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Annual weed competition and management for direct-seeded onion /

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ANNUAL WEED COMPETITION AND MANAGEMENT
FOR
DIRECT-SEEDED ONION

A Thesis Presented

by

CARL D. BANNON

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ABSTRACT

ANNUAL WEED COMPETITION AND MANAGEMENT

FOR

DIRECT-SEEDED ONION

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Competition studies and evaluations of the costs and effectiveness of various weed management systems for onions (*Allium cepa* L.) were conducted in 1986 and 1987 at the Massachusetts Agricultural Experiment Station in South Deerfield. Both weed control and weed competition studies were also conducted in the greenhouse in 1987.

Weed Competition in Onions. Weeds allowed to grow with onions for 1, 2, 3, or 4 weeks after onion emergence limited onion yields by 40, 78, 94, or 100%, respectively, relative to weed-free onions. Conversely, plots kept weed-free for 2, 4, 6, or 8 weeks after emergence, resulted in 80, 19, 29, 0, or 0% yield restrictions, respectively, relative to weed-free onions.

Weed competition restricted onion stand, bulb diameter, and leaf number by 2 weeks after onion emergence. Bulbing was earlier as the initial weedy period increased. Restrictions in onion growth occurred earlier as the weed

density increased.

Weed Management. The best weed control and total onion yield were obtained with preemergence application of DCPA at 6.7 kg/ha followed by a second application of DCPA at 6.7 kg/ha at 6 weeks after planting or with postemergence application of sethoxydim at 0.14 kg/ha or flauzifop-butyl at 0.14 kg/ha tank-mixed with bentazon at 0.28 kg/ha. The preemergence application of propachlor at 6.7 kg/ha followed by a second propachlor application at 4.5 kg/ha at 6 weeks after planting also resulted in excellent weed control and onion yield.

Separate experiments were conducted to evaluate the cost and benefits of DCPA and oxyflourfen in various combinations and frequencies of cultivation and handweeding. In 1986, the best economic return was obtained with the preemergence application of DCPA at 6.7 kg/ha followed by 2 cultivations at 2 and 4 weeks after onion emergence. In 1987, the best marketable onion yield and economic return were obtained with preemergence DCPA at 6.7 kg/ha followed by cultivation, handweeding, and a second application of DCPA at 6.7 kg/ha at six weeks after planting.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1
LITERATURE REVIEW

Introduction

Onion (*Allium cepa* L.), once a major crop in the Connecticut River Valley, has regained its importance in the 1980's (Vengris, 1953). Over 1,600 hectares were harvested in the 1920's, then production declined to 50 hectares in 1964 (Peterson, 1965). From 1978 to 1982, onion production increased from 60 to over 120 hectares (Precheur, 1982). Problems associated with weed control have limited further increase in onion acreage.

Onions are poor competitors with weeds because of slow germination and slow initial growth (Zimdahl, 1980). In addition, their upright leaves lack a dense canopy, resulting in little shading of emerging weeds. Consequently, adequate season-long weed control is vital in onion production (Williams *et al.* 1973; Zimdahl, 1980).

Weed control constitutes the principal cost of onion production (Anonymous, 1985; Majek, 1985; Wicks *et al.* 1973). Onion growers use herbicides, mechanical cultivation, and handweeding in their weed control programs. Lack of effective season-long weed control by registered herbicides makes handweeding the major cost in onion production. Majek (1985) reported that the cost of an effective herbicide program was 1% the cost of handweeding.

Currently, the two herbicides recommended for onion production in New England, DCPA (dimethyl tetrachloroterephthalate) and oxyfluorfen (2-chloro-1-[3-ethoxy-4-nitrophenoxy]-4-[trifluoromethyl] benzene), do not provide the full spectrum of control needed, so some weed species escape control, making cultivation and handweeding inevitable (Bouton and Nicklow, 1986).

Also environmental issues associated with pesticide use, such as the potential of detection in ground water, have forced agricultural research into crop production using reduced application rates of chemicals. The development of agricultural systems using integrations of management practices can lessen the reliance of growers on chemicals and will reduce chances of environmental contamination (Spurrier, 1987).

Weed-Crop Competition

Competition between weeds and crops has been an integral area of research in weed science for many years (van Heemst, 1985; Aldrich, 1984; Zimdahl, 1980).

Most crops require an initial weed-free period in order to prevent a diminished crop yield. Conversely, a time exists in which the emergence of weeds with the crop will not reduce the crop yield. The term "critical period" refers to the time period between these two stages. This is the time period in which weed competition is most severe (Frieson, 1979; Weaver and Tan, 1983).

Critical Periods and Densities. The concept of the critical period is practical for weed management programs since it defines the requirements for chemical and cultural controls (Weaver and Tan, 1983). The critical period of weed competition has been evaluated for many crops (van Heemst, 1985; Zimdahl, 1980). Studies by Weaver and Tan (1983) showed that a single weeding between 28 and 35 days after transplanting was sufficient to prevent a yield loss in tomatoes. Bhowmik (1984) reported that plots receiving a weed-free period between 4 and 6 weeks after transplanting cabbage (*Brassica oleracea* L. var. *capitata*) produced marketable yields equal to that of weed-free plots.

Weed densities affect periods of weed-crop competition. In some situations, low densities of weeds will not restrict the crop yield. For example Ali *et al.* (1986) determined that johnsongrass (*Sorghum halepense* (L.) Pers.) infestation levels less than 15% in sugarcane (*Saccharum officinarum* L.) did not substantially limit the crop. However, natural weed densities as low as 5% of the weed population can produce weed biomass equal to unweeded controls if left to grow for the entire season, as shown by Frieson (1979) with tomatoes (*Lycopersicon esculentum* Mill.). Shadbolt and Holm (1956) demonstrated that a weed stand consisting of 15% of the natural weed population limited onion bulb weight to about 10% of the onion weight obtained from weed-free controls. At 4 weeks of weed competition, bulb weight was not restricted significantly with a 15% stand, whereas a 50% stand produced a significant bulb restriction.

Competitive Effects of Weeds in Onions. Several weed competition studies involving onions have been conducted (Hewson and Roberts, 1973; Roberts, 1976; Wicks *et al.* 1973; Williams *et al.*, 1973). In 1952 and 1953, Shadbolt and Holm (1956) determined the effects of weed competition on carrots (*Daucus carota* L.), onions, and red beets (*Beta vulgaris* L.). Of these vegetables, onions were the most susceptable to early season weed competition. This experiment used three weed densities at 15, 30, and 50% of the natural weed infestation. These results demonstrated that regardless of the weed density, injury to onions was severe by 6 weeks after onion emergence. Onions subjected to early competition showed no recovery from initial competition once the weeds were removed. Onions subject to early season competition produced no new leaves and formed smaller bulbs abnormally early. Heath and Holdsworth (1948) reported that bulbing occurs when leaf production ceases, whereas Sobeih and Wright (1986) reported that bulbing in onions was the result of long day length perception by young developing leaves. Shadbolt and Holm (1956) concluded that early bulb formation was a result of the inability of the onion plant to produce new leaves.

Hewson and Roberts (1973) examined the effects of weed competition on the growth and development of onions. This study used plots kept weed-free, weedy all season, and weedy up to 7.5 weeks after 50% onion emergence. In plots subjected to weed competition for 7.5 weeks, there was little subsequent increase in bulb size or dry weight, and only one or two additional leaves were formed. Also, bulbing was earlier, half of the applied nitrogen and a third of the potassium was taken up by weeds, and weed dry weight was 20 times greater than the crop dry weight. In addition, chlorophyll content was higher in weed-free onions than in corresponding weedy plots.

Wicks et al. (1973) evaluated competition between annual weeds and sweet Spanish onions. The weed complex consisted of 54% redroot pigweed (*Amaranthus retroflexus* L.), 21% kochia (*Kochia scoparia* L.), and 25% grassy weeds. Duration of weeds in the row for 2, 4, 6, and 8 weeks after onion emergence limited onion yields by 20, 20, 40, and 65%, respectively. Conversely, plots kept weed-free until onion emergence and 2, 4, 6, 8, 10, and 12 weeks after emergence had yields decreased by 100, 99, 87, 75, 46, 25, and 5% of the weed-free onions.

A similar study by Roberts (1976) demonstrated no yield loss if weeds were removed by five weeks after 50% onion emergence. After two weeks, weed dry weight was 20 times greater than onion dry weight. For each day that weeds remained after five weeks, final yields decreased nearly 4%. A seven-week initial weed-free period after 50% onion emergence was required to avoid yield loss from late season competition. The critical period in this study was between five and seven weeks after 50% onion emergence. Roberts concluded that if weeds were removed between five and seven weeks after 50% onion emergence, the final yield would not be different than the weed-free check.

A survey by van Heemst (1985) ranked the competitive ability of 26 crops towards weeds in hierarchical order of declining competitive ability. Wheat (*Triticum aestivum* L.) and soybean (*Glycine max* Merr.) were at the top of the list and onions and carrots were at the bottom.

Factors in Plant Competition. Differences in results among competition studies can be attributed to variations in climate, weed species composition, and weed density. Cultural practices such as tillage, cultivar selection, row spacing, planting date, planting density, fertilizer rates, and irrigation also can influence weed-crop competition.

Williams *et al*. (1973) conducted research to evaluate the effects of row spacing on weed competition in sweet corn (*Zea mays* L.), snap beans (*Phaseolus vulgaris* L.), and onions. Narrow row spacing produced higher onion yields in weed-free plots and in plots receiving early or late season weed competition than corresponding wide row spacings. However, all onion plots subjected to weed competition at any time produced yields significantly lower than weed-free plots. They concluded that the onion crop must be kept free for the entire growing season to avoid a yield loss. Narrow row spacing was more effective in preventing a yield loss in the presence of weeds in sweet corn and snap beans than in onions. Some differences in competitive ability can be attributed to differences in plant architecture. Plants producing canopies decrease light penetration to the soil surface, resulting in less available light for weed growth and development. The canopy effect of weed suppression can be increased with increased planting density in rows and decreased spacing between rows.

Planting dates also can influence the degree of weed-crop competition. Weeds differ in environmental requirements for germination. Therefore, different weed species germinate at different times of the year. Knowledge of weed biology and ecology can be used to determine planting dates to give the competitive advantage to the crop. For example, Bhowmik and Curry (1983) found that silage corn yields were increased and fall panicum (Panicum dichotomiflorum Michx.) growth was decreased with early corn planting dates. Also, times of tillage can influence the weed density and species complex. For example, Roberts and Stokes (1973) found that increased numbers of cultivations decreased the density of viable weed seeds but increased the relative abundance of annual bluegrass (Poa annua L.).

Plants differ in photosynthetic abilities under different light and temperature regimes. The efficiency of a plant to assimilate CO_2 influences its competitive nature (Black *et al*., 1969). Efficient plants can assimilate larger amounts of CO_2 in high temperatures and light intensities. Therefore, efficient plants are better competitors since biomass is accumlated faster and photosynthates are produced at higher rates than non-efficient plants. Shading has an effect on the competitive nature of an efficient species since full sunlight is needed to produce maximum photosynthate. Examples of efficient crop species are corn (*Zea mays* L.), sorghum (*Sorghum vulgare* Pers.), and sugar cane (*Saccharum offinarum* L.) and of efficient weed species are redroot pigweed, barnyardgrass (*Echinochloa crusgalli* L.), and large crabgrass (*Digitaria sanguinalis* L.).

In addition to the lack of a plant canopy, onions are inefficient in photosynthesis. This lower efficiency makes onions highly susceptible to competition from fast-growing efficient weeds in the early part of the growing season.

Evaluation of Weed-Crop Competition. Competitive interactions can be evaluated in terms of biomass accumulation of the crop and weeds over time (Aldrich, 1984; Weaver and Tan, 1983). Data collected from destructive sampling during the growing season can be fitted by regression analysis to predict crop losses associated with a given weed biomass. Other studies correlated yield limitations with weed numbers rather than weed weight (Aldrich, 1984; Schweizer, 1973; Weatherspoon and Scheizer, 1971; Wicks et al., 1973).

A growth analysis approach also may be used to explain the nature of crop-weed competition. This technique observes growth parameters of an indicator species, usually the crop plant, such as leaf number, leaf area and fruit number under different regimes of competition. This type of evaluation was used by Hewson and Roberts (1973) to determine competitive effects of weeds on the growth of onions and on corn (Bhowmik and Curry, 1983; Podmayer and Bhowmik, 1986).

A more recent technique to assess weed interference to crops is the sphere of influence (Chandler, 1986; Brecke, 1988; Henry and Bauman; 1988). This method evaluates the influence of single weeds growing at various distances from the crop row during the growing season. This technique is useful for determining the effect of low densities of weeds on crop growth.

Growth parameters of weed-crop interactions and weed population dynamics under different environmental conditions and management practices can be integrated into mathematical models which can aid in understanding the complexities of weed-crop competition (Norris, 1987; Schreiber, 1987). However, widespead applications of mathematical models in weed science is limited, because of the numerous variables involved between different species of plants (Palmblad, 1967; Shaw, 1982).

Weed Control in Onions

Chemical control integrated with mechanical cultivation and handweeding is now the most effective weed control program for onions. Mineral soils indigenous to the Connecticut River Valley limit the number of available herbicides for onion production. Because mineral soils do not form strong complexes with herbicides, the probability of phytotoxicity to onions is high. On the other hand, the muck soils of New York state, for example, are less permeable than mineral soils and allow less herbicide penetration to the root zone. The lack of herbicide penetration to the root zone permits a wider variety of herbicides to be used on muck soils, while reducing the overall cost of onion production in New York State. In addition to reduced costs for weed control, operations in this state are large which permit growers to reduce costs due to economies of scale.

