatment	16	1363204.75	75200.29	33.50**
Error (a)	48			
Replication	3	3566.84	1188.94	4.06
Date of application	2	4095.64	2047.82	5.67**
Error (b)	6	2164.15	360.69	1.23
Replication	3	3566.84	1188.94	4.06
Treatment x date of application	32	23460.68	733.14	2.50
Error (c)	96	28145.50	293.18	
Total	203	1546557.58		

* Significant at 5% level
** Significant at 1% level
C.V. = 19.1%

Date LSD at .05 level = 32.7 gms., at .01 level = 49.6 gms.
Treatment LSD at .05 level = 69.8 gms., at .01 level = 91.5 gms.
Date x treatment LSD at .05 level = 23.7 gms., at .01 level = 31.1 gms.

Appendix Table 16. Dry weight of oat plants grown in core samples from 0-3 inches in depth taken from an established peppermint trial.

Treatment	Rate	I subsample a	I b	I c	I Avg.	II subsample a	II b	II c	II Avg.	III subsample a	III b	III c	III Avg.	Mean
terbacil	3	.8	.8	.9	.83	.8	.8	.9	.83	.8	.9	.9	.86	.84
terbacil + X-77	1+1+1 .5+.5+.5%	.8	1.0	.9	.90	1.0	.8	1.0	.93	2.5	1.8	1.7	2.00	1.28
terbacil	1.5	.9	1.1	1.1	1.03	3.5	2.8	2.5	2.93	4.0	3.6	3.1	3.67	2.54
terbacil + X-77	.5+.5+.5 .5+.5+.5%	4.0	3.2	4.1	3.76	3.2	3.3	3.5	3.33	2.5	3.1	3.2	2.93	3.34
Control	--	4.6	5.5	4.4	4.83	4.3	5.0	4.8	4.70	5.0	5.0	4.2	4.83	4.75

x = 2.61
S = .707
C.V. = 27.0%

LSD .05 = .48 g
LSD .01 = .75 g

Analysis of Variance of Data in Appendix Table 16.

Source	d.f.	SS	MS	F
Reps	2	.81	.405	.802 ns
Tmt	4	30.88	7.52	14.89 **
R x T	8	4.04	.505	
Total	14	34.93		

Appendix Table 17. Dry weight of oat plants grown in core samples from 3-6 inches in depth taken from an established peppermint trial.

		I subsample				II subsample				III subsample				
Treatment	Rate	a	b	c	Avg.	a	b	c	Avg.	a	b	c	Avg.	Mean
terbacil	3	3.2	2.1	2.9	2.73	1.9	2.0	1.8	1.90	3.1	3.8	3.9	3.60	2.74
terbacil + X-77	1+1+1 .5+.5+.5%	4.0	4.8	4.3	4.36	4.2	4.1	4.0	4.10	4.3	4.4	4.2	4.30	4.25
terbacil	1.5	4.0	4.0	3.5	3.83	5.0	4.8	4.3	4.70	4.2	5.0	5.1	4.77	4.43
terbacil + X-77	.5+.5+.5 .5+.5+.5%	4.3	4.0	4.7	4.33	4.0	4.7	4.8	4.50	4.3	4.4	4.2	4.30	4.38
Control	--	4.5	4.2	4.0	4.23	4.4	4.3	4.7	4.46	4.3	4.0	5.0	4.43	4.37

$\bar{\bar{x}}$ = 4.03
S = .52
C. V. = 12.9%

LSD .05 = .33 gm
LSD .01 = .52 gm

Analysis of Variance of Data in Appendix Table 17.

Source	d.f.	SS	MS	F
Reps	2	.44	.22	.81
Tmt	4	6.32	1.58	5.85**
Rep x treatment	8	1.64	.27	
Total	14	8.40		