Quackgrass [*Agropyron repens* (L.) Beauv.] control

in potatoes with quizalofop-ethyl.

by

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Short title

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ABSTRACT

M.Sc. Bernard Poliquin Plant Science

Weed Science

Quackgrass [<u>Agropyron</u> <u>repens</u> L. (Beauv.)] control in potatoes with quizalofop-ethyl.

Field trials were conducted to evaluate the effect of quizalofop-ethyl on quackgrass plants in a potato cropping sequence. Fall and summer applications were compared for their quackgrass control potential. Season-long quackgrass control was obtained with quizalofop-ethyl at 96 g/ha following summer application. An increase in the rate of quizalofop-ethyl did not further improve control. Yields with quizalofop-ethyl at 96 g/ha were similar to standard treatments sethoxydim and fluazifop-butyl at recommended rates. Quackgrass control following a summer application was not maintained through to the following season. Fall applications did not result in adequate control of quackgrass the following season at any of the quizalofop-ethyl rates tested.

RESUMÉ

M.Sc. Bernard Poliquin Phytobiologie
Malherbologie

Le contrôle du chiendent [Agropyron repens L. (Beauv.)] dans la pomme de terre avec le quizalofop-éthyl.

Des études en plein champs ont été effectuées afin d'évaluer les effets du quizalofop-éthyl sur le chiendent. Une comparaison a été faite entre une application faite à l'été et une application faite à l'automne. Une bonne répression du chiendent a été notée suite à des pulvérisations d'été avec le quizalofop-éthyl à une dose de 96 g/ha. Aucune amélioration n'a été notée lorsque la dose du quizalofop-éthyl a été augmentée. Les rendements obtenus avec le quizalofop-éthyl à 96 g/ha sont similaires à ceux obtenus avec les traitements recommandés, le séthoxydime ainsi que le fluazifop-butyl utilisés à des doses commerciales. Une évaluation faite l'année suivant une application d'été a révelée qu'il n'y avait plus de répression du chiendent. La répression du chiendent suite à des applications faites l'automne n'était pas adéquate et ce pour toutes les doses de quizalofop-éthyl mises à l'essai.

A Gisèle, André et Raynald...

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CHAPTER 1

INTRODUCTION

Quizalofop-ethyl is a postemergence grass herbicide from the diphenyl ether family or pyridinyloxyphenoxypropionates. This compound has proven itself particularly effective for the control of quackgrass [Agropyron repens L. (Beauv.)] based on many efficacy trials conducted in Canada. Sufficient data is now available to support the registration of quizalofop-ethyl on major broadleaf crops such as potato and soybean as a spring postemergence treatment for season-long quackgrass control. However, it has not yet been established if the use rates that provide adequate season-long control will provide some longer-term suppression of quackgrass.

The objective of this research project is to evaluate the quackgrass control potential of quizalofop-ethyl as well as its effect on crop yields when sprayed on a potato crop. A comparison between a spring and fall application of quizalofop-ethyl will be made so as to determine whether or not a wider window of application is possible with this compound. This study was therefore divided into two experiments: a spring and a fall application which were repeated in time over two successive years.

CHAPTER 2

QUACKGRASS [Agropyron repens (L.) Beauv.]

2.1 History and distribution

Agropyron repens (L.) Beauv. is described as an old-world species and is thought to have originated in Europe or Asia (Palmer and Sagar, 1983). First reports of its presence in North America date back to 1639 in New England during colonization and it seems that it may have been introduced in Québec during that period (Werner and Rioux, 1977).

In North America, this weed is reported to thrive north of the 35th parallel as climatic conditions south of that point seem to be unfavorable for its growth (Linscott, 1970). Quackgrass is therefore a problem of cool, moist temperate regions of the world and has become troublesome in many agricultural areas due to its dispersal capability, adaptability to modern agricultural practices and its facility for propagation and establishment.

This plant shows no drainage preference, but grows best on fine structured soils and is most vigorous in neutral to alkaline soils with pH varying from 6.5 to 8 (King, 1966). In Canada it has been found in all provinces from Newfoundland to British Columbia and as far north as Labrador and the Northwest Territories. Agropyron repens (L.) Beauv. is especially common in south eastern Canada but seems to be less important in the dryer regions of the prairie provinces (Werner and Rioux, 1970).

In Québec, quackgrass was reported to be present in 75% of 5,000 fields surveyed between 1980 and 1983 (Doyon, 1984). Crops in which quackgrass was most commonly found with a 90% plus incidence rate were corn, wheat, barley, strawberries and raspberries. It was also omnipresent in fields for animal grazing and forage crops. The prevalence of this weed is also of concern in the Atlantic provinces with 98% occurrence in fields surveyed in the maritimes in the summer of 1980 (Sampson, 1983).

The ability of quackgrass to maintain high growth rates through very cool periods of the year, coupled with aggressive vegetative reproduction, the uptake of important key nutrients and the production of allelochemic toxins (Gabor and Veatch, 1981), all contribute to ranking quackgrass as the number-one weed in Eastern Canada.

2.2 Physical characters

Quackgrass is a perennial weed spreading by seeds and rhizomes. Shoots are slender with 3 to 5 nodes and leaves are finely pointed, flat green, scabrous at the margin and on the upper surface, while the lower surface is smooth. Leaf sheaths are round, split with overlapping hyaline margins and have short, spreading auricles at the apex. Ligules are membranous, obtuse, sometimes ciliated and have a length of 0.5 to 1.0 mm. Spikelets are oblong to elliptic, very rigid, 10.0 to 20.0 mm long, 3 to 8 flowered, stalkless, falling entire at maturity and alternate in two rows on opposite sides of the axis with the broader side appressed to it. The fruit is a caryopsis and the species is hexaploid with $2n=42$.

