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RESPONSE OF SEEDLING ONIONS (ALLIUM CEPA) TO FLUAZIFOP-BUTYL AND BROMOXYNIL

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RESPONSE OF SEEDLING ONIONS (<u>ALLIUM CEPA</u>)
TO FLUAZIFOP-BUTYL AND BROMOXYNIL

by

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STATEMENT BY AUTHOR

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Dr. K. C. Hamilton has generously shared his expertise in weed science and impressed upon me the value of a sense of humor. I finish this program with gratitude and appreciation for him.

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ABSTRACT

Fluazifop-butyl ((±)-butyl 2-(4-((5-trifluoromethyl)-2-pyridinyl)oxy)phenoxy)propanoate) and bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) were evaluated for phytotoxicity to onions (Allium cepa L.). The onions were grown under greenhouse conditions. Both chemicals were evaluated separately at four rates and two single and one combination application dates. A tank mix of fluazifop-butyl and bromoxynil was evaluated at the same rates and application dates. The crop oil concentrate, an additive used to enhance the herbicide activity of fluazifop-butyl, was evaluated for its effect on bromoxynil. Also evaluated was the effect of delaying the application (day 1, 2, and 3) of fluazifop-butyl after an application of bromoxynil as compared to the tank mix. Statistical results were based on the average height of the plants and root evaluations when the tests were terminated. Fluazifop-butyl was not phytotoxic to onions. Onion height was affected by bromoxynil and the tank mix. The tank mix appeared more phytotoxic than bromoxynil alone. Crop oil concentrate appeared to increase the phytotoxicity of bromoxynil on onions. The delayed application of fluazifop-butyl after an application of bromoxynil tended to increase the height of onions as compared to the tank mix.

INTRODUCTION

Dry onion (Allium cepa L.) production in Arizona is a 7 million dollar per year business; they are produced year long and are harvested 10 out of 12 months. Weeds are the major production problem. The current herbicide program for onions does not include a reliable postemergence grass herbicide for weeds such as small grains and annual grasses.

Fluazifop-butyl ((±)-butyl 2-(4-((5-trifluoromethyl)-2-pyridinyl) oxy)phenoxy)propanoate), currently registered for use in soybeans, (Glycine max (L.) Merr.), cotton (Gossypium hirsutum L.), and ornamentals, may be a good candidate for grass control in onions. Especially advantageous is that fluazifop-butyl has an extremely low toxicity to plants other than grasses. This herbicide has also been shown to be very effective on many annual and perennial grass species.

Several postemergence broadleaf herbicides are registered for onions. Bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) is particularly effective on the winter annual broadleaf weeds encountered in Arizona-grown onions. Also, onions are tolerant to bromoxynil and this herbicide has been in commercial use in Arizona.

An asset to the grower is to tank mix two herbicides when both require similar application dates. A tank mix saves an extra trip through the crop and allows the herbicides to be applied when needed rather than waiting between applications. The major hindrance to a tank mix occurs when the two herbicides are incompatible. Perhaps the mixture causes a greater phytotoxicity to the crop or one or both of the herbicides could be rendered less effective on the target weeds.

Treatments of fluazifop-butyl and bromoxynil were evaluated separately and as a tank mix. The primary objective of this study was to evaluate the phytotoxic effects of a fluazifop-butyl and bromoxynil tank mix on seedling onions. An experiment designed to evaluate the role of the crop oil concentrate, an additive to fluazifop-butyl, was evaluated. Lastly, an evaluation was made of an experiment designed to address the benefit of delaying a fluazifop-butyl treatment after a treatment of bromoxynil.

LITERATURE REVIEW

Onions

History

The earliest history of onions remains sketchy. Egyptian pictographs dated between 3200 and 2780 B.C. show laborers eating onions (62). The origin of onions is thought to be in Iran and West Pakistan and they are considered one of the first cultivated crops (36, 62). There are species of Allium considered weeds in some cultivated crops. However, Allium cepa has not been found as a wild plant. Allium cepa is grown in all temperate regions of the world and was first brought to America by early colonists (36). Jones and Mann (62) describe in detail historical contributions made to all aspects of onion production.

Classification and Identification

There is general agreement that Allium cepa is a member of the family Liliaceae (36, 57, 62, 64), yet there has also been speculation that Allium cepa could be included in the family Amaryllidaceae (62). Well known members of the genus Allium are the onion, chives (Allium schoenoprasum L.), leek (Allium ampeloprasum L. var. porrum (L.) Gay), garlic (Allium sativum L.), shallot (Allium ascalonicum L.), and the Welsch onion (Allium fistulosum L.) (36, 64). Several obvious characteristics link the different species in this genus. The most obvious of these is the unique alliaceous odor due to allyl sulfide found throughout the Allium species (36, 57). Other distinguishing features of the Allium genus include a scapose stem; a tunicate bulb; narrowly linear, sheathing leaves; perfect, regular flowers found in a terminating simple umbel; persistant perianth; and a three celled ovary with two ovules in each cell (57, 64). The flowers are an important identification tool to separate Allium species (62). Of the many Allium species, Allium cepa is the one all further information will refer to. Allium cepa is known as the onion and is divided into three groups: the common onion, the aggregatum, and the proliferum group.

Morphology

The onion is a monocot with the rare trait of epigeal germination (36, 57). "Development is dependent not only on species, but on the conditions under which the onion is grown" (62). Seasonal changes may make a species grow differently.

Plant Development

"The hypocotyl grows out of the seed coat and the cotyledon soon follows except for the tip which stays in the endosperm and acts as haustorium for food absorption. The root tip is directed upward for 3 to 5 mm then turns downward and accounts for the sharp bend in the cotyledon called the knee" (57). Both the root tip and the cotyledon elongate and the knee is pushed out of the soil (57, 62).

There are several stages of onion seedling development that are important to note. The loop (crook), knee (flag), the first and second true leaf stages are all important concerns for the commercial grower in terms of postemergence herbicide treatments. Formation of the loop stage occurs when the seed coat remains in the soil after germination and a sort of loop is formed while the knee or flag stage occurs when the cotyledon has absorbed all nourishment and the tip within the seed becomes detached (36). Both of these stages are formed by the cotyledon. The next above ground growth is the first true leaf.

The first true leaf emerges from a slit in the cotyledon as the primordial of the second leaf matures; the plant develops leaves rapidly in this manner (57, 62). New leaves arise from the short stem apex in a compact series, outer leaves the oldest (36, 57, 62). The leaf bases thicken, become scales, and form the bulb (36, 57).

Roots of the onion plant are shallow and fibrous. After the primary root, new adventitious roots continue to develop throughout the life cycle (36, 57, 62).

The inflorescence is an umbel borne on a spathe. Flowers are regular and perfect and develop in an irregular pattern. Cross pollination occurs with insects while interpollination in the same umbel is common. The fruit is a three-celled capsule and contains two black seeds per locule (36, 57, 64).

Both inflorescence and bulb formation are induced by environmental factors. Bulb formation occurs when day length and temperature are favorable (62).

Onion Production

Onions are not a seasonal crop and are usually growing somewhere in the United States between February and October (62). In Arizona, onions are grown and harvested year round. The 1982 Arizona Agricultural Statistics (15) states that Arizona's dry onion business had 700 hectares in production, with a harvest of 39,734,700 kilograms valued at 7 million dollars. These figures can be compared to the United States data of 50,200 hectares, 1,876,819,300 kilograms, and 318,500,000. dollars. Of the vegetable, melon (Cucumis melo L.), and potato (Solanum tuberosum L.) industries, dry onions comprise 3%. The green onion industry in Arizona involved 866 hectares, 3,092,000 - 8.2 kilogram cartons valued at 12,368,000 dollars. Maricopa county has the largest onion acreage and best yield in Arizona.

Jones and Mann (62) and Comin (36) detail the factors involved in producing onions by sets, transplants, or direct seeding. Sets are commonly used by the home gardener to produce early green onions. The term 'set' applies to any small dry onion bulb usually less than 2.5 cm in diameter. Sets are the end product of sowing seed thickly to stunt plant growth (62). A transplant is the young seedling of direct seeded onions. Their use usually occurs when the onion crop is grown during the winter and harvested in the spring, or for the summer crop to ensure enough top growth before the initiation of bulbing, or if the cultivar matures late. Direct seeding is the most economical of the methods and has been found successful on both muck and mineral soils, although, weed problems increase with direct seeding. Green onions are usually produced from sets or direct seeding.