Chemical Control. Precheur (1982, 1984) and Sieczka *et al.* (1983) evaluated several registered and experimental herbicides for use on mineral soils. In these studies, registered herbicides alone were inadequate for full-season weed control. Majek (1985), in a study comparing the cost of handweeding and cultivation to the cost of registered and experimental herbicide programs, found that no standard herbicide program provided adequate weed control for onions. In India, Rana et al. (1985) determined that the best economic yield in onions was obtained with a combination of 100 kg N/ha and 2 handweedings. An integrated weed control program, as reported by Henne and Poulson (1980) for carrots and tomatoes, is needed for cost effective onion production.

Integrated Control. The prospects of implementing integrated weed management (IWM) systems as a component of integrated pest management systems (IPM) was discussed by several authors (Bhowmik, 1986; Blair and Parochetti, 1982; Heitefuss and Niemann, 1985; Norris, 1985). However, actual implementation of comprehensive systems aided by mathematical modeling is lacking.

The concept of economic threshold levels is central to IPM programs for insects. The economic threshold is defined as the pest density above which will result in a loss of growers' revenue. Since the economic threshold can vary for individual growers, an action threshold is used in IPM programs. The action threshold is lower than the economic threshold leval to allow for errors in sampling and predictions. Implementation of weed thresholds is difficult because of the explosive population dynamics of weeds. For example one, barnyardgrass plant in 10 meters of sugarbeet row can return approxiamatly 18,000 seeds/m^2 to the seed bank (Norris, 1985). When considering the cost of removing a large population of weeds the following year, the logical threshold for many highly reproductive annual weed species is zero (Norris, 1985). For this reason Norris (1985) introduced the concept of zero threshold levels for weeds in crops, since weed control must exceed 99.99% efficiency, based on computer generated weed seed population dynamics models, to allow the seed bank to remain static. Mengis (1987) supported the concept of zero thresholds after examining the population dynamics of palmer amaranth (Amaranthus palmeri S. Watts) under different weed management systems. It was determined that 18 million weed seeds existed in the seed bank after maintaining a six-year weed-free period. However, research is being conducted to establish economic thresholds for specific weed-crop interactions (Wyse, 1987; Chandler and Bridges, 1987; Smith 1987; Coble 1987). Knowledge of weed biology, population dynamics and dispersion, area of influence and the competitive ability of the crop and weed must be established in order to develop an effective economic threshold level.

The first step in successful IPM programs is growers' cooperation. Accurate record keeping of costs associated with pest control and other variable costs on a per hectacre basis, as outlined by Morzuch (1986), is essential for the development of a cost-effective management program. Baldwin (1986) recommended the use of minimum input weed control systems to reduce the weed control costs in soybean production, designed to reduce weed management inputs to a minimum while reducing weed infestastions below threshold levels. When all of the costs associated with the production of a crop are known, costs can be compared with economic returns. Adjustments can be made to develop the most cost-effective production scheme.

CHAPTER 2

ONION WEED COMPETITION STUDY

Abstract

Weed competition studies in onion (*Allium cepa* L.) were conducted in 1986 and 1987 in South Deerfield, Massachusetts. The competitive effects of duration and densities of weeds on onion growth, quality, and yield were determined. A competition study was conducted under greenhouse conditions in 1987. In the field, the natural population of weeds allowed to grow with onions for 1, 2, 3, or 4 weeks after onion emergence, limited onion yields by 40, 78, 94, or 100% respectively, relative to onions from the weed-free control. Conversely, plots that were kept weed-free for 2, 4, 6, or 8 weeks after emergence, resulted in 80, 19, 29, 0 or 0% yield restrictions, respectively, relative to weed-free onions.

In 1986, weeds restricted onion dry weight, bulb diameter and leaf number by 2 weeks after onion emergence compared to weed-free onions. Bulbing was earlier as the initial weedy period increased. Treatments that were weed-free initially for less than 6 weeks produced onions that were less in dry weight and bulb diameter than weed-free onions. In 1987, a crop failure resulted approximately 4 weeks after onion emergence, due to weather conditions and injury to onions from manual weeding. No differences

occurred between onion growth parameters in 1987 as a result of large experimental error.

The effects of three weed densities on the growth of onions were examined. The original weed densities were 1170 weeds/m^2 and 470 weeds/m^2 in 1986 and 1987, respectively. The original weed densities were thinned to approximately 100, 50, 15, and 0% of the uncontrolled population and referred to as high, medium, low, and weed-free, respectively. Restrictions in onion growth were earlier as the weed density increased; however, at 6 weeks after emergence, all weed densities restricted all phases of onion growth. In the greenhouse, onion fresh weight and leaf number in all weed densities were severely limited at 8 weeks after emergence compared to the weed-free control.

Introduction

Weed-crop competition studies have been an area of research in weed science for many years. Weed-crop competition studies examine the effects of weed duration and densities on crop growth and yields. One method used to determine the effects of weed duration on crop yields is termed the "critical period". It is the specific time at which weeds must be removed to prevent a yield loss.

The critical period of weed competition has been determined for many crops (van Heemst, 1985; Zimdahl, 1980). The concept of the critical period is defined by two components. The first states that the crop must be kept free of weeds for a period of time after crop emergence, after which the emergence of weeds will not significantly limit the crop yield. The presence of weeds prior to this period will restrict crop yields significantly. The second component of the critical period is defined by the period of time that the crop can tolerate initial weed emergence, after which competition will result in a significant yield loss. The length of time between these two periods is termed the critical period (Frieson, 1979).

The critical period of weed competition differs for different weed-crop situations. Crop and weed species differ in their competition and are influenced by environmental conditions and crop management. For example, Weaver and Tan (1983) determined that a single weeding between 28 and 35 days after transplanting was sufficient to maintain yields of tomatoes (*Lycopersicon esculentum* Mill.). Bhowmik (1984) reported that plots receiving a weed-free period between 4 and 6 weeks after transplanting cabbage (*Brassica oleracea* L.) produced marketable yields equal to that of weed-free plots. The critical period has practical implications since it defines the requirements for chemical or cultural weed control (Friesen, 1979).

Weed densities affect the period in which competition occurs. In certain weed-crop situations, low densities of weeds will not limit significantly the crop yield. For example, Ali *et al*. (1986) determined that johnsongrass [*Sorghum halepense* (L.) Pers.] infestation levels less than 15% of the uncontrolled population, did not substantially restrict yields in sugar cane (*Saccharam officinarum* L.). However, Frieson (1979) showed that in tomatoes (*Lycopersicon esculentum* L.) weeds at densities as low as 5% of the uncontrolled weed population produced biomass equal to unweeded controls if left to grow for the entire growing season.

Onions are poor competitors with weeds (Zimdahl, 1980). They have slow germination and initial growth and lack a complete leaf canopy, which make them highly susceptible to early season weed competition (Hewson and Roberts, 1971). A survey of weed competition on crop yield by van Heemst (1985) placed crops in hierarchical order of declining competitive ability, ranking wheat (*Triticum aestivum* L.) and soybean (*Glycine max* Merr.) at the top of the list and onions and carrots (*Daucus carota* L.) at the bottom.

Shadbolt and Holm (1956) examined some effects of weed competition on carrots, beets (*Beta vulgaris* L.) and onions. Of these vegetables, onions were most susceptible to weed competition. This study examined the effect of various weed densities on onion growth. Shadbolt and Holm concluded that, regardless of the weed density, injury to onions was significant by 6 weeks after onion emergence.

Hewson and Roberts (1971) in England determined that the presence of weeds for the first 4 to 6 weeks after 50% onion emergence did not affect yield if the crop subsequently was kept weed free. Also, if the crop was kept clean for the first 6 to 8 weeks after 50% emergence, subsequent weeds did not affect the crop yield. There was a critical period between 5 and 7 weeks after 50% emergence. Hewson and Roberts (1973) found that onions subjected to weed competition for 7.5 weeks after 50% emergence had little subsequent increase in bulb size or dry weight. Wicks *et al*. (1973) evaluated competitive effects between annual weeds and sweet Spanish onions. Duration of weeds in the row for 2, 4, and 6 weeks after onion emergence limited onion yields by 20, 40 and 65%, relative to weed-free onions, respectively. Conversely, plots kept weed-free until onion emergence and 2, 4, 6, 8, 10, and 12 weeks after onion emergence had yields decreased by 100, 99, 87, 75, 46, 25, and 5% that 0f the weed-free plots, respectively.

The objectives of this experiment were to evaluate the competitive effects of weeds in relation to the duration of competition and density of weeds on the growth, yield, and quality of onions.

Materials and Methods

General Methods

Field experements were conducted at the Massachusetts Agricultural Research Station in South Deerfield. Onions ¶Gambler' were sown in Hadley fine sandy loam (Typic, Udifluvents, Mesic) with a double shoe-precision seeder at a density of 39 seeds/m-row. Seeds were planted in rows spaced 38 cm apart. Onion beds consisted of 4 double rows of onions. The experimental area was fertilized with 100 kg/ha of each N, P_2O_5, and K_2O and limed to pH 6.5 to 6.9. The soil was drenched with diazinon (O,O - diethyl O - 2 - isopropyl - 6 - mythylpyrimidin - 4 - yl phosphorothioate) to control onion maggot (*Delia antiqua* L.) in June. The onions were sprayed weekly with diazinon and maneb (mangenese ethylenebisdithiocarbamate) to control onion thrips (*Thrips tabaci* Linde.) and botrytis blast (*Botrytis cinerea* L.), respectively.

In 1986, the initial weed composition was 80% common lambsquarters (*Chenopodium album* L.), 13% fall panicum (*Panicum dichotomiflorum* (L.) Michx.), 4% large crabgrass (*Digitaria sanguinalis* (L.) Scop.), and 3% barnyardgrass (*Echinochloa crus-galli* L.). In 1987, the weed population consisted of 70% lambsquarters, 20% redroot pigweed (*Amaranthus retroflexus* L.), 3% horseweed (*Erigeron canadensis* L.), 3% yellow foxtail (*Setaria lutescens* L.), 3% large crabgrass, and 1% fall panicum.

Effects of the Duration of Weed Competition

The following treatments were used: a) weeds removed at onion emergence and 1, 2, 3, and 4 weeks after onion emergence and then kept weed-free for the remainder of the season; b) plots kept weed-free for 2, 4, 6, and 8 weeks after emergence. Weeds were removed between onion rows by cultivation and weeds within the row were removed by handweeding. Treatments were arranged in 4 randomized complete blocks. In 1986, the plot size was 1.8- by 4.6-m, and in 1987, the plots were 1.8- by 6.1-m.

In 1987, a crop failure resulted due to a hot and dry spring and extremely heavy weed infestations. Sampling was, therefore, terminated at 2 weeks after onion emergence.

Weeds and onion plants were sampled at each scheduled weed removal date from a 15 by 30 cm quadrant in the center two rows. Onions subsequently were sampled at approximately two week intervals after weed removal. In treatments kept initially weed-free, crop and weed plants were sampled at two-week intervals after the period in which weeds were allowed to grow until onion harvest. Weed samples were separated by species. Their fresh and dry weights were recorded, and heights were measured. Weed biomass for plots initially receiving various periods of initial weed competition, was determined at the time of weed removal. Weed biomasss for treatments in which weeds were allowed to grow for the remainder of the season, after various weed-free periods, was determined at onion harvest.

The following growth measurements of onions were recorded:

a) Bulb diameter.

b) Bulbing ratio; the ratio of the maximum diameter of the base to the minimum diameter of the neck. Before bulbing, the maximum diameter at base of the plant was measured.

c) Leaf number.

Onion yields were determined by harvesting 2-m of the the center two rows. The harvested onions were placed in onion bags and cured until the tops were totally brown. The dried tops were then removed, and the onion bulbs were graded into the following sizes: <2.5 cm, 2.5-5.0 cm, and 5.0-7.5 cm. Onions less than 2.5 cm in diameter were considered culls, and onions 2.5 cm and above were considered marketable.

Effect of Weed Density

Field Study. In 1986 and 1987, the plot size was 1.8 by 3-m. Weeds were allowed to grow in a 15-cm band over the onion row for approximately one week. Weeds were then counted and thinned to approximately 100, 50, 15, and 0% of the natural weed density of 1170 weeds/m^2, in 1986. The densities were referred to as high, medium, low, and weed-free, respectively. In 1987, the natural weed density was 470 plants/m^2. Onions and weeds were sampled at approximately two-week intervals after the weed densities were established. The same growth measurements described above for the critical period study were used on these samples. Onions were sampled until weed injury was too severe for further growth measurements on onions. Sampling continued until July 15 in 1986 and June 22 in 1987. Regression analyses were used on data in 1986 to describe the relationship between crop weight and weed density.

Greenhouse Study. In the winter of 1987, a competition study between onions and weeds was conducted in the greenhouse. Seeds of onions, barnyardgrass, and common lambsquarters were sown together in 15-cm plastic pots. At emergence, the weeds were thinned to three densities: low, medium, and high; and the onions were thinned to four plants per pot. The initial weed densities were approximately 2, 4, and 8 weeds per pot for each weed species for the low, medium, and high densities, respectively. A weed-free control also was included. Pots were arranged in 4 randomized complete blocks, with six observations of each treatment within each block. The four blocks were harvested at 2, 4, 6, and 8 weeks after onion emergence. At each harvest, the onions and weeds were measured using the same methods as the field studies. Multiple linear regression was used to evaluate the competitive effects of barnyardgrass and common lambsquarters weight and densities on onion weight.