Rhizomes have many nodes and a scale leaf, bud or branch and fine root system at each node. They are smooth, whitish, may be up to 1.0 m long with a diameter of 1.5 mm (Werner and Rioux, 1977).

Striking characters used in identifying this weed in the field are usually its rhizomatous system, auricles, hairy lower sheaths and seed heads resembling that of wheat. Quackgrass has also been named scientifically as Elytrigia repens (L.) Nevski and Triticum repens L. Other reported common names are twitch grass, wheat grass, quitch grass, knot grass, devil's grass, switch grass and couch grass.

2.3 Propagation

Sexual reproduction

Quackgrass is a wind-pollinated, self-sterile plant. Seed production therefore depends on the proximity of different genotypes and normally seed production is more prevalent at the margin of quackgrass stands since most plants within the stand may originate from a single clone (Williams and Attwood, 1971). However, some genotypes are partly self-fertile (Williams, 1969). Initial infestation of a previously quackgrass-free field can be attributed to a seed present as an impurity in crop seeds, but is more likely to be the result of inoculation with a rhizome piece.

The coleoptile from the seed emerges and gives rise to the first and second successive leaves. At the soil surface where the growing point is located, the third or fourth lower-most buds will develop as primary rhizomes and the next three or four as tillers. Tillers are usually produced when the plant reaches the four- to six-leaf stage while rhizomes are produced at the six- to eight-leaf stage, two to three months after emergence (Palmer, 1958). A seed head is produced on the primary shoot in the second growing season, but tillers usually do not bear seeds. Flowering usually occurs in late June to July. Seeds ripen in early August to early September and drop from the parent plant in late September. Quackgrass seeds possess no special morphological adaptation for dispersal and are reported to remain dormant for a period of two to three years and retain their viability for a maximum of four years (Werner and Rioux, 1977).

Vegetative propagation

Primary rhizomes produced from emerged plants may branch and rebranch early in the season and continue growth during the spring and summer although summer dormancy in rhizome axillary buds has been demonstrated (Johnson and Buchholtz, 1962). Growth is plagiotropic during that period and becomes horizontal in the fall. At this point, the rhizome tip curves upwards, produces a primary aerial shoot and the second year's growth after vernalization (Palmer, 1962). In England, these shoots reach the two-leaf stage in the fall and are reported to continue growth at a slow rate (Palmer, 1958). However, most of these newly formed shoots die during the winter in a cold climate such as that prevailing in Eastern Canada.

In the event where the rhizome is severed from the parent plant during the growing season, the pattern is changed and the rhizome tip immediately forms a new shoot. Apical dominance is broken and buds which had been protected by scale leaves at the nodes of rhizomes are activated to produce new shoot growth.

In open communities, the plant forms a clump during the first growing season due to extensive sub-tillering of the primary tillers.

During the second season, the clump develops into a patch as further clumps of aerial shoots develop from the erected tips of the rhizomes of the first growing season. Adjacent patches then coalesce to form a continuous infestation (Palmer, 1958).

One plant may give rise to as many as 150 rhizomes or rhizome branches from 15 primary rhizomes in the first growing season (Werner and Rioux, 1977). Rhizomes may grow as long as 1.0 m before their tips erect. During active rhizome growth, these rhizomes produce numerous lateral rhizomes from axillary buds. In a closed community, however, clump formation does not occur. Instead, the plant consists of a primary shoot, two or three primary tillers and two to four rhizomes which produce fewer lateral rhizomes than do clumped plants (Palmer and Sagar, 1963). Rhizome growth is renewed annually from axillary buds at the base of aerial shoots and the cycle is repeated. In North America, there is a steady decrease in rhizome bud activity from mid-April to June 1st. The buds are dormant during June and the recovery of growth begins in late June and continues for the rest of the summer (Johnson and Buchholtz, 1962).

2.4 Rhizomatous system

Rhizomes of quackgrass grow somewhat horizontally within the top 5 to 10 cm of soil; they are whitish in color, slender and smooth with scale leaves protecting a bud at each node which occurs every half inch of its length and an apex which is as sharp as a needle. Each individual rhizome may grow up to a length of 1.0 m in one growing season and quackgrass infested fields may have up to 5600 kg of rhizomes per hectare. Rhizomes have been reported to be viable for a period of two to three years.

As stated earlier, axillary buds on rhizomes are released from inhibition when the rhizome apex is removed or when the rhizome is severed from the parent plant. Rhizome segments exhibit polarity such that the apical end develops into an aerial shoot while other buds tend to remain dormant for the most part. Although all buds are capable of developing as a shoot or a lateral rhizome branch, their path of development is determined both by their position on the rhizome piece and by environmental conditions. The closer the bud is to the apex of the rhizome, the more likely it is to develop as a shoot. Buds near the base of the rhizome piece develop as secondary rhizomes and the most basal ones remain dormant (McIntyre, 1969; 1970).

It has been suggested that intra-plant competition for a limited carbohydrate supply might be responsible for this as the apex competes more successfully than other buds due to its greater size and its ability to synthesize mobilizing hormones such as indole acetic acid which transported to lateral buds in sufficiently high amount would inhibit the growth of the latter. The supply of gibberellin from the parent plant may also be essential in maintaining such an apical dominance (McIntyre, 1969).

The growth of rhizomes is plagiotropic. This growth pattern has been shown to be induced since whenever a rhizome is detached from its parent shoot, the apex rapidly curves upwards and changes into an orthotropic aerial shoot. It has been shown, however, that soil compaction may alter this induced pattern of growth as rhizomes tend to grow horizontally when in heavier soils. The angle of growth with the soil surface is normally between 5 and 10°(Palmer and Sagar, 1963).