Special Considerations in Production. Young seedlings are especially susceptible to salt injury. To avoid this, special planting methods or seed beds may be required. The ideal soil pH for onion production is 5.5 to 6.5. Nitrogen, phosphorus, and potassium are usually needed and the need for copper, manganese and zinc should be considered. Major disease problems of onions include onion smut, downy mildew, pink root, powdery mildew, purple blotch, and gray mold. Onion thrips cause most insect damage to onions (36, 44).

Onion Weed Control Principles

A good season-long weed control program for onions is essential since onions are such poor competitors (5, 24, 34, 62, 69, 84). Onion germination is slow and, since a crop canopy never develops, they are left susceptible to intense competition by weeds (5, 24, 69). Losses from weeds equal the combined losses from disease and insects (62). There are several weed control measures available such as mowing, burning, oils, crop rotation, cultivation, and herbicides. Cultivation and herbicides are the most consistent methods of choice. However, early cultivation is often delayed because of the susceptibility of onions to mechanical injury (24). Hence, a good herbicide program is crucial for successful onion production.

There are several problems that impede development of a good herbicide program in onions. The status of onions as a minor crop makes herbicide registration for them more difficult (85). Early postemergence herbicidal treatments are restricted to specific stages of development of the onion due to potential phytotoxicity of the herbicide (69). Also, the residual of the preemergence and postemergence herbicides used on onions is too short for season-long control, thus multiple applications are required (24, 84). Resistant weeds result without the development of new herbicides for onion use.

The main advantage onions have for the potential of a good weed program is they are well adapted for foliar herbicides. Cylindrical leaves and a waxy secretion on the foliage cause spray droplets to either miss or bounce off the onion plant (62, 69). Planting onions following crops that require clean cultivation or crops where weeds have been controlled will enhance the success of an onion crop (5, 62). Also, cultivation is required in onion production. Campbell and Anderson (34) found a significant yield reduction in no till onion plots. Since onions are grown most of the year, herbicides for the control of summer and winter annuals need to be available. Environmental factors that influence the effectiveness of herbicides in onion include rainfall, soil type, temperature, humidity and wind (62). Many considerations are involved in the development of an optimum weed control program for onions. The demand for onions continues and so does research for herbicides to enhance their production.

Current Weed Control in Onions

The need for weed control in onions has been well established. Putnam et al. (80) showed that purslane (*Portulaca oleracea* L.) growth actually increased in the presence of onions and thought that a possible alleopathy existed. Leaving a weed stand for 6 weeks before removal has reduced onion bulb weight by 86% (69). Other studies found that an onion crop must be weed free for from 6 to 20 weeks or a significant reduction in yield would occur (61, 74).

Agricultural Consultant and Fieldman (8), in the 1983 Weed Control Manual, list the herbicides currently registered for use in onions. The list of those herbicides is comprised of bensulide (O,O-diisopropyl phosphorodithioate S-ester with N-(3-mercaptoethyl) benzenesulfonamide), bromoxynil, CDAA(N-N-diallyl-2-chloroacetamide), chlorpropham (isopropyl m-chlorocarbanilate), DCPA (dimethl tetrachloro-terephthalate), dinoseb (2-sec-butyl-4,6-dinitrophenol), glyphosate (N-(phosphonomethyl)glycine), light aromatic oil emulsion, and nitrofen (2,4-dichlorophenyl p-nitrophenylether).

Of these herbicides, only bensulide is recommended for preplant incorporation. The herbicides bensulide, CDAA, DCPA, glyphosate, and light aromatic oil emulstion are all recommended for preemergence treatments in onions while the recommended postemergence herbicides are bromoxynil, CDAA, DCPA, dinoseb, light aromatic oil emulsion, and nitrofen. For suggested rates and exact application timing recommendation, the 1983 Weed Control Manual is quite thorough. Supplemental information of these herbicides is contained in several good sources (25, 39, 69). Both annual grasses and broadleaved weeds are controlled by bensulide, CDAA, chlorpropham, DCPA, light aromatic oil emulsion, and nitrofen; the herbicides bromoxynil and dinoseb work exclusively on broadleaved weeds. Glyphosate has the unusual distinction of being effective on perennial and annual grasses and broadleaved weeds.

Special considerations exist for several of these herbicides. Bensulide has a soil residue of 12 to 18 months and is rendered ineffective in soils with high amounts of organic matter (39, 69). A problem with leaching can occur with CDAA, causing it to be recommended for use on muck soils (8, 69). The preemergence herbicide chlorpropham has a soil residual of only 1 to 2 months (73). Dinoseb is registered in just three California counties. Especially important to note is the temporary removal of nitrofen from the United States market (8). Nitrofen was heavily relied upon for effective preemergence and postemergence weed control in onions, particularly on mineral soils (69). An important consideration for the use of any herbicides in onions is whether the soil is an organic or mineral soil. The type of soil can influence the crop phytotoxicity of the herbicide.

Regional Research in Onion Weed Control

Northeast United States. In 1970, Sanok and Dallyn (83) emphasized the need for a rotation or combinations of herbicides to avoid the buildup of resistant weeds. The herbicide chloroxuron (3-[*p*-(*p*-chlorophenoxy)phenyl]-1,1-dimethylurea) has been tested on both mineral and muck (organic) soils (35, 56). Results from the study on muck soil led to the conclusions that chloroxuron should be applied after the second leaf stage, foliar applications were preferable to directed sprays, and an increase in temperature would increase the phytotoxic effects on onions (57). Grande (50) was looking for a good postemergence herbicide to control weeds at the second leaf stage as the postemergence herbicides are most efficacious when the weeds are small. Previous reliance had been on DCPA preemergence and nitrofen postemergence. Oxadiazon (2-*tert*-butyl-4(2,4-dichloro-5-isopropoxyphenyl)-Δ^2-1,3,4-oxadiazolin-5-one) was tested and determined to be toxic to onions until the fourth leaf stage.

Researchers in the 1980's found varying success with herbicides not registered for use in onions (49, 76, 78, 86, 90). Although there is a general search for effective herbicides to use in onion production, the emphasis is on increasing the options of available postemergence herbicides. The main herbicide relied upon for preemergence control in onions has been and still is DCPA. Therefore, most research programs designed to establish a complete weed control regimen for onions, incorporate DCPA (78, 86, 90).

Precheur (78) was cautious about the potential for developing a good postemergence program in onions. The withdrawal of nitrofen and the high cost of hand labor has put most small onion growers out of business. "Herbicides established safe on muck soils were either too phytotoxic or had too small a margin of safety when used on mineral soils." Nonetheless, Precheur did find success with DCPA or bensulide preemergence plus sethoxydim (2-[1-(ethoxyimino)butyl]-5-[2-ethylthio) propyl]-3-hydroxy-2-cyclohexen-1-one) and bentazon (3-isopropyl-1*H*-2,1,3-benzothiadiazin-4(3*H* -one 2,2-dioxide) postemergence. Oxyfluorfen (2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene) had generally been tested as a postemergence treatment and possible replacement for nitrofen. The wettable powder formulation appears to cause less foliar injury than the emulsifiable concentrate; however, neither formulation caused onion yield reduction (49, 90). Work by Sieczka et al. (90) found success with preemergence DCPA and a postemergence treatment of sethoxydim plus chlorpropham or chloroxuron. Fluazifop-butyl could replace sethoxydim in this regime. Sanok et al. (86) feel there may be a place for propachlor (2-chloro-N-isopropylacetanilide) and diclofop 2-(4-(2,4-dichlorophenoxy)phenoxy)propanoic acid) in onion weed control.

North Central United States. Field testing in 1966, showed DCPA to be a consistently effective preemergence herbicide on both grass and broadleaf weeds with no onion phytotoxicity (51). DCPA has since become an indispensible part of onion weed control. Greig and Gwin (52) found oxidiazon successful as a candidate for a postemergence herbicide in onions. Sometimes researchers will direct their efforts to control a problem weed. In 1977, Boldt and Putnam (26) addressed the question of resistance in prostrate spurge (Euphorbia supina Raf.). Interestingly, they discovered that the spurge left alone did not reduce onion yields, rather, hampered the harvest equipment. A possible solution was the use of a desiccant which could reduce the amount of herbicide required during the season.