Analysis of variance was used to compare all data among treatments. Comparisons of means were made by computing the least significant difference (LSD). In the critical period study, onions in the treatment weedy for 4 weeks did not survive after the weeds were removed. Therefore, this treatment was not included in analyses of onion growth, but growth parameters were recorded in tables as zero. In the weed density study, to reduce the sample variance, comparisons of weed weight and numbers among treatments did not include the weed-free control.

Results

Effects of the Duration of Weed Competition

Effects on Onion Growth and Development. In 1986, one week of initial weed competition inhibited onion dry weight and bulb diameter, relative to the weed-free control (Table 2.1). At this time, the average weed dry weight per plant was 27 times greater than the average onion dry weight per plant, and weed dry weight per unit area was 55 times greater than the corresponding onion dry weight. Weed competition for 2 weeks restricted the average onion leaf number. At 2 to 3 weeks of weed duration, there was no increase in average onion weight per plant, but average weed weight nearly doubled. Average weed dry weight per plant increased from 48 times the average onion dry weight per plant to 91 times greater, and weed dry weight per unit area increased from 98 to 271 times the onion dry weight per unit area. At 4 weeks after onion emergence, average weed dry weight was 80 times greater than average onion dry weight, and weed dry weight per unit area was 176 times the corresponding onion dry weight.

After weeds were removed, onions under competition for 1 week had an average dry weight that was no longer significantly less than the weed-free control at 8 weeks after emergence (Table 2.2). Onions receiving competition for 2 and 3 weeks were less in dry weight than those in weed-free plots for the duration of the growing season.

Table 2.1. Dry weight of onions and weeds and onion bulb diameter and leaf number at various time periods in 1986.

Duration of weed competition	Onion growth parameter						Weed dry weight
	Dry weight		Bulb diameter		Leaf		
	Wd-fr	Wdy[a]	Wd-fr	Wdy	Wd-fr	Wdy	
(weeks)	(g/m^2)		(mm)		(no/plant)		(g/m^2)
1	7.9	4.8	4.6	3.0**	2.0	2.0	266
2	32.0	4.3*	5.2	2.8**	3.0	2.1*	414
3	45.0	4.3**	5.8	1.9**	3.0	1.5*	1170
4	155.5	8.1**	6.9	2.4**	4.7	4.2	1390

*, **/Significantly different from weed-free control by LSD (0.05) and LSD (0.01), respectively.

[a]/Wd-fr = weed-free, Wdy = weedy.

Onions grown with weeds for 4 weeks did not survive after weeds were removed.

Onion leaf number, in the treatment weedy for 1 week, was not less than that of the weed free plots for the entire growing season. If plots were weedy for 2 weeks, the onion leaf number was less than weed-free onions until 8 weeks after onion emergence. After 3 weeks of weeds, there was a reduction in leaf number for the entire season.

By 4 to 6 weeks after onion emergence the average bulb diameter of onions in treatments weedy for 1 and 2 weeks, respectively, were not restricted. In plots weedy for 3 weeks, the bulb diameter was not restricted at 8 weeks after onion emergence. However, the bulb diameter of onions in this treatment was less than the weed free control at 10 weeks after emergence (Table 2.2).

At weeks after emergence the bulbing ratio of onions, weedy for 2 and 3 weeks, was greater than the weed-free control and onions weedy for 1 week (Table 2.2). At 8 weeks after onion emergence, the bulbing ratio after weed competition for 1 to 3 weeks appeared greater than the weed-free control, but the ratios were not statistically significant. At 10 weeks after onion emergence, the bubing ratio of the weed-free control onions was greater than the onions of treatments with initial weedy periods (Table 2.2).

The effects of weed competition were greater in onions subjected to initial weed competition than in onions kept

Table 2.2. Effect of initial weed competition on progressive onion growth in 1986.

Time after onion emergence	Onion dry weight	Leaf number	Bulb diameter	Bulbing ratio
	Period of initial weed competition			
(weeks)	(g/plant)	(no./plant)	(mm)	
	(1 week)			
1	0.01*	2.0	3.0*	0[a]
2	0.20**	3.4	7.0	0.25
6	0.65*	5.3	9.2	0.37
8	1.35	5.9	16.5	2.10
10	2.02	6.3	22.7	1.78
	(2 weeks)			
2	0.02**	2.1*	2.8**	0
6	0.31**	4.5*	9.2	1.75**
8	0.62**	4.8	14.5	1.43
10	0.19**	4.9	22.7	2.27
	(3 weeks)			
3	0.02**	1.5*	1.9**	0
6	0.11**	2.5**	7.6	2.30*
8	0.31**	3.5**	6.6**	2.77
10	0.19**	1.1**	3.5**	0.88**
	(4 weeks)			
4	0.03**	4.2	2.4**	0
6	0	0	0	0

a/Bulbing ratios less than 0.10 were listed as 0.

*, **/Significantly different from weed-free control by LSD (0.05) and LSD (0.01), respectively.

initially weed-free for various periods (Tables 2.3 to 2.6). The average onion dry weight, from plots kept weed-free for 2 weeks after emergence, was less than weed-free onions at 8 weeks after emergence. Onions kept weed-free for 4 weeks were limited in average dry weight, at 6 weeks after emergence and remained restricted for the remainder of the season. The average onion dry weights from weed-free periods of 8 and 10 weeks were not significantly less than weed-free onions for the entire season (Table 2.3).

Bulb diameters of onions kept weed-free for 2 and 4 weeks were limited at 10 weeks after emergence (Table 2.4). Onions in plots kept weed-free longer than 4 weeks were not limited in bulb diameter. The bulbing process was not as early in onions kept weed-free initially as it was in onions under initial weed competition. The bulbing ratio of onions initially weed-free for various periods was not greater than weed-free onions at 6 and 8 weeks after emergence. The bulbing ratio of onions kept weed-free for 4 and 8 weeks were less than weed-free onions at 10 weeks after emergence (Table 2.5).

Onions kept initially weed-free for 2 and 4 weeks were significantly less, in leaf number, than weed-free onions at 10 weeks after emergence. Onions kept weed-free for longer than 4 weeks were not affected in leaf number, relative to the weed-free control, for the entire growing period (Table 2.6).

Table 2.3. Effects of initial weedy and weed-free periods on onion dry weight at various time intervals in 1986.

Time period	Onion dry weight		
	Weeks after onion emergence		
Initial weedy	6	8	10
(weeks)	(g/plant)		
1	0.65	1.35	2.02
2	0.31	0.62	0.94
3	0.11	0.31	0.22
4	0.00	0.00	0.00
Initial weed-free			
2	0.82	0.73	1.01
4	0.64	1.27	1.24
6	--[a]	2.67	3.52
8	--	--	3.77
All season (12 wks)	1.16	2.50	3.04
LSD (0.05)	0.48	1.28	1.77
LSD (0.01)	0.68	1.76	2.40

[a]/Horizontal lines represent no data for treatments in respective sampling periods.

Table 2.4. Effects of initial weedy and weed-free periods on onion bulb diameter at various time periods in 1986.

Time period	Onion bulb diameter		
	Weeks after onion emergence		
Initial weedy	6	8	10
(weeks)	(mm)		
1	9.23	16.45	22.7
2	9.75	14.48	22.7
3	7.58	6.55	3.5
4	0.00	0.00	0.0
Initial weed-free			
2	11.08	12.88	12.88
4	11.00	15.28	16.13
6	--[a]	18.43	33.83
8	--	--	32.40
All season (12 wks)	10.18	19.33	30.10
LSD (0.05)	ns	5.34	10.10
LSD (0.01)	ns	7.30	13.73

[a]/Horizontal lines represent no data for treatments in respective sampling periods.

Table 2.5. Effects of initial weedy and weed-free periods on onion bulbing ratio at various time intervals in 1986.

Time period	Onion bulbing ratio		
	Weeks after onion emergence		
Initial weedy	6	8	10
(weeks)			
1	0.38	2.10	1.78
2	1.75	2.80	2.28
3	2.30	2.77	0.88
Initial weed-free			
2	0.25	1.57	2.65
4	0.88	1.70	2.65
6	--[a]	1.48	3.45
8	--	--	3.40
All season (12 wks)	0.53	1.43	3.55
LSD (0.05)	0.89	ns	1.17
LSD (0.01)	1.23	ns	1.56

[a]/Horizontal lines represent no data for treatments in respective sampling periods.

Table 2.6. Effects of initial weedy and weed-free periods on onion average leaf number at various time intervals in 1986.

Time period	Average onion leaf		
Initial weedy	Weeks after onion emergence		
	6	8	10
(weeks)	(no./plant)		
1	5.25	5.90	6.25
2	4.45	4.83	4.87
3	2.52	3.50	1.13
4	0.00	0.00	0.00
Initial weed-free			
2	5.80	1.57	2.65
4	5.10	1.70	2.65
6	--[a]	1.48	3.45
8	--	--	3.40
All season (12 wks)	5.63	4.53	5.00
LSD (0.05)	0.91	0.99	1.51
LSD (0.01)	1.27	1.35	2.06

[a]/Horizontal lines represent no data for treatments in respective sampling periods.

The sampling period in 1987 lasted only for the first 2 weeks after onion emergence (Table 2.7). Average weed dry weight per plant was 7 times greater than the average onion dry weight per plant 1 week after onion emergence. The weed dry weight per unit area was 13.5 times greater than the corresponding onion dry weight. At 2 weeks after onion emergence, the average weed dry weight per plant was 55 times greater than the average onion dry weight per plant, and weed dry weight per unit area was 85 times greater than onion dry weight. The differences in dry weight between weedy and weed-free onions were not significant after 2 weeks in 1987. The effects of weed competition on bulb diameter and leaf number also were not significant (Table 2.7). Despite the short sampling period in 1987, the initial effects of weed competition was observed.

Weed Biomass. In 1986, the initial weed composition was 80% common lambsquarters. The remaining 20% was a mixture of fall panicum (*Panicum dichotomiflorum* Michx.), large crabgrass (*Digitaria sanguinalis* Scop.), and barnyardgrass. Treatments that were initially kept weed-free for various periods had increasingly greater percentages of grasses at onion harvest as the initial weed-free period increased (Table 2.8). From 2 to 6 weeks of initial weed-free periods, the predominant grasses were fall panicum and large crabgrass. For plots kept weed-free for 8 weeks, there was a greater percentage of barnyardgrass than

Table 2.7. Onion and weed dry weights and onion bulb diameter and leaf number at 1 to 2 weeks after onion emergence in 1987.

Duration of weed competition	Onion growth parameter: Dry weight	Bulb diameter	Leaf	Weed dry weight
(weeks)	(g/m^2)	(mm)	(no./plant)	(g/m^2)
1	5.9	2.6	1.0	90.0
2	5.4	2.9	1.7	460.0

fall panicum. Plots kept weed-free for 10 weeks had weeds that were 100% fall panicum at onion harvest.

The weed density increased to nearly 1400 weeds/m^2 from 1 to 4 weeks of weed duration after onion emergence (Table 2.8). Plots kept weed-free for 2, 4, and 6 weeks had weed densities of 1380, 2640, and 1440 weeds/m^2, respectively, at onion harvest. In treatments kept weed-free for 8 and 10 weeks, weed densities were limited to 911 and 82 weeds/m^2, respectively. Weed fresh weight increased rapidly from 1 to 3 weeks after onion emergence, and then leveled off at approximately 79,000 kg/ha at 4 weeks. After 4 weeks of initial weed-free period, weed weight at onion harvest began to decline. From 6 to 8 weeks of initial weed-free period, the weed biomass at onion harvest dropped from 98,000 kg/ha to 41,000 kg/ha. After 10 weeks weed-free period, weed weight at onion harvest was 4100 kg/ha.

In 1987, the predominant weed species were common lambsquarters (70%) and redroot pigweed (20%), the others included large crabgrass, yellow foxtail (<u>Setaria lutescens</u> Hubb.), horseweed (<u>Erigeron canadensis</u> L.), and 1% fall panicum (Table 2.9). From 1 to 2 weeks after onion emergence, the total weed fresh weight increased from 7210 kg/ha to 35970 kg/ha and the weed density increased from 700 to 740 m^2.

<u>Onion Yield.</u> The total yield of onions was highest in the treatment kept weed-free for 10 weeks. This treatment

Table 2.8. Total weed biomass, species composition by weight, and weed densities in 1986. Weeds harvested at onion harvest for treatments initially weed-free.

Time period		Species of weeds[a]					
Initial weedy	Weed biomass	CHEAL	AMARE	PANDI	DIGSA	ECHCG	Weed density
(weeks)	(kg/ha)	(%)					(weeds/m^2)
1	25000	80	0	13	3	4	270
2	51000	77	0	10	10	3	540
3	79000	79	0	4	6	1	1170
4	79000	88	0	8	3	1	1390
Initial weed-free							
2	108000	23	36	24	17	0	1380
4	150000	11	42	24	12	11	2640
6	98000	0	14	31	55	0	1440
8	41000	0	24	0	38	38	911
10	4100	0	0	100	0	0	81

a/CHEAL, AMARE, PANDI, DIGSA, and ECHCG are codes for common lambsquarters, redroot pigweed, fall panicum, large crabgrass and barnyardgrass, respectively.

Table 2.9. Total weed biomass, species composition by weight and weed densities in 1987.