In North America, rhizome buds show a steady decrease in activity from mid-April to June 1st. During the month of June, the buds are dormant and recovery begins in late June and continues for the rest of the summer. Two types of dormancy were characterized for quackgrass. The first type of dormancy prevails through the entire year and unless rhizomes are cut and separated from the parent plant, over 95% of buds remain inactive during the entire life of the rhizome as a result of apical dominance. The second type of dormancy occurs when buds remain dormant even after the rhizome has been cut in conditions of adequate moisture and cool temperature which favor rhizome growth. This second type has been called late spring dormancy with the amount of old viable rhizomes decreasing during the season while the number of new viable rhizomes increased and the total viable level remained fairly constant (Johnson and Buchholtz, 1962).

2.5 Response to environment

Various experiments have been conducted to determine the effects of environmental factors on the growth pattern of quackgrass. Of these, temperature, light and nitrogen levels are most commonly reported in the literature.

Temperature

At temperatures greater than 20°C, the dry weight of tillers and rhizomes are decreased in quackgrass (Hakansson, 1970). As temperature increases, respiration increases and the level of water soluble carbohydrates in plants decreases resulting in biomass reduction. The impact of high temperature is greatest on rhizome growth as it was also shown that when levels of water soluble carbohydrates are in short supply, existing tillers are favored at the expense of the outgrowth of new buds into secondary tillers and rhizomes. However, other investigators found that although primary rhizome production from the parent plant was inhibited at high temperatures, tiller production was favored which led to an increase in the number of secondary tillers and rhizomes due to the increased number and more advanced stage of development of the primary tillers in these conditions (Rogan and Smith, 1975). All investigators seem to agree, however, that low temperatures favor the development of primary rhizomes at the expense of tillers, and that of secondary rhizomes. Fluctuating temperatures seem to play a major role in the fall for the rhizome to curve upwards and start developing as an aerial shoot. Also, cool temperatures during the winter are necessary for the quackgrass plant to resume active growth in the subsequent spring.

Illumination

McIntyre reported that reducing day length from 18 to 9 hours virtually eliminated rhizome development in favor of shoot production and that long days are necessary for promoting rhizome development (McIntyre, 1967). Light intensity is also very important. For example, rhizome production is completely stopped when low summer light reaches the foliage of quackgrass (Palmer, 1958). Low light conditions favor tiller production, increase the percentage of rhizome buds developing as shoots and the number of shoots produced at older nodes along the rhizome (McIntyre, 1970). However, active rhizome growth quickly resumes under high illumination (Williams, 1970).

Nitrogen levels

High nitrogen levels have been shown to favor the production of tillers from the parent plant while primary rhizome production is promoted by low nitrogen levels (Rogan and Smith, 1975). However, when quackgrass plants were grown in high nitrogen levels, apical dominance in the already existing rhizomes was sufficiently reduced to permit the continued growth of the lateral buds. Also, although the number of primary rhizomes is decreased under these conditions, the total number of rhizomes is increased since the production of secondary rhizomes (those arising from buds on tillers) is favored. High nitrogen levels have also been shown to increase the number of buds activated into shoot growth should the rhizome be severed from the parent plant and/or broken up (McIntyre, 1967). Finally, there seems to be a nitrogen gradient in rhizomes of quackgrass with higher levels being concentrated toward the apex of the rhizome and decreasing amounts toward the base (McIntyre, 1981).

Temperature, light and nitrogen

Overall, all the above factors seem to be related to the carbohydrate levels in the plant. Low temperature which has been reported to favor rhizome development is expected to decrease the rate of respiration in the plant which in turn increases the amount of soluble carbohydrates available for plant growth. Low levels of nitrogen also have a similar effect as the balance in the C:N ratio is altered to favor carbon availability. Following this logic, reducing light intensity will alter the rate of photosynthesis, therefore decreasing the amount of soluble carbohydrates available and the C:N ratio so that rhizome development is decreased. Combinations of the above factors are likely to occur. For example, high nitrogen levels combined with low light intensity will reduce relative carbohydrate levels resulting in strong apical dominance restricting rhizome growth. However, low nitrogen levels combined with high light intensity are likely to favor the growth of axillary buds as carbohydrate levels are no longer limiting. Therefore, temperature, light intensity and nitrogen levels are some of the primary factors influencing quackgrass patterns of growth, carbohydrate levels being the one factor that governs it.

CHAPTER 3

EFFECT OF QUACKGRASS ON CROPS

Quackgrass directly affects crops by decreasing yield and/or crop quality. It competes with many cultivated crops by consuming key nutrients such as N, P and K. In one study, 55% N, 45% P and 68% K were tied up by this weed in mid-July (Bandeen and Buchholtz, 1967).

Various studies have shown striking yield differences between crops grown in weed-free plots and others in quackgrass infested plots. For example, yield reductions of 40 to 70% in cereals (oats and spring wheat) and 85% in corn have been reported (Werner and Rioux, 1977). In corn, tasseling and silking were delayed and ear moisture was increased when the crop was grown in quackgrass infested plots (Ivany, 1978). Quackgrass has also been reported to reduce the quality of crops as it will deform root crops such as potato when rhizomes grow through tubers or roots. Also, seed crops such as cereals may be unsalable if contaminated with quackgrass seeds and it may affect crops indirectly by harboring diseases or insects as an alternate host. Such diseases as brome grass mosaic virus, seedling blight of alfalfa and cereal as well as insects like the cereal leaf beetle have been reported. Allelopathy is also involved in the competitive ability of quackgrass (Gabor and Veatch, 1981).