More recent research has been directed toward finding a replacement for nitrofen (23, 27, 48, 71). A reliable postemergence herbicide for onions appears to be in short supply (79). Oxyfluorfen has been tested in the north central region as a nitrofen substitute. Findings similar to those of researchers in the northeast show the wettable powder formulation less toxic to the onions than the emulsifiable concentrate formulation (27, 48, 71). Although onion growth was severely inhibited at the hook or flag stage (71), Boldt et al. (27) found no reduction in yield with rates up to 0.56 kg/ha and applied at the second leaf stage.

Binning et al. (23) working in Wisconsin, wished to build up a weed control program in onions that had relied mainly on CDAA and chlorpropham. Nitrofen had also been used as a supplement to this program. Their findings included propachlor as a possible substitute for CDAA and oxyfluorfen as a nitrofen replacement. In fact, in 1982, oxyfluorfen was given a section 18 label to replace nitrofen. Bromoxynil was considered for postemergence control, but its range was too narrow and would require multiple applications. The herbicide oxyfluorfen and grass herbicides fluazifop-butyl and sethoxydim were concluded to be an asset to a weed program in onions by effectively controlling escape weeds and late season weed problems.

Western United States. Many changes have occurred since 1965, when dazomet (tetrahydro-3,5-dimethyl-2*H*-1,3,5-thiadiazine-2-thione) and calcium cyanamid were staples in onion weed control (82). In the last half of the 1960's research established DCPA and bensulide as very effective preemergence herbicides in onions (13, 37). Repeated applications of chlorpropham and CDAA was a common weed control practice in 1969 (38). Chloroxuron showed promise as a postemergence treatment following chlorpropham and CDAA. Agamalian (3) experimented with herbicides to compare with nitrofen and chloroxuron, for they were the best postemergence herbicides registered for onions in 1973. For special weed problems, shielded applications of glyphosate to control bermudagrass (Cynodon dactylon (L.) Pers.) and direct spray applications of MSMA (monosodium methanearsonate) for nutsedge (Cyperus spp.) control gave excellent results (65, 66). By 1979, there was a dependence on nitrofen, sulfuric acid, chloroxuron, and DCPA for postemergence weed control and also a wish to add bromoxynil to the availability list in order to control common groundsel (Senecio vulgaris L.) and sowthistle (Sonchus asper (L.) Hill) (5).

The herbicides, DCPA and nitrofen, continued to be relied upon in the 1980's. Agamalian (4) working in California, found an acceptable program with DCPA preemergence; nitrofen, dinoseb, bromoxynil, chloroxuron postemergence and DCPA at layby. Although some researchers have obtained acceptable to very effective results with the postemergence herbicide chloroxuron, its use has become very limited and no longer holds a general registration use in onions.

Brenchley (28) tried diclofop at 0.56 kg/ha when bermudagrass had one to three leaves with satisfactory control. The preemergence herbicide bensulide, was determined to have only marginal safety to onions (19). Further research for an acceptable preemergence herbicide found only DCPA and propachlor adequate for weed control without crop injury; also, a tank mix of the two proved successful (7, 20).

A replacement for nitrofen was at issue in the west and researchers looked to oxyfluorfen (9, 11, 68, 88). Weed control obtained was excellent and the yields were not affected even when applied at the first true leaf stage (9, 88). Oxyfluorfen was shown to be an effective option for direct seeded, transplant, and onions grown for seed (9, 68). Bentazon was very acceptable as a directed spray for yellow nutsedge (*Cyperus esculentus* L.) control (70).

In 1982, Doty and Hamilton (42) looked at the weed problems of both spring and fall grown green onions. Results from the fall treatments indicated that bensulide preemergence, followed by 5% sulfuric acid applied twice, postemergence, gave superior broadleaf and grass control and the highest onion yield of all treatments tested. In the spring, the postemergence herbicide oxadiazon gave good broadleaf control, moderate grass control and the least injury to onions.

Emulsifiable Concentrates

The two herbicides, bromoxynil and fluazifop-butyl, are both commercially formulated as emulsifiable concentrates. An herbicide which is insoluble in water is generally formulated as an emulsifiable concentrate to enable it to be mixed with water for field applications (12). A typical emulsifiable concentrate contains the herbicide, solvent for the herbicide, an emulsifier (usually a nonionic surfactant), a surfactant (for wetting, sticking, and spreading) and oil or organic solvent as the bulk liquid of the formulation. Water is the most common carrier. The combination of an emulsifiable concentrate formulation and water creates an emulsion.

Bromoxynil

Bromoxynil belongs to the herbicide family nitrile (30, 73). Both salts and esters can be formulated from bromoxynil, however, the ester is more herbicidal (12, 97). The common formulation is octanoic acid ester (12, 46, 97). This herbicide was introduced in the early 1960's for selective postemergence broadleaf control in cereal crops and newly seeded grasses (12, 30, 39, 40, 46, 63, 92). Fall and spring broadleaf weeds successfully controlled by bromoxynil have been noted (8, 39). For several crops, bromoxynil is used when weeds are not easily controlled by 2,4-D(2,4-dichlorophenoxy) acetic acid) or MCPA ([(4-chloro-*o*-tolyl)oxy] acetic acid) (12, 69). Bromoxynil treatments are most satisfactory when weeds are small. The best results are obtained with rates between 0.56 to 1.12 kg/ha (97). Plants susceptible to bromoxynil develop symptoms within 24 hours which mainly appear as necrotic lesions that spread until the plant dies (30, 46, 69). Temperature and moisture appear to have an effect on the toxicity of bromoxynil (77). A decrease in temperature and an absence of moisture after an application of bromoxynil seem to increase crop injury. Also, low radiation and high humidity have been found to increase the potency of bromoxynil (87). An explanation may be that herbicides place stress on plants and the plant becomes more susceptible to environmental conditions possibly by influencing leaf uptake (77, 87).

Mode of Action

The fact that bromoxynil is a foliar contact herbicide necessitates thorough spray coverage for optimum results (69). Foliar herbicides must be retained on the leaf, penetrate the cuticle, and be absorbed into the leaf, then move to site of action (63, 87). Bromoxynil is readily absorbed by leaves, yet translocation is thought to be limited (12, 30, 69, 97). However, the observation of slow movement into adjoining leaves and root systems in addition to chlorotic development of untreated leaves raises questions on the extent of translocation (30, 63). The primary route of foliar penetration is cuticular rather than stomatal (63).

Bromoxynil's effectiveness as an herbicide occurs because it inhibits photosynthesis and respiration (12, 16, 46, 69, 94, 97). Specifically, bromoxynil blocks the Hill reaction (photosynthetic electron transport) (12, 16, 67). Hill reaction inhibitors are thought to bind on sights in the chloroplasts (16). Van Oorschot (93) found that inhibitors of Hill reaction activity were also effective in reducing transpiration. This is done by uncoupling oxidative phosphorylation (46). Also, bromoxynil is known to influence enzyme activity (12). For example, barley (Hordeum spp.) seed germination has been observed to be repressed by bromoxynil and the cause is theorized to be the prevention of amylase activity in barley seeds during the first 2 days of germination (63, 67).

Selectivity

The selectivity of bromoxynil depends in part on differences in retention and penetration (46, 63). Morphological differences between cereal and broadleaf species may account for differences in spray retention while differences at sight of action may help explain selectivity. "Selectivity may be physiological and biochemical factors within the plant as well as variation in environmental conditions, formulation and application methods." (67).

Soil Degradation

Bromoxynil has an half life of less than 2 weeks in most soils (63). Degradation of bromoxynil is a direct result of microbial breakdown (40). Studies using sterile and non-sterile soil showed no degradation of bromoxynil in the sterile soil (63). Cullimore and Kohout (40) found that only 0.001% of the total bacterial flora are capable of degrading bromoxynil. An organism, strain BR4, isolated by Cullimore and Kohout, was verified by Smith and Cullimore (91) to degrade bromoxynil to less than 10% in 5 weeks. Temperature appears to influence the rate of breakdown (40, 63). Soil type also has an effect on the rate of disappearance (60). Bromoxynil breakdown in peat soil took 4 weeks longer than in sand. Explanation of this observation involved the higher adsorption of peat, the higher absorption in soil solution due to higher moisture content, and the latent period it takes for microflora to activate. Also, bromoxynil at 50 ppm has been shown to decrease nitrate formation by up to 50% (53, 63).