Time period Initial weedy	Weed biomass	Composition of weeds[a] CHEAL	AMARE	ERICA	PANDI	DIGSA	SETLU	Weed density
(weeks)	(kg/ha)			(%)				(weeds/m^2)
1	7200	70	20	3	1	3	3	700
2	36000	77	12	0	5	7	0	740

[a]/CHEAL, AMARE, ERICA, PANDI, DIGSA, and SETLU are codes for common lambsquarters, redroot pigweed, horseweed, fall panicum, large crabgrass, and yellow foxtail, respectively.

also had the greatest total marketable onion yield (Table 2.10). Yields from treatments that were weedy for 1, 2, and 3 weeks after onion emergence were all less than those from plots kept weed-free for 10 weeks. However, the yield of the weed-free control was greater than only that of the treatment initially weedy for 3 weeks. Onions kept weed-free for 2 and 6 weeks were not less than onions kept clean for 10 weeks. No onions kept initially weed-free for any length of time produced significantly less in total onion yield than the weed-free control.

The effects of the various weedy and weed-free periods on onion grades at harvest are shown in Table 2.10. The weed-free control had 83% marketable onions with 96% in the range of 2.5 - 5.0 cm. The only onions that fell within the 5.0 - 7.5 cm grade were harvested from the weed-free control. Onions harvested after 1 week of initial weed competition had 90% marketable onions. The yield of nonmarketable onions increased to 40% if weeds were initially present for 2 weeks. There were 79% marketable onions from the treatment that was weedy for 3 weeks; however, the onion yield from this treatment was the lowest of all treatments. For plots kept weed-free for 2 weeks the marketable onion yield was 19%. If onions were kept weed-free for 4 weeks, the marketable yield increased to nearly 80%. If onions were kept weed-free for 6 weeks, the marketable yield was 56%. Treatments kept weed-free for 8

Table 2.10. Yield and grade of onions for critical period study in 1986.

Time period	Onion yield			
	Bulb size class (cm)			
Initial weedy	0-2.5	2.5-5.0	5.0-7.5	Total
(weeks)	(kg/ha)			
1	520	4810	0	5300
2	790	1210	0	2000
3	67	340	0	490
4	0	0	0	0
Initial weed-free				
2	1520	240	0	1760
4	1450	5730	0	7180
6	2600	3330	0	5930
8	910	8080	0	9000
10	960	12490	0	13000
All season (12 weeks)	1514	7060	328	8901
LSD (0.05)	1212	7548	ns	7657

and 10 weeks were both approximately 90% marketable. The effect of weedy and weed-free periods on total onion yield, expressed as a percentage of the weed-free control, is illustrated in Figure 2.1. Yields from treatments initially weedy dropped rapidly from 1 week of initial weed duration. Conversely, after 2 weeks weed-free period, onion yields increased rapidly. Based on this study, the critical period of weed competition was between 3 and 6 weeks after onion emergence.

Effect of Weed Density

Field Study. In 1986, differences between the average onion dry weight per plant between the weed-free control and weedy control (high density) occurred at 2 weeks after onion emergence (Table 2.11). The bulb diameter of onions in the high and medium weed densities were smaller compared to the weed-free control. There was also a decrease in leaf numbers of onions in the high weed density compared to the weed-free control (Table 2.11).

High (200/m^2) and medium (150/m^2) densities of weeds restricted onion dry weight at 4 weeks after onion emergence, compared to weed-free onions. At 6 weeks after onion emergence, all weed densities decreased onion dry weight. The dry weight of onions in the high weed density was reduced to zero, and onions in the weed-free control tripled in dry weight from 4 to 6 weeks after emergence.

The medium and high weed densities inhibited bulb

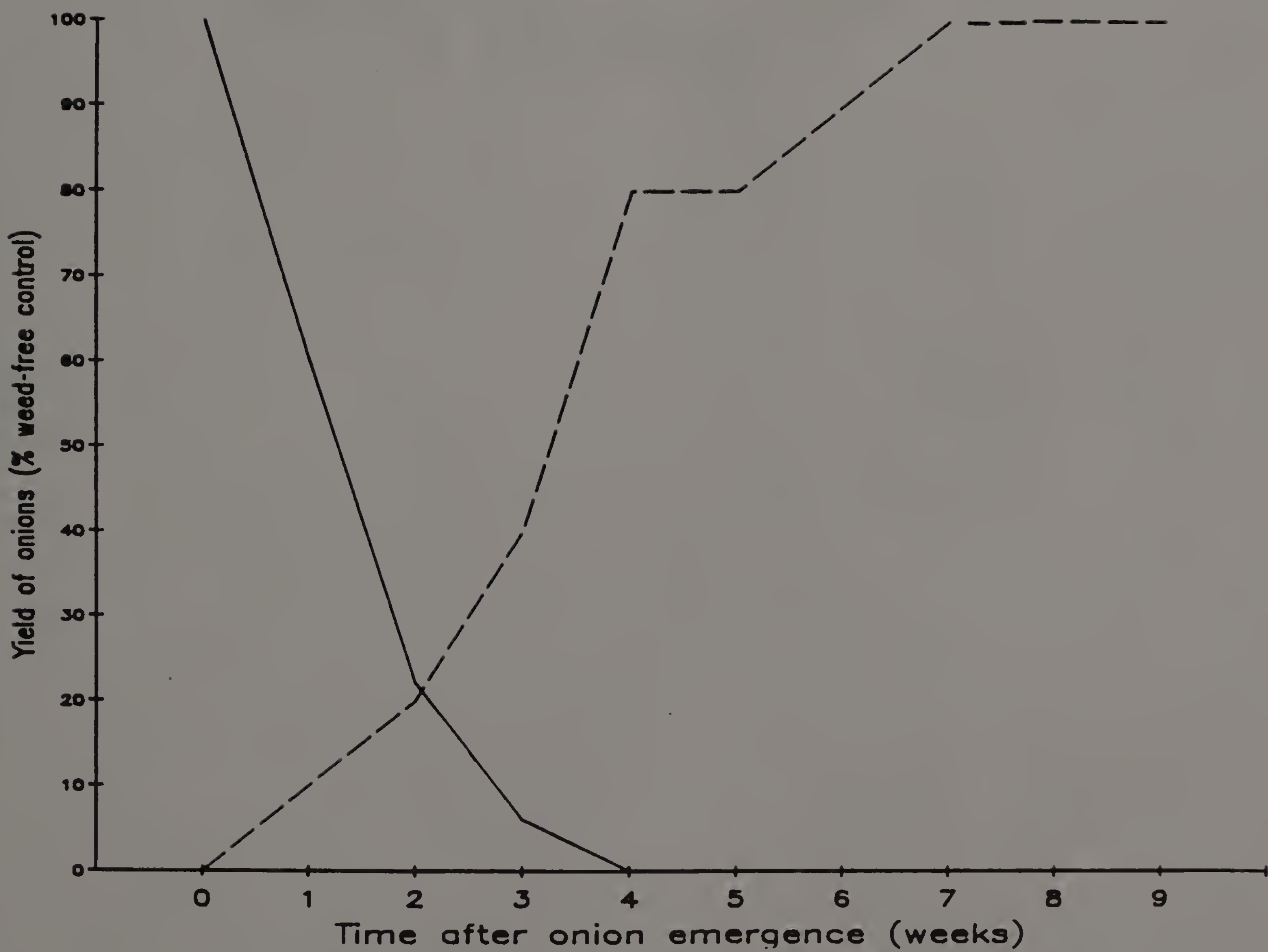

Figure 2.1. The effect of weedy (descending line) and weed-free (ascending line) periods on total onion yield in 1986.

Table 2.11. Effect of the duration of weed competition and density on onion dry weight, bulb diameter and leaf number 1986.

Duration of competition	Weed density	Growth parameter: Onion dry weight	Bulb diameter	Leaf number
(weeks)		(g/plant)	(mm)	(no./plant)
2	zero	0.01	5.1	3.0
2	low	0.06	4.6	2.9
2	medium	0.06	4.1*	3.0
2	high	0.02**	2.7**	2.5**
4	zero	0.28	8.0	4.6
4	low	0.18	7.0	3.4**
4	medium	0.14*	3.9**	3.0**
4	high	0.07*	2.3**	2.5**
6	zero	0.95	12.6	5.8
6	low	0.28**	6.4**	3.6**
6	medium	0.14**	4.6**	2.5**
6	high	0**	0**	0**

*,** Significantly different from weed-free control at LSD (0.05) and LSD (0.01), respectively.

diameter at 6 weeks after emergence, relative to the weed-free control. Onion bulb diameters in the low weed density were not reduced at this time. By 8 weeks after emergence, onions at all weed densities were smaller in bulb diameter than the weed-free control (Table 2.11). Onion leaf numbers from all weed densities were decreased from 6 to 8 weeks after onion emergence (Table 2.11).

Regressions were calculated between onion and weed weight (Figure 2.2). The following equation resulted in the best fit of the data:

$$\underset{(2.9)}{Y = 24.0} - \underset{(0.19)}{0.70X} \qquad R^2 = 0.42$$

where Y is the predictied onion fresh in 30.5-cm of row at 2 to 6 weeks after onion emergence. X is the average number of annual weeds present in 30.5-cm of onion row and the values in parenthesis below the coefficients are their standard deviations.

In 1987, differences in onion dry weight were not significant 4 weeks after emergence (Table 2.12). However, there were apparent reductions in dry weight in onions grown with weeds at 2 weeks after onion emergence. Onion bulb diameters were also not significantly affected at 4 weeks after emergence in weedy onions. Onion leaf numbers were reduced at a significant level by 4 weeks after emergence. At 4 weeks after emergence, onions in the low and high weed densities were restricted severely in dry weight and bulb

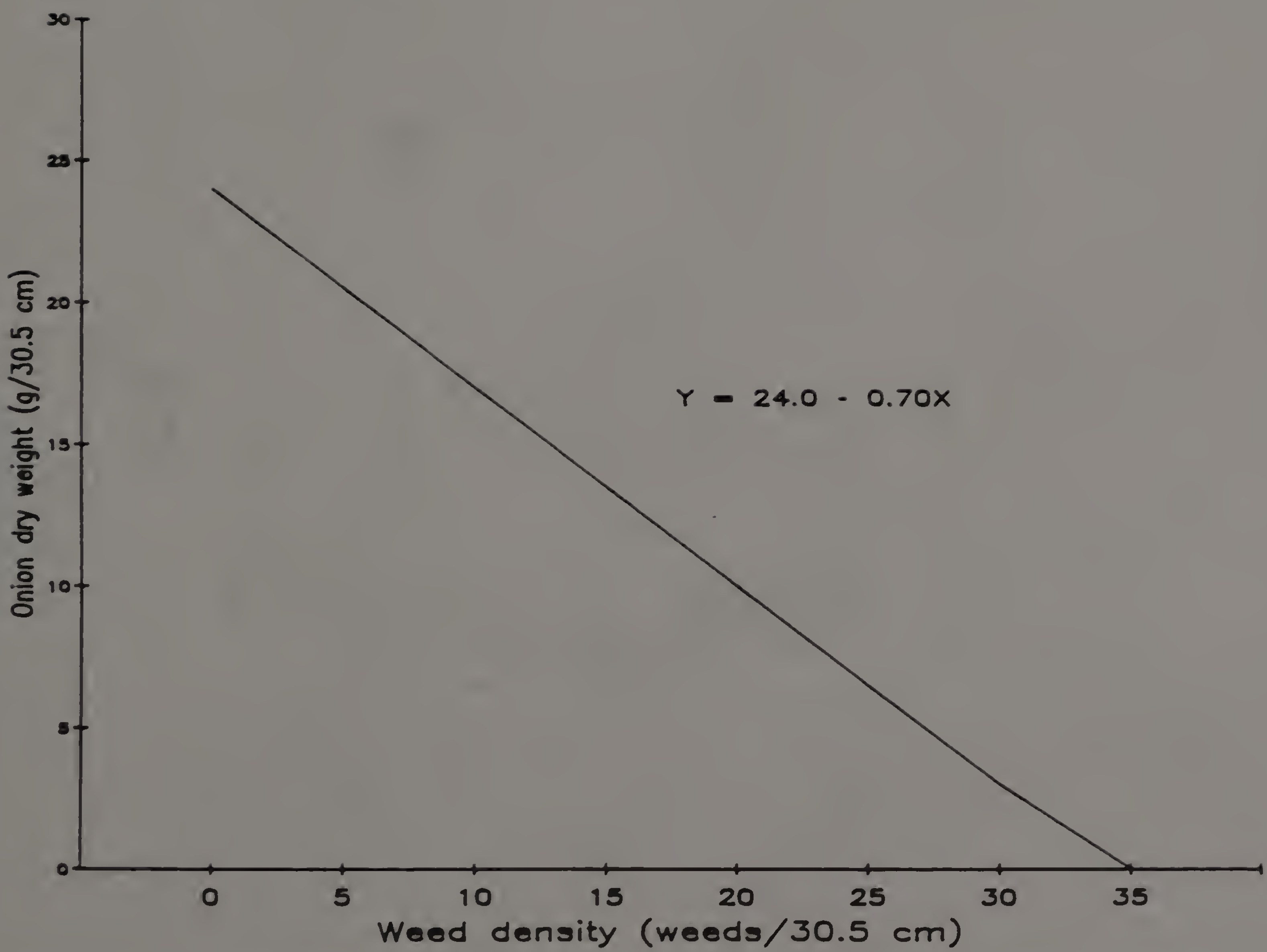

Figure 2.2. Regression of weed density on onion dry weight from 2 to 6 weeks after onion emergence with R^2=0.42 in 1986.

Table 2.12. Effect of the duration of weed density on onion dry weight, bulb diameter and leaf number in 1987.