Despite its generalized detrimental effects on crops, quackgrass has also demonstrated some valued uses in certain instances. For example, because of its tolerance to dry weather and its capability to withstand close grazing, it is valuable in forage pastures and also shows acceptable quality as silage (Perez-Trejo et al., 1979). Due to its dense rhizomatous system it is also preferred for natural erosion control along riverbanks, terraces and right of ways (Werner and Rioux, 1977).

CHAPTER 4

CONTROL STRATEGIES

Control strategies used to combat quackgrass have been mostly cultural or chemical in nature. New active chemicals are being synthesized that show activity on this weed and biological methods are being studied with possible future application.

4.1 Cultural

Desiccation

Desiccation, by bringing the rhizomes to the soil surface by cultivation is effective, provided that rhizomes are completely exposed to dry air. The moisture content of the rhizomes must be reduced from 65 to 10% to inhibit growth and the ambiant air must be extremely dry for that technique to work (Cussans, 1971). Desiccation by itself is therefore not the ultimate answer due to the difficulty of exposing all of the rhizomatous material under the right conditions, but it may be useful as part of a program to control quackgrass.

4.1.2 Depletion and fragmentation

Depletion of the carbohydrate levels by cultivating at regular intervals is probably the most useful cultural practice known (Turner, 1969). It has been shown that no rhizome or shoot will be produced if that level is brought below 10% of the original amounts. The recommended interval between cultivations is 14 to 21 days since during that period, the young leaf growth (up to the second-leaf stage) is drawing heavily on food reserves in the rhizome and is not producing photosynthates and exporting to underground storage organs. Cultivation breaks rhizomes into pieces and stimulates the growth of new shoots by destroying apical dominance. Further cultivation when the plant reaches the 2-leaf stage weakens the plant until no more carbohydrates are available and growth is stopped. Fragmentation basically follows the same principle as depletion in that rhizomes are cut into pieces so that shoot production is favored from rhizomes that have low amounts of carbohydrates available due to their small size. Burying such pieces to a depth where carbohydrate levels will not be sufficient to maintain the growth of shoots to the soil surface is then needed to achieve control. The general rule for burying is a depth of 6 inches for rhizomes fragmented to a length of 6 inches (Hakansson 1971, Cussans 1971).

Shade and competition

Shade provided by a strong competitive crop is also one of the best and cheapest control measures as rhizome production is reduced under such conditions (Hakansson, 1971). However, quackgrass must first be sufficiently exhausted by other control measures to permit strong establishment of the crop.

4.2 Biological

The selection of an agent for the biological control of quackgrass

In order for a biological control agent to achieve maximum effectiveness in reducing the density of its host, it should attack it at a time when it is phenologically most vulnerable to damage (Harris, 1971). In the case of quackgrass, one would immediately think of an insect or pathogen that would thrive on its rhizomatous system since the reproduction and persistence of quackgrass are associated with this characteristic. A weevil (Notaris bimaculatus) has been reported to have such a feeding habit (Westra et al. 1981). However, the rhizomatous system of quackgrass can be extremely dense and the insect population would need to be high to maintain shoot emergence at low levels. Also, a good lesson can be learned from the cultural practices that have been devised to control quackgrass. A successful agent could therefore be one that would feed throughout the growing season on successive flushes of quackgrass shoots until no more reserves were available at the rhizome level to sustain the growth of young shoots above the soil line. This could also be achieved by a pathogen under the mycoherbicide approach although more than one application may be necessary if the pathogen is unable to survive in between flushes.

Thus, it seems reasonable to suggest that quackgrass is most vulnerable to attack when carbohydrate levels in the rhizomes are at their lowest as a result of the growth of young shoots drawing actively on their underground food source. An agent that would further weaken this source by feeding directly on the rhizomes or the young emerging plants early in the season, would therefore be of the most successful type, especially, if it is well adapted to the climatic conditions prevailing at that time.

Attempts to find agents suitable for the biological control of quackgrass

Palmer and Sagar (1963) list a variety of natural enemies reported to feed or parasitize quackgrass including five nematodes, 24 insects, 21 fungi and one virus. No efforts have been made for the selection of insects for the biological control of quackgrass (Watson, 1986), but the evaluation of native pathogens as potential biological control agents has received some attention (Sampson, 1983; Sampson and Watson, 1985).

Native pathogens

During a survey conducted throughout Eastern Canada in 1979 and 1980, 30 pathogens were recorded on quackgrass (Sampson, 1983). Of these, ten were selected for host specificity studies and only three were found to be specific to quackgrass. These studies suggested that *Urocystis agropyri* could be a successful organism as it has demonstrated the ability to restrict the vegetative reproduction of quackgrass.

4.3 Chemical

The following chemicals have been registered or show activity against quackgrass in cultural situations: atrazine, amitrole, dalapon, trichloroacetic acid, paraquat, glyphosate, sethoxydim, fluazifop-butyl, haloxyfop-methyl and quizalofop-ethyl. Rates are reported in grams or kilograms of active ingredient per hectare.

Atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine)

Atrazine is registered for quackgrass control in corn at a rate of 2.25 kg/ha applied in the fall and 2.25 kg/ha in the following spring on emerging quackgrass shoots. This treatment helps the depletion of quackgrass carbohydrate reserves but does not destroy the rhizome buds. Corn must be grown for two to three years following such a treatment as soil residues prevent the establishment of any other crop. Atrazine is a photosynthetic inhibitor that is absorbed through the roots and foliage of plants. It is then translocated acropetally in the xylem and accumulates in the apical meristems. Tolerant plant species such as corn are not susceptible due to differential metabolism of the parent herbicidal molecule.