Bromoxynil Use in Onions

General considerations exist pertaining to bromoxynil use in onions. Onions are most tolerant to applications of bromoxynil at the second to fifth leaf stage (1, 8, 73). No surfactants should be added (92). Applications should be withheld if thrips or wind have damaged the waxy coating on onion foliage. Low radiation and high relative humidity decrease yields (73, 92). "Our data suggest that onion growers should apply the postemergence herbicides to onions on warm, sunny days, and avoid cloudy weather with its associated high relative humidity." (73). Lastly, bromoxynil should not be used 24 hours before or after cultivation, irrigation or rain (92).

Most of the field research on bromoxynil use in onions appears to be in the western United States. Some successful testing of bromoxynil has occurred in northeast and north central United States (23, 47, 89). Early work with bromoxynil in the western United States resulted in varying degrees of success. In 1968, Dunster (43) found that yields were not reduced when bromoxynil was applied at the flag leaf stage at rates up to 1.12 kg/na even though the crop sustained considerable leaf burn. Rates of bromoxynil at 0.28 and 0.56 kg/ha were able to adequately control purslane and nightshade (Solanum sp.) regardless of size (1). Furthermore, bromoxynil was able to control London rocket (Sisymbrium irio L.) and common sunflower (Helianthus annuus L.), but yields of onion were reduced (72).

Field research in the 1980's produced generally positive results for use of bromoxynil as an important postemergence broadleaf herbicide in onions. However, the major negative aspect of bromoxynil is its phytotoxicity to onions at certain stages of development. Normally, the second leaf stage and later provides acceptable tolerance of bromoxynil, yet there have been exceptions. Bell et al. (21) found that rates of 0.34 and 0.67 kg/ha did not injure onions at the one to two leaf stage, instead, injury occurred at the three to six leaf stage with the same rates. Researchers Brenchley and Zamora (29) found unacceptable onion injury at the second leaf stage, but thought a possible explanation involved weather conditions predisposing the onions to bromoxynil injury.

Although bromoxynil did not control grass, it did provide good broadleaf control without significant loss in onion yields (14, 41). Agamalian and Kurtz (6) found it tested well in comparison to nitrofen and is recommended for the postemergence portion of a comprehensive weed control program for onions (4). Anderson (10) discovered acceptable weed control when bromoxynil was teamed with diclofop or sethoxydim on overwintered onions.

Fluazifop-butyl

"Fluazifop-butyl is a highly selective grass herbicide that controls a broad range of annual and perennial grasses while possessing a wide margin of safety when applied topically to broadleaved crops" (55). Along with its distinct safety to non-graminaceous crops, fluazifop-butyl has very high LD 50's (46, 48, 97). Currently, it is registered for use in cotton, soybeans, and ornamentals (59). Research has established a wide range of grasses controlled by fluazifop-butyl and more research continues (18, 45, 54, 55, 58). Especially good results have been obtainéd using fluazifop-butyl for quackgrass (*Agropyron repens* L.) control in the northeast (22, 95, 98). Injury symptoms include loss of vigor, yellow or reddening chlorosis, with eventual death (54, 59).

Anderson (12) includes fluazifop-butyl in the family, aromatic carboxylic. The formulation of fluazifop-butyl is its ester into an emulsifiable concentrate. Water is the carrier. Buhler and Burnside (31) found fluazifop-butyl to be more phytotoxic in a carrier volume below 190 l/ha. A nonionic surfactant or crop oil concentrate is recommended to enhance foliar absorption (12, 54, 59, 81, 97). There is disagreement on whether the addition of the adjuvant to fluazifop-butyl enhances lower rates or higher rates of the herbicide (54, 81). Although there is agreement that drought stress and low relative humidity will necessitate higher rates of fluazifop-butyl for grass control. Recommended rates lie between 0.14 and 0.56 kg/ha (97). Fluazifop-butyl is best suited for early postemergence when annual grasses are small and actively growing (12, 32, 45, 59, 97). Repeated applications on perennial grass may be necessary. If used preemergence, a higher rate is required (12, 32).

Mode of Action

Since fluazifop-butyl is a foliar applied herbicide, good coverage is important. After rapid leaf absorption, the herbicide is translocated via the phloem and xylem to roots, rhizomes, stolons, and growing points until the plant is killed (12, 97). This process is quite slow and can take several weeks to kill the entire plant. However, no new growth occurs after an application. The mechanism of action is not known at this time, but fluazifop-butyl is rapidly hydrolyzed to fluazifop in the plant at low rates (97). Fluazifop-butyl is considered rainfast, because rain 1 hour after application has little or no effect on the herbicide's potency (12, 59, 97).

Soil Degradation

Fluazifop-butyl has less mobility than fluazifop in soils, however, fluazifop-butyl is degraded faster than fluazifop in moist soils. The half-life of fluazifop-butyl is less than 1 week while the half-life of fluazifop is about 3 weeks.

Fluazifop-butyl Use in Onions

At this time, little information has been published concerning fluazifop-butyl for use in onion weed control. Although, the potential for fluazifop-butyl in a comprehensive weed control program in onions looks very promising. Sieczka et al. (90), referred to earlier, recommended fluazifop-butyl for postemergence grass control in onions. Beaver et al. (17) reported that fluazifop-butyl did not successfully control foxtail (*Hordeum leporinum* Link), but did control barnyard-grass (*Echinochioa crusgalli* (L) Beauv.) with no onion phytotoxicity. Onions have yet to be reported susceptible to fluazifop-butyl phytotoxicity at any stage of growth.

Adjuvants

The inclusion of this section in the literature review is due to the recommended use of an adjuvant with fluazifop-butyl and its role in a tank mix of fluazifop-butyl and bromoxynil. "Presence or absence of adjuvants in many herbicidal treatments greatly affects their efficacy" (33). For the purpose of clarity, adjuvant will be used to include both surfactants and crop oil concentrate. Agamalian (2) found the addition of an adjuvant to chloroxuron and nitrofen caused both herbicides to be more phytotoxic to onions. A great deal more information is available on surfactants than on crop oil concentrates, but their purpose seems to be the same: to increase herbicidal effectiveness (12, 46, 69, 96).

Surfactants

Fletcher and Kirkwood (46) suggest, "The role of the surfactant is complex and little understood." There is general agreement that surfactants enhance foliar penetration of herbicides by lowering surface tension (12, 46). The site at which surfactants influence herbicidal activity is at the point of application and in the immediate underlying tissue (12). Rate of uptake is altered by surfactants and they can change an herbicide's response to temperature and humidity (46).

"Surfactants are used in formulation to enhance some aspect of the original formulation and improve the herbicide quality." (12). Four major groups exist based on their ionization in water: anionic, cationic, nonionic, and amphoteric. The nonionic surfactant does not ionize in aqueous solution allowing its use in hard water or strong acid solutions. Of great herbicidal advantage is that surfactants form stable emulsions. Anderson (12) has written a lengthy and detailed description of surfactants.

There are several reasons that foliar penetration is increased with surfactants due to the lower surface tension (12, 69). The area of contact has been increased and air films are eliminated. Surfactants act as a stabilizing agent for herbicides during cuticular or stomatal penetration. Spray droplets tend to stick to the plant better and the herbicide does not dry out on the leaf surface. Lastly, nonpolar plant substances may be altered, such as waxy cuticle or cell membrane, so that the herbicide is more readily absorbed (69, 75).

Crop Oil Concentrates

Most current nonphytotoxic crop oil concentrates contain about 80% phytobland oil and 20% surfactant (96). The original crop oils on the market had only 1 to 2% surfactant. The surfactant serves as an emulsifying agent. With the advent of the relatively new oil plus surfactant concentrates, the amount of phytobland oil needed per hectare has decreased. Oils free of impurities are the least phytotoxic. The role of crop oil concentrates is like the surfactant, to increase herbicidal effectiveness.