Duration of competition (weeks)	Weed density	Onion dry weight (g/plant)	Bulb diameter (mm)	Leaf number
2	zero	0.04	2.4	1.1
2	low	0.04	2.4	1.1
2	medium	0.03	2.3	1.1
2	high	0.03	2.4	1.4
4	zero	0.27	5.5	2.9
4	low	0.03	4.5	2.0**
4	medium	0.13	5.3	2.0**
4	high	0.07	4.9	2.0**

*,** Significantly different from weed-free control at LSD (0.05) and LSD (0.01), respectively.

Table 2.13. Effect of weed densities on weed dry weight in 1986 and 1987.

Duration of competition	Weed density	Weed dry weight 1986	Weed dry weight 1987
(weeks)		(g/m^2)	
2	low	199	53
2	medium	314	108
2	high	1042	379
LSD (0.05)		305	ns
LSD (0.01)		481	ns
4	low	1223	1072
4	medium	1391	764
4	high	2046	1396
LSD (0.05)		ns	ns
6	low	3366	--
6	medium	2352	--
6	high	6237	--
LSD (0.05)		ns	

diameter, but were not significant.

In 1986, differences in weed dry weight per unit area were significant at 2 weeks after emergegence. (Table 2.13). There were no differences between average weed dry weights per plant at this time. By 4 weeks after onion emergence, there was no difference among the weed weights per unit area for the various densities; however, there was a difference among the average weed dry weights per plant. At 6 weeks after onion emergence, there was no difference between weed dry weight per unit area or average weed dry weight. In 1987, there was no significant difference among weed dry weights, but greater dry weights in low density weeds were apparent by 4 weeks after onion emergence (Table 2.13).

Greenhouse Study. In the greenhouse, onion fresh weight per pot was less in the high and medium weed densities compared to weed-free onions at 2 weeks after emergence (Table 2.14). However, the average onion fresh weights per plant were not less than weed-free onions at this time. The bulb diameters were inhibited in all onions growing with weeds, but only the bulb diameter of onions in the high weed density was less significantly than weed-free onions (Table 2.14). The leaf numbers of weedy onions were not reduced from the weed-free onions at this time. Onion fresh weight per pot in the low weed density was half that of weed-free onions, but the difference was not statistically significant. Average onion fresh weights per plant and bulb diameter also were not significantly different among treatments at this time. High weed density reduced the leaf numbers of onions compared to weed-free onions.

At 6 weeks after onion emergence, there was a difference between onion fresh weights per pot in the high and medium weed densities compared to the weed-free control. At this time, there was a difference between onion leaf numbers in the medium and high weed densities and weed-free onions.

At 8 weeks after onion emergence, there were significant differences between onions in all weed densities in relation to weed-free onions, in both fresh weights per pot and average fresh weight per plant. There was also an increase in the bulbing ratio of onions in the high weed density, compared to weed-free onions, indicating earlier bulbing in weedy onions. The bulb diameter was not less in weedy onions from the weed-free control. All weed densities resulted in restrictions in onion leaf number in comparison to weed-free onions at this time.

The following multiple linear regression equation best described the relationship between onions and weeds harvested 6 weeks after onion emergence:

$$\underset{(0.35)}{Y = 2.98} - \underset{(0.13)}{0.3ECHCG} - \underset{(0.06)}{0.16CHEAL} \qquad R^2 = 0.50$$

Table 2.14. Effect of weed densities on onion growth parameters in greenhouse conditions in 1987.

Duration of competition	Weed density	Fresh weight	Bulb diameter	Bulbing ratio	Leaf
(weeks)		(g/pot)	(mm)		(no./plant)
2	zero	0.57	1.5	0.0	1.2
2	low	0.42	1.1	0.0	1.1
2	medium	0.30*	1.2	0.0	1.1
2	high	0.27*	0.9*	0.0	1.0
4	zero	1.03	2.7	0.0	2.2
4	low	0.58	2.4	0.0	2.0
4	medium	0.37*	2.3	0.0	1.9
4	high	0.30*	2.1	0.0	1.6*
6	zero	3.55	1.9	0.0	3.0
6	low	1.97	1.6	0.0	2.3
6	medium	0.63**	1.8	0.0	1.8*
6	high	0.66**	1.7	0.0	1.7**
8	zero	3.95	2.0	0.0	4.5
8	low	0.75**	2.0	0.1	2.3**
8	medium	0.73**	1.9	0.4	2.2**
8	high	0.43**	2.0	1.8*	1.9**

The column heads Fresh weight, Bulb diameter, Bulbing ratio and Leaf appear under the spanning heading "Onion growth parameters".

*, ** Significantly different from weed-free control by LSD (0.05) and LSD (0.01), respectively.

where Y equals the onion fresh weight per pot and ECHCG and CHEAL are the barnyardgrass and common lambsquarters densities per pot, respectively. The values below the coefficients are their standard deviations.

At 2 weeks after onion emergence, there was a difference in fresh weight and density, per pot, of barnyardgrass among weedy treatments (Table 2.15). The fresh weight of barnyardgrass in the low weed density was less than the barnyardgrass fresh weight in the high weed density. There was no difference in the average fresh weight per plant of barnyardgrass among weed densities at this time. There were also no differences among common lambsquarters fresh weights per pot or fresh weights per plant at 2 weeks after onion emergence.

At 4 and 6 weeks after onion emergence, there was no difference in barnyardgrass number or fresh weight among weed densities. There was a difference between common lambsquarters density in low and medium weed densities in comparison to the high weed density; however, there was no difference in common lambsquarters fresh weight among weed densities. At 8 weeks after onion emergence, there were differences in both barnyardgrass and common lambsquarters numbers per pot among weedy treatments. There was also a difference in barnyardgrass fresh weight per pot between the high and low densities. Barnyardgrass average fresh weight per plant was not different among densities at this time.

Table 2.15. Effect of weed density on barnyardgrass and common lambsquarters fresh weight under greenhouse conditions in 1987.

Duration of competition	Weed density	Weed species ECHCG[a]	CHEAL
(weeks)		(g/plant)	
2	low	4.1	0.03
2	medium	1.9	0.05
2	high	1.7	0.00
LSD (0.05)		1.7	ns
4	low	9.8	0.50
4	medium	5.4	1.90
4	high	6.7	3.30
		ns	ns
6	low	9.8	0.94
6	medium	5.4	0.15
6	high	6.7	0.21
		ns	ns
8	low	15.4	1.70
8	medium	15.6	0.90
8	high	21.8	0.30
		ns	ns

a/ ECHCG and CHEAL are codes for barnyardgrass and common lambsquarters, respectively.

Differences in common lambsquarters fresh weight were not significant; but there were greater average common lambsquarters fresh weights per plant in the low weed density.

Discussion

These results confirm that weed competition to onions is severe and onion yields are limited to zero if weeds are allowed to grow with the crop for the entire season.

The results agree with those of Hewson and Roberts (1971) who determined that the presence of weeds in onions until the 2- to 3-leaf stage of onions will not limit the yield, provided the crop is subsequently kept weed-free. In our study, the average onion leaf number was 2 to 3, at 2 to 3 weeks after onion emergence. Duration of weeds beyond this time drastically restricted onion growth. Hewson and Roberts (1971) found that the 2- to 3-leaf stage of onions occurred at approxiamately 5-1/2 weeks after 50% onion emergence.

If onions were kept weed-free until the 5- to 6-leaf stage, subsequent weeds did not inhibit the crop yield (Table 2.6). The time in which this growth stage occurred was approxiamately 8 weeks after emergence.

A large experimental error existed in final yield. This error contributed to a large LSD value, making differences between the weed free control and other treatments statistically insignificant. Reasons for this large variation can be attributed to fungi and insect damage. Weedy plots adjacent to clean plots provided a favorable habitat for these crop pests, resulting in inadequate control. The lack of control was a main factor contributing to the poor yield of onions in the weed-free control and treatments kept weed-free after 1 and 2 week weedy periods. This result also shows that besides direct effects of weed competition, the presence of weeds also can limit crop yields by providing a favorable environment for other crop pests.

Wicks et al. (1973), with irrigated sweet Spanish onions in Nebraska, reported that onions must be kept weed-free for 12 weeks to prevent a yield loss. Differences between studies can be attributed to variation in climate, crop variety, cultural practices and weed composition. In addition, critical period studies can differ in their starting time, for example, some studies use sowing or transplanting as starting points. These discrepencies between studies make comparisons difficult to make.

The species composition and emergence patterns of weeds are important factors that affect the critical period. The weed species composition in this study was similar to weeds surveyed by Vengris (1953) in Connecticut River Valley onion fields. At that time, important weeds in onions were large crabgrass, barnyardgrass, common lambsquarters, and redroot pigweed, which were the dominant weed species in this study. Weeds differ in competitive ability and in times of emergence. Regression coefficients derived from the greenhouse weed density study showed that barnyardgrass was more competitive than common lambsquarters. This result was true in the the greenhouse because the temperature was high enough for the C4 species, barnyardgrass, to emerge before common lambsquarters. Competition between common lambsquarters and barnyardgrass resulted in barnyardgrass inhibiting the growth of common lambsquarters (Table 2.15). The increased competitive ability of C4 plant species agrees with reports by Black et al. (1969) who stated that effecient C4 species are more efficient at higher temperatures and light than C3 species because of the ability to assimilate higher rates of CO_2, therefore accumulating biomass faster than non-efficient C3 species. In the field, cooler temperatures in the spring prevented germination of C4 species, but the C3 species, common lambsquarters, began to emerge before the crop. This gave common lambsquarters a competitive advantage over onions and later emerging weeds. Treatments kept initially weed-free for various periods were infested with C4 grasses late in the season, indicating that grasses are the most important weeds in onions later in the season (Table 2.8). Regardless of the weed species, however, if any weeds were present between 3 to 6 weeks after onion emergence, interference with onion growth was severe.

The densities of weeds have an important effect on the period in which weed competition occurs in crops. In the field study, regardless of the weed density, weed competition resulted in significant restrictions in all phases of onion growth by 6 weeks after emergence. This effect of weed density agrees with studies by Shadbolt and Holm (1956) in Wisconsin, who found that weed competition, regardless of the density, was severe by 6 weeks after emergence. Hewson and Roberts (1971) found that weed densities from 0 to 150/m^2 considerably affected the time in which competition occurred. However, further increases in weed density from 150/m^2 to 850/m^2 resulted in little correlation between weed density and the time in which the critical period occurred. In our study, the low weed density was approximately 150/m^2. Onion dry weight and bulb diameter were limited at 2 weeks after emergence regardless of the density (Table 2.11). However, only the high weed density resulted in significant reductions in onion dry weight, while the medium and high densities produced significantly smaller onion bulbs at this time. The lack of statistical significance in growth parameters between weedy and weed-free onions early in the season can be explained by the large experimental error among treatments which resulted in high LSD values.

The effect of weed competition on onions in our study is in agreement with other published studies. The first effect is a restriction in the onion bulb diameter, followed by reductions in leaf number. The reduction in leaf number coincides with premature bulbing (Table 2.2). Heath and Holdsworth (1948) reported that bulbing begins when leaf production ceases. Bulbing in onions is a function of the perception of long day stimulus by young developing leaves (Sobeih and Wright, 1986). Under weed competition, onions produce fewer leaves, and bulbing begins before the critical day length is reached (Hewson and Roberts, 1973).

The factors involved in plant competition were not determined in this study, although shading by weeds was most likely an important factor. At 2 weeks after onion emergence, the average onion leaf height was less than half the average weed height. Hewson and Roberts (1973) suggested that nitrogen was initially competed for, and later moisture stress was a factor. The rapid yield reduction after the critical period was reached (Figure 2.1) could partially be a result of injury to onion roots when weeds were removed. Wicks et al. (1973) reported a 20% yield limitation when weeds were removed 2 weeks after emergence. They suggested that injury to onions at this time was a result of weed removal operations. The yield of weeds at 2 weeks after emergence in the study by Wicks et al. was only 80 kg/ha, whereas the weed yield in our study was 50,000 kg/ha at this time.

These results suggest that the onion crop must be kept weed-free from 3 to 6 weeks after emergence. However, herbicides presently available for onion production will not selectively kill all the weeds present once they have emerged. For this reason a preemergent herbicide is needed. Preememergence herbicides inhibit the the emergence of the spring flush of weeds. Weeds that were present later in the season, after the initial flush of weeds were removed, were mainly grasses. Knowledge of the emergence patterns of weed species can define the requirements for postemergent weed control.

These results do not suggest that there is an "economic threshold level" for weeds in the onion crop. Weeds present later in the season, if left to produce seed, will create large weed populations for the following season. Norris (1985) introduced the concept of zero threshold for annual weeds, since subeconomic levels of weeds will add enormous amounts of seeds to the seed bank. For example, one barnyardgrass plant can add 18,000 seeds/m^2 to the seed bank (Norris, 1985). Norris concluded from weed population dynamic models that weed control must exceed 99.99% efficiency if weed populations are to remain static. The concept of zero threshold was supported by Mengis (1987), who found that palmer amaranth (Amaranthis palmeri S. Watts) was present at levels of 18 million seeds/ha after a 6-year weed-free period. The study by Mengis was part of a larger integrated pest management study which examined the effect of 2 weed management systems on weed seed population dynamics and yields of cantaloupe (*Cucumis melo* L.), bell pepper (*Capsicum annum* L.), cotton (*Gossypium hirsutum* L.), and onion.