Amitrole (3-amino-s-triazole)

Amitrole is registered for the control of quackgrass in the fall or spring at 3.36 to 5.23 kg/ha for non-crop areas. The application must be performed to actively growing quackgrass plants. Plowing or discing should follow the application by 10 to 14 days. A subsequent cultivation may also be needed when emerging quackgrass shoots reach the two-to three-leaf stage. This compound is absorbed both by the roots and foliage. It is translocated via the xylem and phloem and accumulates in leaves where chlorophyll formation is inhibited. Of special interest in relation to quackgrass control is the inhibition of regrowth from buds. Dormant buds are not affected however.

Dalapon (2,2-dichloropropionic acid)

Dalapon is useful for quackgrass control in crops such as potatoes, apples, grapes, peas, flax and others. It is applied at a rate of 0.84 kg/ha (flax) to 22 kg/ha (non-crop land) when quackgrass plants are fully emerged. The application must be performed during the previous fall if sensitive crops are to be planted in the treated area (cereals, beans, corn). A spring application should be performed when the emerged quackgrass shoots reach a height of 10 to 15 cm. Cultivation of the site should not be performed within 14 days of application. No crop, with the exception of potatoes, should be planted within 30 days after spraying. The compound is absorbed both by the foliage and roots and is translocated via the xylem and the phloem within the plant where meristematic growth is inhibited following accumulation in plant tissues.

TCA (trichloroacetic acid)

Trichloroacetic acid is recommended for quackgrass control in non-crop areas at a rate of 3.6 kg/ha. It is applied on emerged quackgrass plants using standard spray equipment. TCA is absorbed more readily by roots than by foliage and it translocates easily within the plant and accumulates in growing tissues where it inhibits plant growth. The compound has a residual activity varying from three to 10 weeks.

Paraquat (1,1'-dimethyl-4-4'-bipyridinium ion)

Paraquat is a non-selective herbicide registered for quackgrass control in most crops as selectivity is dependent on placement in all cases. A rate of 0.5 to 1.0 kg/ha will provide complete desiccation of aerial parts of quackgrass and will be helpful in a long-term control strategy by reducing rhizome carbohydrate levels through impaired photosynthesis. This compound is readily absorbed by the foliage and green bark of all plant species and shows very little translocation within plants. It causes phytotoxicity within plants by inducing the disruption of cell membranes and chloroplasts. Only plants with an extremely thick waxy cuticle or those with mature bark are tolerant to applications to paraquat by way of a physical barrier. Paraquat has no residual activity as it is adsorbed to soil particles upon contact.

Glyphosate (N-(phosphonomethyl) glycine)

Glyphosate is a non-selective, translocated foliar herbicide that has no crop restrictions for the control of quackgrass. Selective use can be obtained by timing to avoid contact with the crop or by the use of barriers. Rates of 1.7 to 2.5 kg/ha applied to actively growing (three to five leaves) quackgrass shoots show excellent efficacy. Both a spring or fall application are recommended. An interval of 10 days is recommended prior to cultivation following application. No residual activity has been shown and crops can be seeded directly into treated areas. Glyphosate is absorbed through the foliage of plants and is readily translocated to aerial parts of the plant as well as roots and rhizomes where it inhibits the synthesis of amino acids.

Sethoxydim

Registered on most broadleaf crops for the control of quackgrass, sethoxydim must be applied when quackgrass plants are actively growing (three- to six-leaf stage) so that maximum translocation is achieved to rhizome buds. A rate of 0.75 to 1.0 kg/ha is recommended for adequate quackgrass control. This compound is readily absorbed by the foliage and is translocated both basipetally and acropetally within plants. It accumulates within plant meristems and causes the inhibition of plant growth. Sethoxydim displays very little residual activity at rates used for the control of quackgrass.

Fluazifop-butyl

Also registered on most broadleaf crops for the control of quackgrass, fluazifop-butyl displays slightly better quackgrass control than sethoxydim at recommended use rates. Quackgrass plants must be actively growing (three- to six-leaf stage) at application for efficacy to be optimal. Rates of 0.6 to 0.85 kg/ha are necessary for perennial grassy weed control. Fluazifop-butyl is readily absorbed by the foliage of plants and is translocated via the xylem and phloem to aerial and underground plant parts where it accumulates into meristems and inhibits cell division and elongation. When used at recommended rates, crops can be planted immediately into treated areas.

Haloxyfop-methyl and Quizalofop-ethyl

Both compounds are members of the diphenyl ether family as is fluazifop-butyl. They both display excellent activity on quackgrass when applied to actively growing plants. Although not yet registered, selectivity to most broadleaf crop species has been demonstrated at rates where excellent quackgrass control was obtained. Both diphenyl ethers are absorbed readily by foliage and translocate within the plant via the xylem and the phloem to meristems where cell division and elongation is inhibited. Although preemergence weed control has been demonstrated on annual grasses with both compounds, rates required were very high. Rates tested for postemergence quackgrass control have not shown residual activity.

CHAPTER 5

POSTEMERGENCE GRASS HERBICIDES

General characteristics

The introduction of postemergence grass herbicides for use in broadleaf crop is considered by many as a major breakthrough in herbicide technology. The first compound in this area was a grass herbicide for use in cereals, diclofop-methyl (methyl 2-°4-(2,4-dichlorophenoxy)phenoxy propanoate), introduced in the United States in 1975 by the Hoescht Company. Since the introduction of diclofop-methyl, a continuing series of similar compounds have been under investigation, many of which have originated in Japan. Because of toxicology problems and other reasons, some have been terminated. Compounds currently registered or under investigation are: sethoxydim, fluazifop-butyl, haloxyfop-methyl, quizalofop-ethyl, fenoxaprop and chloproxydim.