METHODS AND MATERIALS

Common Methods and Procedures

Sixteen tests were conducted to determine survival and growth responses of seedling onions to fluazifop-butyl and bromoxynil. All tests were conducted in a greenhouse at the University of Arizona Campbell Avenue Farm, Tucson, Arizona. A description of the materials and procedures common to all tests follows. Individual tests will then be described.

The greenhouse had a day temperature of 29 C and 21 C during the night. Ten hours of daylight existed during that period. The containers used were 10.2 cm deep plastic pots. Each container had two holes drilled in the bottom. The holes were loosely plugged with cotton to prevent soil loss and still allow good drainage.

Air dried field soil was used which was obtained from the Kl border at the University of Arizona Casa Grande Highway Farm. The soil contained 60% sand, 25% silt, 15% clay, and 1% organic matter; and was sifted through a 6.5 mm mesh screen. Nitrogen, at the rate of 22 kg/ha, was incorporated with 450 cc of the soil.

The fertilized soil was poured into a pot. Ten seeds of Sweet Spanish White Valencia onion were then placed on the soil and covered with 150 cc of unfertilized soil. Each pot was placed on an aluminum baking tray. Twenty pots were on each tray.

Initial watering was over the top with 200 cc poured through filter paper placed on the soil to avoid crusting. A clear plastic sheet was placed over each tray to enhance emergence and removed after emergence. The pots were watered over the top until the first true leaf stage and then sub-irrigated as needed. The ten seedlings in each pot were thinned to four at the flag leaf stage.

Herbicides were applied from a height of 30 cm over the top of the onions with a knapsack sprayer. The sprayer used was fitted with a single nozzle and a 8003 tip. Air pressure was set at 2.8 kg/cm^2 and spray volume was 380 ℓ/ha.

After an herbicide application, the pots were replaced on the tray. The pots were arranged on the tray in a randomized complete block design with five treatments replicated four times. An untreated check was one of the treatments in each test.

Herbicide applications were made at the first true leaf stage, seedlings being about 4 cm high; and, or, 10 to 14 days later, when the seedlings were 6 to 8 cm high. Tests were terminated 10 to 14 days after the last herbicide application. At that time, the average height of the seedlings in each pot was determined. The plants were held in an upright position and measured from the soil line to the tip of green tissue. (A certain amount of dieback occurred on all onion leaves.) Survival of the four seedlings was noted. If any green remained on a plant, it was considered alive. Root development was determined by a visual evaluation at the bottom of the pot and compared to the untreated check. The pot was turned over and the root development was rated on a scale of 0 to 10. A 10 denoted normal root development while a 0 denoted none. Both height and root development data were analyzed by Duncan's Multiple Range at the 5% level. Survival was noted as percent alive of the original four seedlings.

Important to note at this time is the variation observed in seedling onion growth independent of herbicide treatments. There seemed to be an abnormal growth pattern with the onions in this study. The growth was unusually slow and more onion tip dieback occurred than would be expected. Nutrient deficiency and salt injury were considered as possible explanations. Neither of these possibilities was verified, although, a salt accumulation was found to exist in the upper soil level of the pots. What effect this unusual growth had on the herbicide treatments is not known, however, results could have been confounded.

Fluazifop-butyl at Four Rates and Two Single and One Combination Application Dates

Three tests were conducted to evaluate fluazifop-butyl on seedling onions. Each test contained an untreated check and four treatments of herbicide at 0.07, 0.14, 0.21, and 0.28 kg/ha. Crop oil concentrate is a recommended adjuvant for fluazifop-butyl and was added to the herbicide at a rate of 2.3 ℓ/ha. The application dates included an early, a late, and a combination of early and late. The early application occurred at the first true leaf stage, and the late application occurred 10 to 14 days later.

The early application test was planted on January 1, 1984. Fluazifop-butyl was applied 22 days later. Seedlings were 4 cm tall. On February 6, the seedlings were evaluated and the test terminated.

The late application test was planted on January 1, 1984. Fluazifop-butyl was applied 36 days later. Seedlings were 8 cm tall. On February 21, the seedlings were evaluated and the test was terminated.

The combination application test was planted on January 1, 1984. Fluazifop-butyl was applied on January 23, and February 6, 1984. Seedlings were 4 cm and 8 cm tall, respectively. On February 21, 1984, the seedlings were evaluated and the test was terminated.

Bromoxynil at Four Rates and Two Single and One Combination Application Dates

Three tests were conducted to evaluate bromoxynil on seedling onions. Each test contained an untreated check and four treatments of bromoxynil at 0.07, 0.14, 0.21, and 0.28 kg/ha. The application dates include an early, a late, and a combination of early and late. The early application occurred at the first true leaf stage and the late application occurred 10 to 14 days later.

The early application test was planted on January 5, 1984. Bromoxynil was applied 26 days later. The seedlings were 4 cm tall. On February 13, 1984, the seedlings were evaluated and the test was terminated.

The late application test was planted on January 5, 1984. Bromoxynil was applied 43 days later. The seedlings were 8 cm tall. On February 26, 1984, the seedlings were evaluated and the test was terminated.

The combination application test was planted on January 5, 1984. Bromoxynil was applied on January 31, and February 17, 1984. The seedlings were 4 cm and 7 to 8 cm tall, respectively. On February 26, 1984, the seedlings were evaluated and the test terminated.

Fluazifop-butyl and Bromoxynil Tank Mix
at Four Rates and Two Single and One
Combination Application Dates

Two trials with three tests each were conducted to evaluate fluazifop-butyl and bromoxynil tank mix on seedling onions. Each test contained an untreated check and four treatments of tank mix with each herbicide at 0.07, 0.14, 0.21, and 0.28 kg/ha. Crop oil concentrate, the adjuvant for fluazifop-butyl was added to the tank mix at the rate of 2.3 l/ha. The application dates included an early, a late, and a combination of early and late. The early application occurred at the first true leaf stage and the late application occurred 10 to 14 days later.

Trial 1. The early application test was planted on December 30, 1983. The tank mix was applied 19 days later. Seedlings were 4 cm tall. On January 30, 1984, the seedlings were evaluated and the test terminated.

The late application test was planted on December 30, 1983. The tank mix was applied 32 days later. Seedlings were 7 cm tall. On February 14, 1984, the seedlings were evaluated and the test terminated.

The combination application test was planted on December 30, 1983. The tank mix was applied on January 18, and January 31, 1984.

Seedlings were 4 cm and 6 to 7 cm tall, respectively. On February 13, 1984, the seedlings were evaluated and the test terminated.

Trial 2. The early application test was planted on January 5, 1984. The tank mix was applied 26 days later. Seedlings were 4 cm tall. On February 13, 1984, the seedlings were evaluated and the test terminated.

The late application test was planted on January 5, 1984. The tank mix was applied 43 days later. Seedlings were 7 cm tall. On February 26, 1984, the seedlings were evaluated and the test terminated.

The combination application test was planted on January 5, 1984. The tank mix was applied on January 31, and February 17, 1984. Seedlings were 4 cm and 6 to 7 cm tall, respectively. On February 26, 1984, the seedlings were evaluated and the test terminated.

The Effect of the Crop Oil Concentrate on Bromoxynil

The role of the crop oil concentrate was investigated by assessing its affect on bromoxynil in a fluazifop-butyl and bromoxynil tank mix. The test included two trials with the following treatments: an untreated check, fluazifop-butyl, bromoxynil, bromoxynil plus crop oil concentrate, and a fluazifop-butyl and bromoxynil tank mix. The rate used in all treatments was 0.14 kg/ha and the crop oil concentrate was added at 2.3 l/ha.

Trial one was planted on December 30, 1983. The herbicide applications occurred on January 18, 1984. Seedlings were 4 cm tall. On January 31, 1984, the seedlings were evaluated and the test terminated.

Trial two was planted on January 1, 1984. The herbicide applications occurred on January 23, 1984. Seedlings were 6 to 7 cm tall. On January 30, 1984, the seedlings were evaluated and the test terminated.

Delayed Application of Fluazifop-butyl
After an Application of Bromoxynil

The possible reduction of phytotoxic effects associated with a tank mix of fluazifop-butyl and bromoxynil was examined by delaying the application of fluazifop-butyl after an application of bromoxynil. The test included two trials with the following treatments: an untreated check, a tank mix of fluazifop-butyl and bromoxynil, and bromoxynil followed by fluazifop-butyl applied 1, 2, and 3 days later. The rate used in all treatments was 0.14 kg/ha and the crop oil concentrate was added at 2.3 l/ha.