Reports by Norris and Mengis suggest that onions should be kept weed-free for the entire season. Knowledge of the critical period can help in developing chemical and cultural weed control programs by defining the times in which lack of control will result in a yield loss. However, reductions in the weed seed bank are especially important for onions, since they often require handweeding. Other crops, such as corn (*Zea mays* L.) do not require handweeding so reductions in the weed seed bank are not as important. However, if onions are to be grown continuously, it could be most economical to achieve 100% weed control to reduce the cost of future weed control.

CHAPTER 3

ONION WEED MANAGEMENT SYSTEMS

Abstract

Field studies were conducted in 1986 and 1987 in South Deerfield, Massachusetts to evaluate the efficacy of herbicides and to evaluate the cost and effectiveness of several weed management systems for onions (*Allium cepa* L.). A separate experiment was conducted under greenhouse conditions in 1987 to evaluate several experimental postemergence herbicides for onion production.

In the field herbicide evaluation, the best weed control and onion yields were obtained with preemergence application of DCPA (dimethyl tetrachloroterephthalate) at 6.7 kg/ha followed by; a second application of DCPA at 6.7 kg/ha at 6 weeks after planting, or postemergence sethoxydim (2-[1-(ethoxyimino) butyl]-5-[2-ethylthio)propyl]-3-hydroxy-2-cyclohexene-1-one) at 0.14 kg/ha or flauzifop-butyl [((±) butyl 2-[4-[(5-(trifluoromethyl)-2-pyridinyl) oxy] phenoxy] propanoate] at 0.14 kg/ha tank-mixed with bentazon (3-isopropyl-1H-2, 1, 3-benzothiadiazin-4(3H)-one 2, 2-dioxide) at 0.28 kg/ha. Preemergence propachlor (2-chloro-*N*-isopropylacetanilide) at 6.7 kg/ha , followed by a second propachlor application at 4.5 kg/ha 6 weeks after planting also resulted in excellent weed control and onion yield. The greenhouse study demonstrated that sethoxydim and bentazon provided effective weed control with no injury to

onions at the 1-leaf stage.

The cost of weed management systems and net economic returns were estimated, utilizing the 2 currently recommended herbicides for onion production in New England, DCPA at 6.7 kg/ha and oxyflourfen [2-chloro-1 (3-ethoxy-4-nitrophenoxy)-4-(triflouromethyl) benzene] at 0.033 kg/ha, in combination with various timings and frequencies of cultivation and handweeding. In 1986, the best economic return was obtained with preemergence application of DCPA followed by 2 cultivations at 2 and 4 weeks after onion emergence. In 1987, the best marketable onion yield and economic return were obtained with preemergence application of DCPA followed by cultivation and handweeding at 6 weeks after planting and then second application of DCPA. The best system using preemergence DCPA followed by postemergence oxyflourfen, in producing marketable onion yield and net return, was 2 oxyflourfen applications at the 3- to 4- and 5- to 6-leaf stage of onions and 2 handweedings at 6 and 8 weeks after planting. The use of herbicides in weed management systems corresponded to savings, compared to cultivation and handweeding only, of $8,900 and $11,700/ha in 1986 and 1987, respectively.

Introduction

Onions were once a major crop in Massachusetts. Over 1,600 hectares per year were harvested in the 1920's with an annual value of over $200,000 (Peterson, 1965). Onion production declined to 50 hectares in 1964, and increased to over 120 hectares from 1978 to 1982. A major factor contributing to the decline and limiting further increases of onion production is the high cost of weed control, which constitutes approximately 40% of the total costs and 80% of the labor costs of onion production (Anonymous, 1985).

Onions are highly susceptible to weed competition (Zimdahl, 1980). They have a slow germination and initial growth, and their leaves lack a dense canopy, resulting in little shading of emerging weeds. Consequently, season-long weed control is vital in onion production.

Onion growers employ herbicides, cultivation, and handweeding in their weed control programs. The high cost of weed control in onion production can be attributed to the expense of handweeding, which constitutes nearly 60% of the cost of weed control (Anonymous, 1985). Herbicides alone are economical, but currently registered herbicides for onion production in New England; DCPA and oxyflourfen do not provide the full season and spectrum of weed control needed, so some weed species survive, making cultivation and handweeding inevitable. Cultivation is the least costly weed control component used, but cultivation leaves a band of weeds over the onion row that will inhibit the yield to zero if left for the entire growing season. Hand labor, therefore, is a needed component of onion weed control. An integrated weed management system utilizing herbicides, cultivation, and handweeding is needed for cost-effective onion production.

There is little published literature on the economics of weed management. Henne and Poulson (1980) found that integrating timely herbicide applications, cultivations, and hand labor gave the best economic returns in tomatoes (Lycopersicon esculentum Mill.) and carrots (Daucus carota L.). Majek (1985) evaluated the cost and effectiveness of handweeding and cultivation compared to registered and experimental herbicide programs for several vegetables. It was determined that lettuce (Lactuca sativa L.), onions, and parsley (Petroselinum crispum L.) were most susceptible to weed competition and standard herbicide programs did not provide adequate weed control in cabbage (Brassica oleracea L.) onions, and parsley. An effective herbicide program was 1% the cost of handweeding in onions. Rana et al. (1985), in India, evaluated levels of nitrogen and handweedings on the economic yield of onions. Net profit was highest with a combination of 2 handweedings and 100 kg of N/ha. Baldwin (1986) proposed the use of minimum herbicide input programs to reduce the weed control cost in soybeans (Glycine max Merr.). The minimum input programs were based on careful choice of herbicides to control specific weeds, timely postemergence applications at reduced rates, band applications, economically directed sprays, and judicious use of new herbicides. Menges (1987), in a study of weed seed population dynamics during 6 years of weed management systems, reported a savings of $793 to $1,222/ha when using herbicides compared to handweeding in onions.

The objectives of the study were to (1) evaluate the efficacy of registered and experimental herbicides in providing effective and safe weed control for onions; and (2) develop a cost-effective integrated weed management program for onions utilizing mechanical, manual, and chemical means of weed control.

Materials and Methods

General Methods

Onion cultivar 'Gambler' was sown in Hadley fine sandy loam (Typic, Udifluvents, Mesic) at the Massachusetts Agricultural Experiment Station in South Deerfield in 1986 and 1987. The onions were seeded with a double-shoe precision seeder at a rate of 39 seeds/m of double row. Seeds were sown in double rows spaced 30-cm apart with four rows/bed. The experimental area was fertilized with 100 kg/ha of each N, P_2O_5 and K_2O and limed to pH 6.5 to 7.0. The soil was drenched with diazinon (O,O-diethyl-O-2-isopropyl-6-methylpyrimidin-4-yl phosphorothiate) to control onion maggots (Delia antiqua Meigen.) in June. The onions were sprayed weekly with diazinon and maneb (mangenese ethylenebisthisiocarbamate) to control onion thrips (Thrips tabaci Linde.) and botrytis blast (Botrytis cinera L.) respectively.

The principal weeds present were common lambsquarters (Chenopodium album L.), redroot pigweed (Amaranthus retroflexus L.), large crabgrass [Digitaria sanguinalis (L.) Scop.], and yellow foxtail (Setaria lutescens Hubb.).

Herbicides were applied with a backpack CO_2 sprayer with a delivery rate of 187 L/ha for preemergence treatments and 374 L/ha for postemergence treatments. The nozzle size for preemergence applications was 8002S and 8004S nozzles were used for postemergence treatments.

Onion yields were determined by harvesting 2 m of the two center rows. Harvested onions were cured in bags and topped when the onion tops turned totally brown.

Analyses of variance was used to statistically evaluate the data. Multiple comparisons were made between treatment means using the least significant difference (LSD).

Weed Control

Field Study. The plot size was 1.8 by 6.1 m. Preemergene herbicides were applied on April 23, 1987. All plots, including the weedy and weed-free controls, were cultivated and handweeded prior to postemergence applications, in June. The first postemergence herbicides were applied on June 20, 6 weeks after planting (6 WAP), the second postemergence treatments were applied July 2 (8 WAP), and the third postemergence applications were on July 16 (10 WAP). Weed control was rated at 4, 11, 13, and 15 WAP on May 22, July 9 and 25, and August 8, respectively. Ratings consisted of visual evaluations based on 0 to 100% control and phytotoxicity, with 0% indicating no weed control or no phytotoxicity and 100% indicating complete weed control and death of crop. Weed counts were also recorded by sampling the weed population, by species, in 1 m of onion row.

The preemergence treatments included DCPA at 6.7 kg ai/ha and propachlor at 6.7 kg/ha. Postemergence herbicide treatments are listed in Table 3.1. Propachlor and DCPA were also applied 6 WAP at 4.5 and 6.7 kg/ha, respectively. Second applications of DCPA and propachlor were applied after onions were cultivated and handweeded, so they were applied postemergence to the crop and preemergence to weeds. The first oxyflourfen treatments were applied at the 3- to 4-leaf stage of onions, and second oxyflourfen treatments were applied at the 5- to 6-leaf stage. Treatments containing sethoxydim, flauzifop-butyl, or BAS 514 00H (3,7-dichloro-8-quinolinecarboxylic acid) were applied at the 2- to 4-leaf stage of annual grasses. The two rates of BAS 514 00H were applied with and without the surfactant, BAS 09 002S at 0.5% (v/v). Crop oil at 1.25% and 0.5% (v/v) was mixed with sethoxydim and flauzifop-butyl treatments, respectively.

The treatments were replicated four times in randomized complete blocks. Weedy and weed-free controls were included.

Greenhouse Study. A greenhouse study was conducted in 1987. Onions were sown in 10-by 15-cm flats with seeds of barnyardgrass (*Echinochola crus-galli* L.) and common lambsquarters. Untreated checks and weed-free controls were also included. Herbicides were applied to onions and weeds, 3 WAP on March 27 at the 2- to 4-leaf stage of barnyardgrass, and the 1-leaf stage of onions.

Treatments were replicated six times in randomized complete blocks. Weed control and phytotoxcicity were rated on a 0 to 100% scale, with 0 corresponding to no control or phytotoxicity, and 100% corresponding to total weed control and totally dead plants, respectively.

Onion Weed Management Systems

The economics of various weed management systems for onions were evaluated in 1986 and 1987. The systems utilized combinations of DCPA and oxyflourfen with various frequencies of cultivations and handweedings. All treatments, excluding the hand-weeded control, received a preemergence application of DCPA at 6.7 kg/ha. Oxyflourfen was used at the reduced rate of 0.033 kg/ha.

The systems used in 1986 and 1987 are listed in Tables 3.15 and 3.16, respectively. The cost of herbicides were based on 1986 retail prices. Machine and operator costs were based on Cooperative Extension Service vegetable budgets (Anonymous, 1985). Handweeding time was recorded in the field, at a cost of $5/hour. The total costs of labor, machinery, and chemicals per hectare were calculated and compared with the economic returns of the various systems. Onion prices were based on 1986 and 1987 wholesale prices.

Results

Weed Control

Field Study. No phytotoxicity was noticed for any of the treatments. Therefore, no phytotoxicity ratings were reported.

The first rating was taken 2 WAP. Visual ratings showed significant differences in all plots treated with herbicides from the untreated control. Propachlor, at 6.7 kg/ha, applications gave greater weed control than treatments with DCPA. Fall panicum (Table 3.1), large crabgrass (Table 3.2), and commom lambsquarters (Table 3.4) control were excellent with propachlor, as evidenced by both control rating and weed count (Table 3.5). Yellow foxtail was not present in the experimental area at 4 WAP so its control was not evaluated until 11 WAP (Table 3.3). Redroot pigweed control was not significant among treatments as a

Table 3.1. Fall panicum control in onions with preemergence and postemergence applications of various herbicides in 1987.

Treatment	Application Method	Rate	Control[a] Weeks after planting 4	11	13	15
		(kg ai/ac)	(%)			
DCPA	Pre	6.72	75	23	20	21
DCPA +	Pre	6.72				
DCPA	Post 1[b]	6.72	73	90	90	80
DCPA +	Pre	6.72				
Bentazon +	Post 2[c]	0.28				
Sethoxydim +	Post 2	0.14				
Oil conc.		1.25%	59	73	83	73
DCPA +	Pre	6.72				
Bentazon +	Post 2	0.28				
Flauzifop +	Post 2	0.14				
Oil conc.		0.25%	61	76	96	99
DCPA +	Pre	6.72				
BAS51400H	Post 2	0.28	70	44	13	28
DCPA +	Pre	6.72				
BAS51400H	Post 2	0.56	74	54	31	28
DCPA +	Pre	6.72				
BAS51400H +	Post 2	0.28				
BAS09002S		0.5%	56	75	31	50
DCPA +	Pre	6.72				
BAS1400H +	Post 2	0.56				
BAS09002S		0.5%	70	79	63	59

Continued on following page.

Table 3.1 (cont.)

Treatment	Application Method	Rate	Control[a] Weeks after planting 4	11	13	15
		(kg ai/ac)	(%)			
Propachlor +	Pre	6.72				
Propachlor	Post 2	4.48	98	96	91	95
DCPA +	Pre	6.72				
Oxyflourfen	Post 2	0.067	56	8	6	45
DCPA +	Pre	6.72				
Oxyflourfen +	Post 2	0.033				
Oxyflourfen	Post 3[d]	0.033	68	9	25	14
DCPA +	Pre	6.72				
Oxyflourfen	Post 2	0.67				
Oxyflourfen	Post 3	0.33	75	7	23	15
Untreated			0	0	0	0
Handweeded			100	100	100	100
LSD (0.05)			19	19	19	25

a/ Weed control ratings were taken 4, 11, 13 and 15 WAP.

b/ Post 1 applied 6 WAP.

c/ Post 2 applied at the 2- to 4-leaf-stage of grasses and the 3- to 4-leaf-stage onions, 8 WAP.

d/ Post 3 applied at the 5- to 6- leaf-stage of onions, 10 WAP.