These compounds can be divided into two different groups according to their chemical structure. The first group which includes fluazifop-butyl, fenoxaprop, haloxyfop-methyl and quizalofop-ethyl, has a phenoxy propionic acid group associated with various derivatized aromatic compounds. These compounds are referred to as the pyridinyloxyphenoxypropionates or the diphenyl ethers. The other group which includes sethoxydim and chloproxydim has various derivatized alkyl imino groups on a derivatized cyclohexene group and are referred to as the cyclic ketones. In general, both of these new groups of compounds have considerable flexibility in terms of timing of application for weed control. Annual grasses in the three- to five-leaf stage are the most sensitive but larger plants are also controlled. The growth rate of weeds seems to be the most important factor determining efficacy. Cold, wet or dry conditions usually cause a reduction in efficacy. Conditions that favor rapid penetration and translocation lead to maximum toxicity.

Visual symptoms

As a group, these new chemicals lead to the cessation of growth of grasses quite rapidly after application while meristematic tissues gradually become chlorotic followed by necrosis and death. Older leaves also show signs of senescence and pigment changes. Swisher and Corbin (1982) evaluated the efficacy of sethoxydim on johnsongrass. One day after treatment, localized necrotic zones were seen in developing leaves and internodes; three days after treatment, the shoot apex was disorganized and necrotic, and collapsed cells were seen at the apex, leaf primodia and at the base of expanding leaves; five days after application, the entire apical region and developing leaves had degenerated and little cellular detail was discernible. Similar symptoms were observed on johnsongrass roots.

Systemic action

These two groups of compounds have similar systemic action. Experiments on bud viability of quackgrass rhizomes following foliar applications of glyphosate, sethoxydim, fluazifop-butyl, haloxyfop-methyl and two other compounds were conducted (Dekker and Chandler, 1985). Although none of the herbicides completely eliminated either bud viability or new rhizomes from forming after treatment, all the herbicides moved throughout the plant and in all sections of the rhizome system (Dekker and Chandler, 1986).

Site of action

Selectivity among plant species to postemergence herbicides can be due to differences in site of uptake, spray retention, herbicide absorption and translocation, site of action or herbicide metabolism. Both the diphenyl ethers and the cyclic ketones affect areas of high metabolic activity within meristematic regions of susceptible species. The accumulation of fluazifop-butyl is greatest at nodes near the quackgrass rhizome tips and least in nodes near the mother shoot (Chandrasena and Sagar, 1986). Similar results were obtained with sethoxydim on johnsongrass (Swisher and Corbin, 1982) and with haloxyfop-methyl on yellow foxtail (Buhler et al., 1985). Studies on the site of action of quizalofop-ethyl showed that following translocation within established plant of *Echinochloa crusgalli*, the compound was accumulating in meristematic tissues at the stem base (Ikai et al., 1985). Symptoms (swelling) appeared first in the meristem just below the shoot apex followed by the severe destruction of young cells including those in intercalary meristems.

Translocation

Since the site of action of both the diphenyl ethers and the cyclic ketones is distant from the main site of absorption, toxic amounts of foliar applied herbicides must translocate in the plant. Differences in the ease of translocation might account for differences in efficacy between the compounds on a given weed species. For example, complete control and suppression of shoot regrowth in quackgrass require higher rates of sethoxydim than in other rhizomatous grasses. This may indicate that sethoxydim does not translocate as readily throughout the perennial system of quackgrass. Also, the regrowth of wirestem muhly was lesser with fluazifop-butyl and sethoxydim than haloxyfop-methyl at early clipping intervals. It was suggested that this could be due to slower translocation of haloxyfop-methyl in this weed (Hicks and Jordan, 1984).

The time required for the herbicides to translocate to their site of activity generally corresponds to the appearance of visual symptoms. At low rates, the translocation of fluazifop to the rhizomes of quackgrass occurs mainly between six and 48 hours after application and 72 hours after spraying, at least 90% of the buds accumulate a lethal dose (Chandrasena and Sagar, 1986). Movement was shown to be both acropetal (leaves and stems) and basipetal (root system). This was indicative of a typical phloem dependent movement. Also, the concentration of C^{14} activity which accumulated in the leaves and stems above and below the treated leaf and the activity in the rhizomes increased with time, suggesting that movement is associated with a source to sink relationship in the plant. However, most of the C^{14} taken up by plants is retained in the treated leaves themselves. Only small amounts are translocated to meristematic sinks. Less than 1% of the applied quizalofop-ethyl was needed to achieve efficacy in barnyard grass (Ikai et al., 1985). This may be partly due to a disruption of the translocation pathway as meristems gradually become necrotic following absorption.

Metabolism

The speed of translocation of the diphenyl ethers and the cyclic ketones can also depend on the rapidity of transformation of the formulated chemical molecule to the active metabolite form (Hicks and Jordan, 1984). The esters of the pyridinyloxyphenoxypropionic acids are rapidly hydrolysed after absorption by quackgrass. The free acids are then translocated and are the active form of these herbicides in the metabolic sinks (Hendley et al., 1985). These products are formulated in an ester form because of the resulting lipophilicity which leads to enhanced leaf penetration and therefore, higher concentrations of the acid at the sites of action.