Trial one was planted on January 6, 1984. The initial herbicide applications occurred on January 31, 1984. Seedlings were 8 cm tall. On February 14, 1984, the seedlings were evaluated and the test was terminated.

Trial two was planted on January 6, 1984. The first herbicide treatments occurred on February 14, 1984. Seedlings were 6 to 7 cm tall. On February 26, 1984, seedlings were evaluated and the test terminated.

RESULTS AND DISCUSSION

Fluazifop-butyl at Four Rates and Two Single and One Combination Application Dates

The early, late, and combination, early and late, applications of fluazifop-butyl sprayed over the top of seedling onions at the rates of 0.07, 0.14, 0.21, and 0.28 kg/ha showed no significant difference between treatments in plant height or root development (Table 1). Survival was not affected.

No visual symptoms were observed on the seedling onions with any treatment and application date of fluazifop-butyl. Fluazifop-butyl does not appear phytotoxic to onions at these treatment levels and application dates.

Bromoxynil at Four Rates and Two Single and One Combination Application Dates

The early application of bromoxynil at 0.14 kg/ha and greater, sprayed over the top of seedling onions, significantly reduced height (Table 2). The untreated check and the 0.07 kg/ha treatments; and the 0.14, 0.21, and 0.28 kg/ha treatments did not differ significantly. Evaluation of root development revealed no significant differences between treatments. Survival was not affected.

The late application of bromoxynil at 0.07 kg/ha and greater, sprayed over the top of seedling onions, significantly reduced height. The 0.07 and the 0.14 kg/ha treatments did not differ significantly.

Table 1. Response of seedling onions to fluazifop-butyl.

Treatment	Response		
Fluazifop-butyl	Survival	Height[a]	Root rating[a] 10=normal[b] 0=none
(kg/ha)	(% of check)	(cm)	
Early application:			
Untreated check	100	10.00 a	10.00 a
0.07	100	9.50 a	10.00 a
0.14	100	9.00 a	9.50 a
0.21	100	9.75 a	10.00 a
0.28	100	9.00 a	8.75 a
Late application:			
Untreated check	100	7.50 a	10.00 a
0.17	100	7.00 a	9.25 a
0.14	100	7.25 a	9.75 a
0.21	100	7.00 a	9.50 a
0.28	100	7.25 a	9.50 a
Combination application:			
Untreated check	100	6.75 a	9.75 a
0.17	100	6.00 a	9.75 a
0.14	100	7.25 a	10.00 a
0.21	100	7.00 a	10.00 a
0.28	100	7.00 a	10.00 a

[a]Values in a column within a test followed by the same letter do not differ significantly at the 5% level according to Duncan's Multiple Range.

[b]Visual evaluation at bottom of pot.

Table 2. Response of seedling onions to bromoxynil.

Treatment	Response		
Bromoxynil	Survival	Height[a]	Root rating[a] 10=normal[b] 0=none
(kg/ha)	(% of check)	(cm)	
Early application:			
Untreated check	100	9.25 a	10.00 a
0.07	100	8.25 a	10.00 a
0.14	100	7.75 b	10.00 a
0.21	100	7.75 b	9.25 a
0.28	100	7.25 b	9.50 a
Late application:			
Untreated check	100	6.25 a	10.00 a
0.07	100	5.75 b	9.00 a
0.14	100	5.50 bc	9.25 a
0.21	100	5.25 cd	9.25 a
0.28	100	5.00 d	9.75 a
Combination application:			
Untreated check	100	7.00 a	9.25 a
0.07	100	6.00 b	10.00 a
0.14	100	6.50 b	10.00 a
0.21	100	6.00 b	10.00 a
0.28	100	6.00 b	9.75 a

[a]Values in a column within a test followed by the same letter do not differ significantly at the 5% level according to Duncan's Multiple Range.

[b]Visual evaluation at bottom of pot.

Also, the 0.14 and the 0.21 kg/ha treatments; and the 0.21 and the 0.28 kg/ha treatments did not differ significantly. Evaluation of root development revealed no significant difference between treatments. Survival was not affected.

The combination, early and late, application of bromoxynil at 0.07 kg/ha and greater, sprayed over the top of seedling onions, significantly reduced height. There was no significant difference between the 0.07, 0.14, 0.21, and 0.28 kg/ha treatments. Evaluation of root development revealed no significant difference between treatments. Survival was not affected.

Stage of development appears to be a factor in the degree of phytotoxicity exhibited by seedling onions after an application of bromoxynil. Bromoxynil appears more phytotoxic to seedling onions at the early application date, when the plants are in the beginning of the first true leaf stage. Visual symptoms include tip burn; a spotted, yellow chlorosis; and bending. The spotted, yellow chlorosis, and the bending began at the 0.21 kg/ha treatment. Severity of symptoms increased with an increase of bromoxynil. Also, symptoms lessened when the herbicide application occurred at the late application date.

Fluazifop-butyl and Bromoxynil Tank Mix
at Four Rates and Two Single and One
Combination Application Dates (Two Trials)

Trial 1. The early application of the tank mix at 0.14 kg/ha and greater, sprayed over the top of seedling onions, significantly reduced height (Table 3). The untreated check did not differ

Table 3. Response of seedling onions to a bromoxynil and fluazifop-butyl tank mix: Trial 1.

Treatment	Response		
Bromoxynil and Fluazifop-butyl	Survival	Height[a]	Root rating[a] 10=normal[b] 0=none
(kg/ha)	(% of check)	(cm)	
Early application:			
Untreated check	100	9.75 a	9.50 a
0.07	100	8.75 ab	9.25 a
0.14	100	8.25 b	9.00 a
0.21	100	8.00 bc	9.75 a
0.28	100	7.25 c	8.00 a
Late application:			
Untreated check	100	6.75 a	9.75 a
0.07	100	5.75 a	10.00 a
0.14	100	5.50 a	9.75 a
0.21	100	5.50 a	9.75 a
0.28	100	5.50 a	9.50 a
Combination application:			
Untreated check	100	6.75 a	10.00 a
0.07	100	6.50 a	9.50 a
0.14	100	6.25 ab	10.00 a
0.21	100	5.75 b	9.25 a
0.28	100	6.00 b	8.75 a

[a]Values in a column within a test followed by the same letter do not differ significantly at the 5% level according to Duncan's Multiple Range.

[b]Visual evaluation at bottom of pot.

significantly from the 0.07 kg/ha treatments. Also, the 0.07, 0.14, and 0.21 kg/ha treatments; and the 0.21 and 0.28 kg/ha treatments did not differ significantly. Evaluation of root development revealed no significant difference between treatments. Survival was not affected.

The late application of the tank mix sprayed over the top of seedling onions at the rates of 0.07, 0.14, 0.21, and 0.28 kg/ha showed no significant difference between treatments in plant height or root developments. Survival was not affected.

The combination, early and late, application of the tank mix at 0.21 kg/ha and greater, sprayed over the top of seedling onions, significantly reduced height. The untreated check, 0.07, and 0.14 kg/ha, and the 0.14, 0.21, 0.28 kg/ha treatments did not differ significantly. Evaluation of root development revealed no significant difference between treatments. Survival was not affected.

Trial 2. The early application of the tank mix at 0.14 kg/ha and greater, sprayed over the top of seedling onions, significantly reduced height (Table 4). The untreated check and the 0.07 kg/ha; and the 0.14, 0.21, 0.28 kg/ha treatments did not differ significantly. Evaluation of root development revealed no significant difference between treatments. Survival was not affected.

The late application of the tank mix at 0.07 kg/ha and greater, sprayed over the top of seedling onions, significantly reduced height. The 0.07, 0.14, 0.21, and 0.28 kg/ha treatments did not differ significantly. Evaluation of root development revealed no significant difference between treatments. Survival was not affected.

Table 4. Response of seedling onions to a bromoxynil and fluazifop-butyl tank mix: Trial 2.