Table 3.2. Large crabgrass control in onions with preemergence and postemergence applications of various herbicides in 1987.

Treatment	Application Method	Rate	Control[a] Weeks after planting 4	11	13	15
		(kg ai/ac)	(%)			
DCPA	Pre	6.72	81	49	58	45
DCPA + DCPA	Pre Post 1[b]	6.72 6.72	86	93	78	78
DCPA + Bentazon + Sethoxydim + Oil conc.	Pre Post 2[c] Post 2	6.72 0.28 0.14 1.25%	66	73	86	89
DCPA + Bentazon + Flauzifop + Oil conc.	Pre Post 2 Post 2	6.72 0.28 0.14 0.25%	51	76	98	95
DCPA + BAS51400H	Pre Post 2	6.72 0.28	76	65	46	34
DCPA + BAS51400H	Pre Post 2	6.72 0.56	69	57	46	44

Continued on following page.

Table 3.2 (cont.)

Treatment	Application Method	Rate	Control[a] Weeks after planting 4	11	13	15
		(kg ai/ac)	(%)			
DCPA +	Pre	6.72				
BAS51400H +	Post 2	0.28				
BAS09002S	0.5%		75	77	74	71
DCPA +	Pre	6.72				
BAS1400H +	Post 2	0.56				
BAS09002S	0.5%		75	90	84	86
Propachlor +	Pre	6.72				
Propachlor	Post 2	4.48	90	81	68	66
DCPA +	Pre	6.72				
Oxyflourfen	Post 2	0.067	75	35	26	25
DCPA +	Pre	6.72				
Oxyflourfen +	Post 2	0.033				
Oxyflourfen	Post 3[d]	0.033	68	1	30	31
DCPA +	Pre	6.72				
Oxyflourfen	Post 2	0.67				
Oxyflourfen	Post 3	0.33	70	36	24	32
Untreated			00	00	00	00
Handweeded			100	100	100	100
LSD (0.05)			16	24	24	26

a/ Weed control ratings were taken 4, 11, 13 and 15 WAP.

b/ Post 1 applied 6 WAP.

c/ Post 2 applied at the 2- to 4-leaf-stage of grasses and the 3- to 4-leaf-stage onions, 8 WAP.

d/ Post 3 applied at the 5- to 6-leaf-stage of onions, 10 WAP.

Table 3.3. Yellow foxtail control in onions with preemergence and postemergence applications of various herbicides in 1987.

Treatment	Application Method	Rate	Control[a] WAP 11	13	15
		(kg ai/ac)	(%)		
DCPA	Pre	6.72	25	20	20
DCPA +	Pre	6.72			
DCPA	Post 1[b]	6.72	93	78	74
DCPA +	Pre	6.72			
Bentazon +	Post 2[c]	0.28			
Sethoxydim +	Post 2	0.14			
Oil conc.		1.25%	73	100	96
DCPA +	Pre	6.72			
Bentazon +	Post 2	0.28			
Flauzifop +	Post 2	0.14			
Oil conc.		0.25%	70	58	31
DCPA +	Pre	6.72			
BAS51400H	Post 2	0.28	68	28	45
DCPA +	Pre	6.72			
BAS51400H	Post 2	0.56	80	89	73

Continued on following page.

Table 3.3 (cont.)

Treatment	Application Method	Rate	Control[a] WAP 11	13	15
		(kg ai/ac)	(%)		
DCPA +	Pre	6.72			
BAS51400H +	Post 2	0.28			
BAS09002S		0.5%	83	93	93
DCPA +	Pre	6.72			
BAS1400H +	Post 2	0.56			
BAS09002S		0.5%	93	94	94
Propachlor +	Pre	6.72			
Propachlor	Post 2	4.48	81	68	66
DCPA +	Pre	6.72			
Oxyflourfen	Post 2	0.067	11	5	30
DCPA +	Pre	6.72			
Oxyflourfen +	Post 2	0.033			
Oxyflourfen	Post 3[d]	0.033	30	21	5
DCPA +	Pre	6.72			
Oxyflourfen	Post 2	0.67			
Oxyflourfen	Post 3	0.33	00	19	18
Untreated			00	00	00
Handweeded			100	100	100
LSD (0.05)			21	21	28

a/ Weed control ratings were taken 11, 13 and 15 WAP.

b/ Post 1 applied 6 WAP.

c/ Post 2 applied at the 2- to 4-leaf-stage of grasses and the 3- to 4- leaf-stage onions, 8 WAP.

d/ Post 3 applied at the 5- to 6-leaf-stage of onions, 10 WAP.

Table 3.4. Common lambsquarters control in onions with preemergence and postemergence applications of various herbicides in 1987.

Treatment	Application Method	Rate	Control[a] Weeks after planting 4	11	13	15
		(kg ai/ac)	(%)			
DCPA	Pre	6.72	80	30	78	48
DCPA +	Pre	6.72				
DCPA	Post 1[b]	6.72	86	100	91	91
DCPA +	Pre	6.72				
Bentazon +	Post 2[c]	0.28				
Sethoxydim +	Post 2	0.14				
Oil conc.		1.25%	74	78	84	75
DCPA +	Pre	6.72				
Bentazon +	Post 2	0.28				
Flauzifop +	Post 2	0.14				
Oil conc.		0.25%	66	56	70	63
DCPA +	Pre	6.72				
BAS51400H	Post 2	0.28	78	20	40	43
DCPA +	Pre	6.72				
BAS51400H	Post 2	0.56	73	41	45	46

Continued on following page.

Table 3.4 (cont.)

Treatment	Application Method	Rate	Control[a] Weeks after planting 4	11	13	15
		(kg ai/ac)	(%)			
DCPA +	Pre	6.72				
BAS51400H +	Post 2	0.28				
BAS09002S		0.5%	73	66	83	75
DCPA +	Pre	6.72				
BAS1400H +	Post 2	0.56				
BAS09002S		0.5%	79	73	93	93
Propachlor +	Pre	6.72				
Propachlor	Post 2	4.48	91	90	75	73
DCPA +	Pre	6.72				
Oxyflourfen	Post 2	0.067	78	23	50	39
DCPA +	Pre	6.72				
Oxyflourfen +	Post 2	0.033				
Oxyflourfen	Post 3[d]	0.033	76	50	63	70
DCPA +	Pre	6.72				
Oxyflourfen	Post 2	0.67				
Oxyflourfen	Post 3	0.33	76	73	73	71
Untreated			00	00	00	00
Handweeded			100	100	100	100
LSD (0.05)			12	29	29	26

a/ Weed control ratings were taken 4, 11, 13 and 15 WAP.

b/ Post 1 applied 6 WAP.

c/ Post 2 applied at the 2- to 4-leaf-stage of grasses and the 3- to 4-leaf-stage onions, 8 WAP.

d/ Post 3 applied at the 5- to 6-leaf-stage of onions, 10 WAP.

Table 3.5. Weed counts for various preemergence and postemergence herbicide treatments 11 and 15 WAP in 1987.

Treatment	Weed Density							
	June 22 11 WAP				August 8 15 WAP			
	PANDI	DIGSA	SETLU	CHEAL	PANDI	DIGSA	SETLU	CHEAL
	(no./m row)							
DCPA	1.8	1.3	1.0	0.5	0.8	1.5	2.0	0.8
DCPA + DCPA	0.3	0.5	0.3	0.3	0.0	0.8	0.8	0.0
DCPA + Bentazon + Sethoxy. + Oil conc.	1.5	1.0	0.3	0.0	0.8	0.5	0.0	0.3
DCPA + Bentazon + Flauzifop + Oil conc.	1.5	1.0	1.3	1.0	0.0	0.3	0.3	1.3
DCPA + BAS51400H	1.3	1.5	1.0	0.0	1.8	1.5	1.0	0.8
DCPA + BAS51400H	1.3	1.3	1.3	1.8	1.0	1.5	0.5	1.5

Continued on following page.

Table 3.5 (cont.)

Treatment	Weed Density							
	June 22 11 WAP				August 8 15 WAP			
	PANDI	DIGSA	SETLU	CHEAL	PANDI	DIGSA	SETLU	CHEAL
DCPA + BAS51400H + BAS09002S	1.0	1.5	1.5	1.0	1.0	1.0	0.8	0.8
DCPA + BAS1400H + BAS09002S	0.5	0.8	0.5	0.3	1.3	1.3	0.3	0.0
Propachlor + Propachlor	0.3	0.5	0.5	0.3	0.3	1.3	1.0	1.3
DCPA + Oxyflour.	2.0	1.3	1.5	0.8	0.8	1.0	2.0	0.5
DCPA + Oxyflour. Oxyflour.	2.3	1.0	0.3	0.3	1.5	1.5	1.0	0.3
DCPA + Oxyflour. Oxyflour.	1.8	0.3	0.5	0.0	1.3	1.8	1.3	0.3
Untreated	1.5	8.8	1.8	1.3	1.3	4.5	2.0	1.0
Hw ck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LSD (0.05)	1.2	1.2	0.9	0.9	1.1	0.9	1.3	0.8

result of its low population in the experimental area and redroot pigweed control is not included in ratings after 2 WAP.

The second weed control rating was at 2 weeks after the first postemergence herbicide application and at 11 WAP. Common lambsquarters control was excellent in plots treated with subsequent applications of either DCPA or propachlor. Propachlor at 6.7 kg/ha followed by a second application at 4.5 kg/ha 6WAP gave better common lambsquarter control than oxyflourfen at 0.033 kg/ha. Oxyflourfen at 0.067 kg/ha applied at the 3- to 4-leaf stage of onions provided better common lambsquarters control than oxyflourfen at 0.033 kg/ha. Common lambsquarters number/m row were not significantly different at this time. BAS 514 00H, at both rates, controlled common lambsquarters better when the surfactant, BAS 09 002S, was added. Bentazon gave better control than BAS 514 00H without the surfactant. Fall panicum and other grasses were controlled most effectively with subsequent applications of DCPA or propachlor, at 11 WAP. Propachlor controlled fall panicum better than the treatments of flauzifop-butyl or sethoxydim applied at the 2- to 4-leaf stage of grasses. BAS 514 00H at both rates, mixed with BAS 09 002S, gave better control of fall panicum and yellow foxtail, than the low rate of BAS 514 00H without BAS 09 002S. Oxyflourfen did not give adequate grass control.

Two weeks later, 13 WAP, flauzifop-butyl or sethoxydim tank-mixed with bentazon gave the best total weed control. Common lambsquarters control was greatest in plots treated with DCPA and in plots treated with 0.56 kg/ha of BAS 514 00H mixed with BAS 09 002S at 5% v/v (Table 3.4). Common lambsquarters control declined at this time in plots treated with propachlor. Bentazon control of lambsquarters increased slightly from 2 to 4 weeks after spraying. With oxyflourfen, common lambsquarters control increased when a second treatment was applied at the 5- to 6-leaf stage of onions. Grass control was best with either sethoxydim or flauzifop-butyl. Fall panicum and large crabgrass control with flauzifop-butyl was 10% greater than in plots treated with sethoxydim. DCPA or propachlor, applied twice, continued to give effective control of fall panicum and yellow foxtail. Large crabgrass control declined in plots treated with propachlor. Treatments of BAS 514 00H mixed with BAS 09 002S gave good yellow foxtail control 13 WAP. Large crabgrass and fall panicum were not controlled as effectively with this mixture. Grass control in treatments receiving oxyflourfen remained ineffective.

At the final rating (15 WAP), postemergence treatements of sethoxydim or flauzifop-butyl in combination with bentazon gave the best total weed control. The best lambsquarter control was obtained with either subsequent DCPA applications or with BAS 514 00H mixed with BAS 09

002S. Sethoxydim and propachlor treatments resulted in the best grass control. Propachlor continued to give excellent fall panicum and yellow foxtail control, but large crabgrass control continued to decline. Excellent yellow foxtail control also was obtained with BAS 514 00H at 0.56 kg/ha mixed with BAS 09 002S at 5% v/v. This mixture also produced effective crabgrass control. BAS 514 00H without BAS 09 002S did not give commercially acceptable weed control. Single preemergence applications of DCPA and postemergence applications of oxyflourfen also did not provide effective weed control.

The best total onion yields were obtained with preemergence DCPA followed by; DCPA, bentazon and sethoxydim, flauzifop-butyl and bentazon, and with preemergence propachlor followed by a second propachlor application (Table 3.6). DCPA followed by postemergence bentazon and sethoxydim and the treatment of 2 propachlor applications produced yields that were significantly greater than the handweeded control.

<u>Greenhouse Study.</u> The first herbicide rating was 1 week after treatment (1 WAT), when onions were in the 1 leaf stage and barnyardgrass was in the 2 to 4 leaf stage. Phytotoxicity was greatest in onions treated with bentazon in combination with sethoxydim. Although BAS 514 00H did not result in significant phytotoxicity, injury to onions was greater if BAS 514 00H was mixed with BAS 09 002S (Table

Table 3.6. Total onion yields as affected by various weed management systems in 1987.

Treatment	Application Method	Rate	Total yield
		(kg ai/ac)	(kg/ha)
DCPA	Pre	6.72	38082
DCPA +	Pre	6.72	
DCPA	Post 1[a]	6.72	58390
DCPA +	Pre	6.72	
Bentazon +	Post 2[b]	0.28	
Sethoxydim +	Post 2	0.14	
Oil conc.		1.25%	62349
DCPA +	Pre	6.72	
Bentazon +	Post 2	0.28	
Flauzifop +	Post 2	0.14	
Oil conc.		0.25%	42211
DCPA +	Pre	6.72	
BAS51400H	Post 2	0.28	27866
DCPA +	Pre	6.72	
BAS51400H	Post 2	0.56	32324

Continued on following page.