Also, the molecule of haloxyfop-methyl is rapidly absorbed by the foliage of both grasses and dicots and hydrolysed to its acid metabolite, haloxyfop, presumably by carboxylesterases. Haloxyfop is the main translocated material (Gronwald, 1986). Similarities were found with the cyclic ketones as only a small proportion of sethoxydim remains unchanged after absorption in both soybeans and johnsongrass. Three different metabolites compose a large percentage of the radioactivity recovered from various plant parts (Swisher and Corbin, 1982). Experiments with haloxyfop-methyl showed that the parent molecule was hydrolysed and translocated to metabolic sinks in both susceptible and tolerant species. Differential metabolism could be involved at the cellular level (Buhler et al., 1985).

Mode of action

The modes of action proposed by various workers are similar for both the cyclic ketones and the diphenyl ethers. Sethoxydim is primarily a phloem mobile compound, translocated in a source to sink manner along with photosynthates following application. The death of tissue located in sink regions disrupts the flow of nutrients and herbicide from mature exporting leaves. Dead cells no longer serve as metabolic sinks, and decreased transport to these injured regions occur. The resulting accumulation of sugars in mature leaves provides the erythrose-4-phosphate, phosphoenol pyruvate and acetyl coenzyme A required for anthocyanin synthesis. This explains the accumulation of anthocyanin pigments in mature leaves of susceptible plants and the reduction in translocation from treated leaves to apical regions resulting in cell death in metabolic sink regions of the plant and the subsequent disruption of photosynthethate and herbicide transport (Swisher and Corbin, 1982). Selectivity at the site of action can be the result of the inhibition of cell division and elongation in the growing points of grasses. Evidence was found that haloxyfop-methyl behaves as an auxin antagonist since it inhibits the auxin-induced elongation of oat coleoptiles. Haloxyfop was shown to cause rapid depolarization of the electrogenic components of cell membranes in oat coleoptile cells and the possible inhibition of lipid synthesis at the cellular level and a reduction in the respiration rate and ATP content. The latter, however, seems to be the result of cell growth impairment rather than the cause (Gronwald, 1986). Quizalofop-ethyl was shown to inhibit protein, RNA and lipid synthesis within 8 hours of incubation with the cell membrane being central to further elucidation of a specific site of action (Ikai et al., 1985). Studies with sethoxydim showed results similar to those with quizalofop-ethyl. The chemical causes increases in sugar and anthocyanin levels in the plant while it inhibits growth, chlorophyll accumulation and respiratory activity (Asare et al., 1983). Cytological studies also showed that sethoxydim interfered with mitosis by preventing cell wall formation resulting in binucleate cells. It was suggested that phytoxicity may therefore be due to both physiological and cytological effects (Asare et al., 1983).

CHAPTER 6

MATERIALS AND METHODS

6.1 Field studies

6.1.1 Trial establishment

All field trials were conducted on the property of Mr. Jean-Yves Guérin in St-Michel de Napierville, Québec. The field had been cropped to potatoes for four years prior to 1985, but the quackgrass infestation became so overwhelming that it was left uncropped during the 1985 season. The soil type was a sandy loam with 3.02% organic matter, 68.5% sand, 18% silt and 13.5% clay with a pH of 5.45. Prior to cropping the field to potatoes in 1986 the site was ploughed, followed by discing and harrowing twice each in the spring.

The potato variety Superior was used in all three years of the study. The crop was planted using a two-row potato planter. Potato seed pieces were sown 18 cm apart within rows and 91.5 cm between rows at a depth of 10 to 13 cm for a seeding rate of 2551 kg/ha. A chemical fertilizer (1134 kg/ha of 15-20-20) was applied at planting. Rows were planted in an East/West direction.

The experimental design was a randomized complete block design with four replicates. Each plot was 6.0 m by 6.0 m and contained seven rows of potatoes. The outer rows on each side of each plot were considered as border rows with the treatments being applied to the five center rows.

All herbicide applications were performed using a CO_2 pressurized small plot sprayer with a two-meter boom and 8003 TEEJET nozzles at a pressure of 300 kPa and a volume of 250 liters of spray solution per hectare. Climatic conditions at application were recorded and are presented in Tables one and two. The middle row (number four) was kept as a division on which the overlap from the spray swath of herbicides was targeted.

Two experiments were conducted and both were repeated for two consecutive growing seasons, 1986 and 1987. In experiment number one, potatoes were planted on May 14, 1986, and May 8, 1987. Herbicides were applied in the spring, postemergence to the crop, when quackgrass plants were in the three- to six-leaf stage (June 19, 1986, and June 17, 1987) (Table 1). Cultivation consisted in hilling the potatoes once during the growing season before the crop canopy started to close in the rows. This operation was performed on July 5 in 1986 and July 10 in 1987.

In experiment number two, potatoes were planted on the same dates as those mentioned for experiment number one, but herbicide applications were performed post harvest in the fall when the regrowth of quackgrass was in the three- to four-leaf stage. During the growing season preceding these applications, the potato crop was also hilled once at the same dates as indicated for experiment number one. Herbicide treatments were applied on September 17, 1986, and September 27, 1987 (Table 2). All four sites were recropped to potatoes maintaining plot locations the year following applications so as to assess long-term

Table 1. Conditions at application for the summer application. (experiment 1)

	June 19, 1986	June 17, 1987
Air temperature	15°C	26°C
Relative humidity	75%	50%
Wind speed	0 km/hr	0 to 5 km/hr
Wind direction	-	South West
Soil temperature	18°C	21°C
Soil condition	Dry	Moist
Crop height	15 to 25 cm	17 to 22 cm
Quackgrass stage	3 to 4 leaves	3 to 6 leaves
Quackgrass density (shoots/m^2)	328	348.5

Table 2. Conditions at application for the fall application. (experiment 2)

	September 17, 1986	September 27, 1987
Air temperature	5°C	17°C
Relative humidity	70%	70%
Wind speed	0 km/hr	0 to 5 km/hr
Wind direction	-	West
Soil temperature	5°C	11°C
Soil condition	Moist	Moist
Crop height	No crop	No crop
Quackgrass stage	3 to 4 leaves	3 to 4 leaves
Quackgrass density (shoots/m^2)	488	307.5

efficacy of the treatments.