Treatment	Response		
Bromoxynil and Fluazifop-butyl	Survival	Height[a]	Root rating[a] 10=normal[b] 0=none
(kg/ha)	(% of check)	(cm)	
Early application:			
Untreated check	100	9.00 a	10.00 a
0.07	100	8.50 a	9.75 a
0.14	100	7.00 b	9.25 a
0.21	100	7.00 b	8.50 a
0.28	100	6.25 b	9.50 a
Late application:			
Untreated check	100	6.25 a	10.00 a
0.07	100	5.25 b	9.75 a
0.14	100	5.25 b	10.00 a
0.21	100	4.50 b	9.75 a
0.28	100	4.75 b	9.75 a
Combination application:			
Untreated check	100	6.75 a	10.00 a
0.07	100	6.50 a	9.00 a
0.14	100	6.25 ab	9.25 a
0.21	100	5.75 c	9.25 a
0.28	100	6.00 bc	9.75 a

[a]Values in a column within a test followed by the same letter do not differ significantly at the 5% level according to Duncan's Multiple Range.

[b]Visual evaluation at bottom of pot.

The combination, early and late, application of the tank mix at 0.21 kg/ha and greater, significantly reduced height. The untreated check, 0.07, and 0.14 kg/ha treatments did not differ significantly. Evaluation of root development revealed no significant difference between treatments. Survival was not affected.

Stage of development appears to be a factor in the degree of phytotoxicity exhibited by seedling onions after an application of a fluazifop-butyl and bromoxynil tank mix. The seedling onions seem to be more susceptible at the early application date when the plants are in the beginning of the first true leaf stage. Visual symptoms include tip burn; a spotted, yellow chlorosis; bending and necrosis at the growing point; and a necrotic spotting on the leaves. The spotted, yellow chlorosis and tip burn began with the 0.07 kg/ha treatment. All the symptoms were observable with the 0.14 kg/ha and higher treatments. Severity of symptoms increased with increased rates of the tank mix. Also, symptoms lessened when the application occurred at the late application date.

The Effects of Crop Oil Concentrate on Bromoxynil (Two Trials)

Trial 1. The bromoxynil plus crop oil concentrate and the tank mix treatments significantly decreased the height of seedling onions (Table 5). These two treatments were not significantly different. The untreated check, fluazifop-butyl, and the bromoxynil treatments were not significantly different. However, the bromoxynil treatment did differ significantly from the bromoxynil plus crop oil concentrate. The crop oil concentrate does appear to increase the phytotoxicity of

Table 5. Response of seedling onions to bromoxynil, bromoxynil plus crop oil concentrate, and other treatments.

Treatment	Response		
All treatments applied at 0.14 kg/ha	Survival	Height[a]	Root rating[a] 10=normal[b] 0=none
	(% of check)	(cm)	
Trial 1			
Untreated check	100	8.00 a	9.00 a
Fluazifop-butyl	100	8.75 a	8.75 a
Bromoxynil	100	8.50 a	8.50 a
Bromoxynil plus oil	100	6.75 b	7.75 ab
Tank mix	100	6.75 b	6.00 b
Trial 2			
Untreated check	100	9.25 a	9.00 a
Fluazifop-butyl	100	8.75 ab	9.00 a
Bromoxynil	100	8.00 bc	8.75 a
Bromoxynil plus oil	100	7.50 c	8.50 a
Tank mix	100	7.00 c	9.00 a

[a]Values in a column within a test followed by the same letter do not differ significantly at the 5% level according to Duncan's Multiple Range.

[b]Visual evaluation at bottom of pot.

bromoxynil which would account for the apparent increased phytotoxicity of the tank mix as compared to the apparent phytotoxic effects associated with fluazifop-butyl or bromoxynil applied separately.

Root development decreased with the tank mix treatment. The tank mix and the bromoxynil plus crop oil concentrate treatments did not differ significantly. Also, the untreated check, fluazifop-butyl, bromoxynil, and bromoxynil plus crop oil concentrate treatments did not differ significantly. Survival was not affected.

Trial 2. The bromoxynil, bromoxynil plus crop oil concentrate, and the tank mix treatments significantly reduced the height of seedling onions. The untreated check and fluazifop-butyl treatment did not differ significantly. Bromoxynil, bromoxynil plus crop oil concentrate, and the tank mix did not differ significantly. In this test, the pattern is not as clear as in Trial 1 and may be due to the later treatment date and that the onions were evaluated only 7 days after treatment. Evaluation of root development revealed no significant difference between treatments. Survival was not affected.

The means of each treatment from both trials were combined and plotted as percent of the untreated check. The trend of the crop oil concentrate's influence on phytotoxicity when combined with bromoxynil is clearly shown (Figure 1).

Delayed Application of Fluazifop-butyl After an Application of Bromoxynil (Two Trials)

Trial 1. Although none of the treatments in Trial 1 differed significantly, there is a noteworthy trend that developed (Table 6). The tank mix applied over the top of onions decreased plant height,

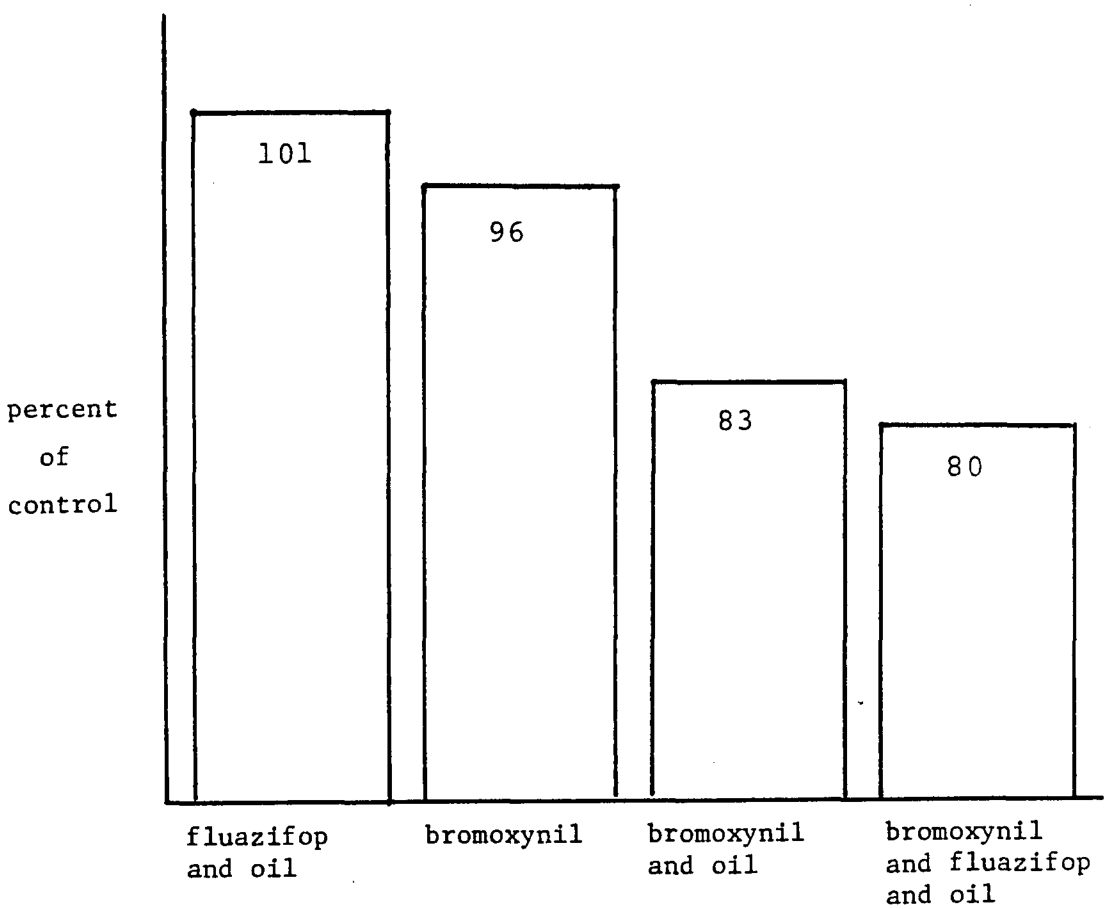

Figure 1. The height response of seedling onions in determining the effect of crop oil concentrate on bromoxynil.

Table 6. Response of seedling onions to a delayed application of fluazifop-butyl after an application of bromoxynil.