Table 3.6 (cont.)

Treatment	Application Method	Rate	Total yield
		(kg ai/ac)	(kg/ha)
DCPA +	Pre	6.72	
BAS51400H +	Post 2	0.28	
BAS09002S		0.5%	39595
DCPA +	Pre	6.72	
BAS1400H +	Post 2	0.56	
BAS09002S	0.5%		28261
Propachlor +	Pre	6.72	
Propachlor	Post 2	4.48	71554
DCPA +	Pre	6.72	
Oxyflourfen	Post 2	0.067	16072
DCPA +	Pre	6.72	
Oxyflourfen +	Post 2	0.033	
Oxyflourfen	Post 3[c]	0.033	29774
DCPA +	Pre	6.72	
Oxyflourfen	Post 2	0.67	
Oxyflourfen	Post 3	0.33	40418
Untreated			0
Hand weeded			42079
LSD (0.05)			22350

a/ Post 1 applied 6 WAP.

b/ Post 2 applied at the 2- to 4-leaf-stage of grasses and the 3- to 4-leaf-stage onions, 8 WAP.

c/ Post 3 applied at the 5- to 6-leaf-stage of onions, 10 WAP.

3.7). Phytotoxicity continued to be greater in onions treated with bentazon and sethoxydim at 2 to 3 WAT. Onions were completely recovered from phytotoxicity at 4 WAT.

All herbicides produced significant barnyardgrass control, compared to the untreated control, at 1 WAT (Table 3.8). Common lambsquarters control was best in treatments with bentazon at 0.28 kg/ha and with BAS 514 00H at 0.56 kg/ha plus BAS 09 002S at 5% v/v (Table 3.9). BAS 514 00H at 0.28 kg/ha did not give effective common lambsquarters control at this time. At 2 and 3 weeks after spraying, bentazon mixed with sethoxydim, and BAS 514 00H at 0.56 kg/ha mixed with BAS 09 002S resulted in the best total weed control. By 4 WAT, all herbicide treatments effectively controlled barnyardgrass and there was no significant difference among herbicide treatments. Bentazon control of common lambsquarters continued to decline at 5 WAT. All BAS 514 00H treatments resulted in increasing common lambsquarter control 5 WAT, beyond which control began to decline. At 5 weeks after spraying, BAS 514 00H at 0.56 kg/ha mixed with BAS 09 002S produced better common lambsquarters control than bentazon.

Onion Weed Management Programs

In 1986, the best onion yield was obtained with the preemergence application of DCPA at 6.7 kg/ha followed by 2 cultivations and 2 handweedings, 6 and 8 weeks after onion

Table 3.7. Phytoxicity rating in onions for postemergence applications of various herbicides under greenhouse conditions in 1987.

Treatment	Rate	Phytoxicity			
		1 WAT[a]	2	3	4
	(kg ai/ha)	(%)			
Bentazon + Sethoxydim + Oil conc.	0.28 0.14 0.5%	9.2	9.2	6.7	0.0
BAS 514 00H	0.28	1.7	1.7	0.0	0.0
BAS 514 00H	0.56	1.2	0.0	1.7	0.0
BAS 514 00H + BAS 09 002S	0.28 0.5%	5.3	3.3	1.7	0.0
BAS 514 00H + BAS 09 002S	0.56 0.5%	3.3	4.2	0.0	0.0
Untreated		0.0	0.0	0.0	0.0
LSD (0.05)		4.8	4.8	5.6	ns
LSD (0.01)		3.3	3.3	ns	ns

a/ WAT = Weeks after treatment.

Table 3.8. Barnyardgrass control in onions with postemergence applications of various herbicides under greenhouse conditions in 1987.

Treatment	Rate	Control				
		1 WAT[a]	2	3	4	5
	(kg ai/ha)	(%)				
Bentazon + Sethoxydim + Oil conc.	0.28 0.14 0.5%	41	77	83	99	99
BAS 514 00H	0.28	29	55	78	99	100
BAS 514 00H	0.56	32	69	87	98	100
BAS 514 00H + BAS 09 002S	0.28 0.5%	39	63	78	95	98
BAS 514 00H + BAS 09 002S	0.56 0.5%	43	75	90	100	00
Untreated		00	00	00	00	00
LSD (0.05)		11	11	11	5	1
LSD (0.01)		15	15	15	7	2

a/ WAT = Weeks after treatment.

Table 3.9. Common lambsquarters control in onions with postemergence applications of various herbicides, under greenhouse conditions in 1987.

Treatment	Rate	Control 1 WAT[a]	2	3	4	5
	(kg ai/ha)	(%)				
Bentazon + Sethoxydim + Oil conc.	0.28 0.14 0.5%	35	48	19	39	13
BAS 514 00H	0.28	19	18	24	38	32
BAS 514 00H	0.56	24	18	33	44	27
BAS 514 00H + BAS 09 002S	0.28 0.5%	27	22	24	45	29
BAS 514 00H + BAS 09 002S	0.56 0.5%	39	34	53	63	51
Untreated		00	00	00	00	00
LSD (0.05)		20	20	31	28	25
LSD (0.01)		28	28	45	41	35

a/ WAT = Weeks after treatment.

emergence (Table 3.10). The best net economic return was obtained with a preemergence application of DCPA at 6.7 kg/ha followed by cultivations at 2 and 4 weeks after emergence. Handweeding increased production costs by $3,000 to $4,000/ha. However, handweeding increased onion yields significantly over the yields obtained by only cultivation or the postemergence applications of oxyflourfen. The treatment that had handweeding and cultivation, at 2 week intervals, resulted in a net economic loss of $3,833/ha.

In 1987, the best total marketable yield and economic return were obtained when DCPA at 6.7 kg/ha was applied 2 times separated by 1 cultivation and handweeding at 6 WAP (Table 3.11). The most effective treatment, in producing total marketable onion yields and net economic returns was two sequential application of oxyflourfen at the 3- to 4-leaf and at the 5- to 6-leaf stage of onions, combined with cultivation and handweeding at 6 and 8 WAP.

Discussion

These results suggest that the most effective weed management system for onions is a preemergence application of DCPA at 6.7 kg/ha, followed by cultivation and handweeding at 4 to 6 weeks after planting, and then a second application of DCPA at 6.7 kg/ha. This treatment produced the greatest marketable yield and economic return. Oxyflourfen can also be effective if it is applied at 0.033

Table 3.10. Onion weed management systems, yields, prices, weed control costs and net economic returns in 1986.

Management Systems	Timing	Yield	Cost[a]	Returns gross	Returns net
		(kg/ha)	($/ha)		
DCPA	Pre	3934.00	98.20	1298.20	1200.00
DCPA + 1 cv	Pre 6 WAE	13918.00	139.10	4593.00	4459.00
DCPA + 1 cv + hw	Pre 6 WAE	23477.00	3124.00	7747.30	4623.40
DCPA + 2 cvs	Pre 6+8 WAE	15740.00	120.40	5194.20	5073.70
DCPA + 2 cvs + 2 hw	Pre 6+8 WAE 6+8 WAE	17950.00	4032.10	5923.60	1891.60
DCPA + oxy	Pre 6 WAE	5485.00	112.90	1810.20	1697.30
DCPA + cv + oxy	Pre 6 WAE	9211.00	148.70	3039.00	2890.80
DCPA cv+oxy+hw	Pre 6 WAE	14450.00	3138.60	4768.60	1630.00

Continued on following page.

Table 3.10 (cont)

Management Systems	Timing	Yield	Cost[a]	Returns gross	Returns net
		(kg/ha)	($/ha)		
DCPA + oxy	Pre 8 WAE	4040.00	112.90	1333.33	1220.00
DCPA + cv + oxy	Pre 8 WAE	9108.00	148.70	3025.70	2857.00
DCPA + oxy + hw	Pre 8 WAE	17439.00	4632.40	5754.80	1122.40
DCPA + oxy	Pre 6+8 WAE	8527.00	127.60	2813.90	2686.30
DCPA + oxy + cv	Pre 6+8 WAE	9496.00	174.50	3120.60	2946.00
DCPA + 2 cv+hw	6+8 WAE	24950.00	4659.40	8233.70	3579.30
hw + cv	2 wk int	19731.00	10364.30	6511.30	-3833.00

a/ Weed control costs were based on the following: cultivation, $14.50/ha; DCPA, $39.75/ha; oxyflourfen, $8.44; and handweeding, $5.00/ha.

Table 3.11. Onion weed management systems, yields, prices, weed control costs and net economic returns in 1987.

Management Systems	Timing	Yield	Cost	Returns gross	Returns net
		(kg/ha)	($/ha)		
DCPA	Pre	00	39.75	00.00	-39.75
DCPA + 1 cv	Pre 6 WAP	84.78	134.10	27.98	-106.00
DCPA + 1 cv + hw	Pre 6 WAP	15150.24	1554.70	4999.58	3445.00
DCPA + cv + hw + oxy	Pre 6 WAP 6 WAP	13222.27	2091.80	4363.35	2272.00
DCPA + cv + hw + DCPA	Pre 6 WAP 6 WAP	35344.63	1490.00	11663.73	10174.00
DCPA + cv + hw cv + oxy	Pre 6 WAP 3-4 lf[a]	14377.69	2035.10	4744.64	2710.00
DCPA + cv + hw + oxy + cv 5-6 lf	Pre 6 WAP 3-4 lf	27319.65	1749.00	9015.49	7270.00
DCPA + cv + hw + oxy + cv + oxy	Pre 6 WAP 3-4 lf 5-6 lf	17597.79	2292.80	5807.27	3514.00
DCPA + cv + hw + oxy + cv + oxy	Pre 6 WAP 3-4 lf 5-6 lf 5-6 lf	33346.93	2498.40	11004.49	8506.00
cv + hw	2 wk int	23586.79	9280.50	7783.64	-1497.00

a/ Weed control costs were based on the following: cultivation, $14.50/ha; DCPA, $39.75/ha; oxyflourfen, $8.44; and handweeding, $5.00/ha.

to 0.067 kg/ha, at approximately 2 week intervals after the 3- to 4-leaf stage of onions. In addition, oxyflourfen must be applied to grass weeds at the 1-leaf stage and to broadleaf weeds when only the cotyledons have emerged, to be effective at reduced rates. The treatment of preemergence DCPA at 6.7 kg/ha followed by an application of 6.7 kg/ha at 6 WAP resulted in excellent weed control for the main part of the growing season, but fall panicum emergence at the end of the season interfered with harvesting operations. This indicates that a third cultivation, handweeding and application of DCPA at approximately 12 weeks after planting would be beneficial. A potential problem when using DCPA postemergent to the crop and preemergent to weeds is that the crop must be totally weed-free for DCPA to be effective, since DCPA is only effective to germinating seeds. A solution to this problem could be an application of oxyflourfen to control emerging weed seedlings, prior to a second or third application of DCPA.

The results from field studies showed that preemergence applications of propachlor and postemergence applications of sethoxydim or flauzifop-butyl have excellent potential. Propachlor has been a commonly used herbicide for onion production, but is no longer recommended in New England (Bouton and Nicklow, 1986). Preemegence propachlor at 6.7 kg/ha gave excellent weed control until approximately 6 WAP; if onions were subsequently cultivated and handweeded, a second treatment can be applied. However, like DCPA, propachlor must be applied prior to the emergence of weeds to be effective. Plots treated with propachlor also had late germinating large crabgrass. This may not result in competition between onions and weeds, but could interfere with harvesting and curing practices.

The grass conrol herbicides, sethoxydim and flauzifop-butyl, both have excellent potential for onion production. Greenhouse studies show that applications as early as the 1-leaf stage of onions caused relatively no injury to onions. The grass control herbicides would be most effective when combined with a preemergence application of DCPA or propachlor. Precheur (1982) reported that sethoxydim gave effective grass control with no phytotoxicity when used in combination with a preemergence application of DCPA or pre-plant incorporated bensulide (O,O-diisopropyl phosphorodithioate S-ester with N-(2-mercaptoethyl) benzene sulfonamide). Annual grasses can be controlled with a postemergence application of sethoxydim at 0.14 kg/ha or flauzifop-butyl at 0.14 kg/ha 4 to 6 weeks after the pre-plant or preemergence herbicide application. In our study, all weeds emerging after preemergence herbicides were annual grasses. If broadleaf weeds were present, bentazon mixed with either of the grass herbicides is effective against broadleaf weeds if applied to the 2- to 4-leaf stage. Bentazon at 0.56 kg/ha was effective against common lambsquarters and redroot pigweed seedlings, without causing phytotoxicity to onions. BAS 514 00H with or without BAS 09 002S did not perform satisfactorily in field conditions. These treatments did not provide sufficient fall panicum control, which significantly inhibited onion yield. Our study showed that the herbicides presently recommended for onion production in New England; DCPA and oxyflourfen can be effective at the reduced rates of 6.7 and 0.033 kg/ha respectively, if used at the proper timing and combined with at least 2 cultivations and 2 handweedings. Sethoxydim or flauzifop-butyl, if registered for onion production, would significantly lower the labor cost by reducing or eliminating the need for handweeding. They would also negate the need for repeated applications of DCPA.

In our study, the cost of handweeding and cultivation only, was 3 to 6 times greater than effective systems using DCPA and oxyflourfen. This corresponded to differences in net economic returns of $8,900/ha in 1986, and 11,700/ha in 1987.

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