Treatment	Response		
Bromoxynil and Fluazifop-butyl at 0.14 kg/ha	Survival	Height[a]	Root rating[a] 10=normal[b] 0=none
	(% of check)	(cm)	
Trial 1			
Untreated check	100	8.00 a	8.75 a
Tank mix	100	6.00 a	8.75 a
Day 1	100	6.75 a	8.75 a
Day 2	100	7.25 a	9.50 a
Day 3	100	7.25 a	8.75 a
Trial 2			
Untreated check	100	7.00 a	9.75 a
Tank mix	100	6.00 a	9.75 a
Day 1	100	5.50 a	9.75 a
Day 2	100	6.00 a	9.50 a
Day 3	100	6.00 a	10.00 a

[a]Values in a column within a test followed by the same letter do not differ significantly at the 5% level according to Duncan's Multiple Range.

[b]Visual evaluation at bottom of pot.

however, when a delay occurred in the application of fluazifop-butyl after an application of bromoxynil, plant height increased. An increase in height began with a 1-day delay and a further increase occurred with a 2-day delay. The 3-day delay remained the same as the 2-day delay height (Figure 2). Evaluation of root development revealed no significant difference between treatments. Survival was not affected.

Trial 2. There was no significant difference between treatments. The trend shown in Trial 1, is not apparent in this trial. However, Trial 2 was treated on a later date than Trial 1 and the cultural and environmental effects may have influenced the outcome of this test. Evaluation of root development revealed no significant difference between treatments. Survival was not affected.

Fluazifop-butyl has not been reported to be phytotoxic to onions. The results obtained in this study do not change that statement. At rates up to 0.28 kg/ha and treatments applied as early as the beginning of the first true leaf, no onion injury was observed.

The results obtained from treatments of bromoxynil appear consistent with the literature. In order to lessen phytotoxic effects of bromoxynil, application should not be made before the second leaf stage (2, 9, 77). In this study, the initial treatment of bromoxynil occurred at the beginning of the first true leaf stage. The onions incurred more severe injury with this early treatment than with the treatment applied 10 to 14 days later. This study does not include yield data, therefore, no comparisons can be made with the literature

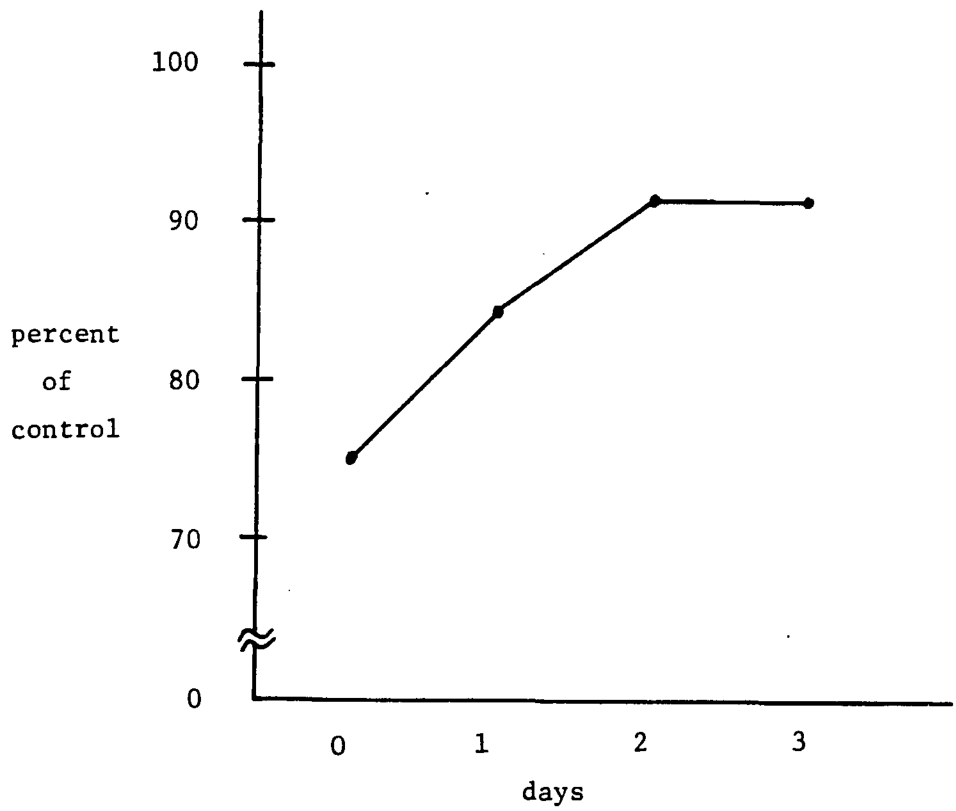

Figure 2. The height response of seedling onions to a delayed application of fluazifop-butyl after an application of bromoxynil.

concerning the effects of bromoxynil on onion yield. Also, the literature contains no information on onion root evaluations with the use of bromoxynil preventing any comparison with this study.

The tank mix of fluazifop-butyl and bromoxynil did appear more phytotoxic to onions at both stages of development than bromoxynil alone. Since no reported tank mix of these two herbicides has been used in onion production, no comparison of results can be made. Also, yield data are essential before considering a fluazifop-butyl and bromoxynil tank mix in onion production and should be included in any field testing of the tank mix.

The increased phytotoxicity of the tank mix may be accounted for by the inclusion of crop oil concentrate used to enhance the formulation of fluazifop-butyl. Bromoxynil may have been affected in the tank mix by the crop oil concentrate in such a way as to increase its phytotoxic effects on onions. Agamalian (3) concluded that an increase of phytotoxicity to onions from the herbicides chloroxuron and nitrofen was due to the addition of adjuvants to their formulation.

CONCLUSION

Seedling onions treated with fluazifop-butyl at four rates and two single and one combination application dates did not significantly differ in plant height or root development. Fluazifop-butyl was not phytotoxic to onions at rates up to 0.28 kg/ha and applications as early as the beginning of the first true leaf stage.

Treatments of bromoxynil at four rates and two single and one combination application dates, reduced the height of seedling onions. Root development did not differ between treatments. The stage of development of the onions at the time of treatment probably caused a greater phytotoxic response than later applications would have.

Similarly, treatments of a fluazifop-butyl and bromoxynil tank mix at four rates and two single and one combination application dates reduced the height of onions (with the exception of the late application in Trial 1). Root development did not differ significantly between treatments. The tank mix appeared to be more phytotoxic to the onions than bromoxynil alone. Field tests would be appropriate for further testing of the tank mix on onions. Moreoever, the stage of development at the time of treatment should be considered. Onions may be more tolerant of a fluazifop-butyl and bromoxynil tank mix at a later stage of development.

Trial 1 of the test to determine the effect of the crop oil concentrate on bromoxynil, onion height differed significantly between the treatments of bromoxynil and bromoxynil plus crop oil concentrate.

Although this is not enough evidence to draw the conclusion that the crop oil concentrate increased the phytotoxicity of bromoxynil, the evidence is enough to warrant field testing of the fluazifop-butyl and bromoxynil tank mix. Root development did decrease significantly with the tank mix in trial 1. In trial 2, plant height and root development did not differ significantly between treatments.

Further evidence of the increased phytotoxic effects of bromoxynil due to the crop oil concentrate is demonstrated by a trend found in trial 1 of the delayed application test. The tank mix appeared to decrease plant height while a delay in the fluazifop-butyl treatment after a treatment of bromoxynil appeared to increase plant height. In both trial 1 and 2, plant height and root development did not differ significantly between treatments.

In closing, bromoxynil has been well established as an effective postemergence broadleaf herbicide for use in onions, especially in Arizona. As for the future of fluazifop-butyl in Arizona onion production, its potential seems impressive and its incorporation into an onion weed control program seems likely. "The success of a new herbicide depends ultimately upon its potential to improve the cost effectiveness of crop production" (49). A tank mix of fluazifop-butyl and bromoxynil would surely enhance cost efficiency of the herbicides, yet only if the seemingly increased phytotoxicity does not affect yields. Another consideration is the suggestion by the manufacturers of fluazifop-butyl not to tank mix, because of possible loss of potency in grass control (63). If by field testing, the tank mix (other brands of nonionic surfactant or crop oil concentrates could be tested) is determined detrimental either on weed control or onion yields, then an alternative program should be studied such as the delayed application of fluazifop-butyl after an application of bromoxynil.

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