All sites were sprayed with other pesticides to protect the crop from insects and to prevent broadleaved weed populations from interfering with the study. In 1986, metribuzin [4-amino-6-tert-butyl-3-(methylthio)-as-triazin-5(4h)-one] at a rate of 750 g/ha and a tank mix of deltamethrin [(RS)-cyano(3-phenoxyphenyl)methyl(1RS)-cis-trans-3-(2,2-dichloroethenyl)-2,2dimethylcyclopropanecarboxylate] at 125 g/ha and endosulfan [6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin 3-oxide] at 400 g/ha were sprayed on June 10th and 30th respectively to control broadleaved weeds and the colorado potato beetle.

6.1.2 Treatment lists

Four rates of quizalofop-ethyl (DPX6202-23), one rate of sethoxydim and one rate of fluazifop-butyl were compared to an untreated control for postemergence control of quackgrass in potatoes. The selected treatments for experiment number one where applications were to be made in the summer were quizalofop-ethyl at 96 g/ha + 0.5% v/v Canplus 411, quizalofop-ethyl at 144 g/ha + 0.5% v/v Canplus 411, quizalofop-ethyl at 192 g/ha + 0.5% v/v Canplus 411, quizalofop-ethyl at 240 g/ha + 0.5% v/v Canplus 411, sethoxydim at 810 g/ha + 2.0% v/v Assist and fluazifop-butyl at 750 g/ha + 0.1% v/v Agral 90 and an untreated check (Table 3). Rates although listed in g/ha in the text and tables were calculated in g.a.i./ha.

The same treatments with one exception were evaluated for quackgrass control after potato harvest in fall (experiment number two). The four quizalofop-ethyl rates and the rate of sethoxydim were

Table 3. Treatment list for the summer application (experiment 1)

	Treatment	Rate g/ha	Surfactant
1-	Untreated	-	-
2-	Quizalofop-ethyl	96	Canplus 411 at 0.5% v/v
3-	Quizalofop-ethyl	144	Canplus 411 at 0.5% v/v
4-	Quizalofop-ethyl	192	Canplus 411 at 0.5% v/v
5-	Quizalofop-ethyl	240	Canplus 411 at 0.5% v/v
6-	Sethoxydim	810	Assist at 2.0% v/v
7-	Fluazifop-butyl	750	Agral 90 at 0.1% v/v

retained, but the fluazifop-butyl treatment was replaced with glyphosate at 890 g/ha (Table 4).

6.1.3 Assessment of quackgrass [*Agropyron repens* L. Beauv.)] control

Assessment of quackgrass visual control was made using a scale of 0 to 100 (0-no control, 100-complete control) (Frans et al., 1986). Each plot was independently evaluated by two people and the average rating

was recorded. These assessments were performed 2 weeks after application (July 1, 1986, and July 3, 1987) for experiment number one.

In order to assess long-term control of quackgrass on sites sprayed the previous summer, sampling was performed on the same plots one year following application. Quackgrass density was determined by counting the number of quackgrass shoots in four 0.5 m by 0.5 m quadrats randomly placed within each plot and the height of five quackgrass shoots selected at random were measured in each quadrat. These parameters were obtained at the same time as the visual assessments (July 1, 1986, and July 3, 1987) and also in the year following application [July 2, 1987 (1986 application) and July 29, 1988 (1987 application)].

Quackgrass density and height data were also obtained following the post-harvest applications of experiment number two. The ratings were performed on July 2, 1987, (fall 1986 application) and July 29, 1988, (fall 1987 application).

Table 4. Treatment list for the fall application (experiment 2)

	Treatment	Rate g/ha	Surfactant
1-	Untreated	-	-
2-	Quizalofop-ethyl	96	Canplus 411 at 0.5% v/v
3-	Quizalofop-ethyl	144	Canplus 411 at 0.5% v/v
4-	Quizalofop-ethyl	192	Canplus 411 at 0.5% v/v
5-	Quizalofop-ethyl	240	Canplus 411 at 0.5% v/v
6-	Glyphosate	890	-
7-	Sethoxydim	810	Assist at 2.0% v/v

6.1.4 Quackgrass shoot dry weight

Quackgrass shoot dry weight was obtained by cutting all quackgrass shoots at soil surface in three 0.5 m by 0.5 m quadrats placed at random within each plot. These quadrat samples were dried at 50°C for 24 hours and weighed on a Mettler electronic scale immediately after removal from the air dryer.

Sampling dates were August 13, 1986, and August 11, 1987, for experiment number one as well as August 11, 1987, and August 30, 1988, for experiment number two.

6.1.5 Visual crop injury

Visual assessment of crop injury was made on a scale of 0 to 100 (0-no phytotoxicity, 100-complete kill) (Frans et al., 1986). Each plot was independently evaluated by two people and the average rating was recorded.

Since quizalofop-ethyl is known to cause limited short-term interveinal chlorosis of lower leaves of potato plants early in the season, ratings were performed at the same time as quackgrass control assessments: July 1, 1986, and July 3, 1987, shortly after application and on July 2, 1987, (1986 application) and on July 29, 1988, (1987 application) for experiment number one. Crop injury ratings for experiment number two were performed on July 1, 1987, (fall 1986 application) and July 29, 1988, (fall 1987 application).

6.1.6 Rhizome fresh weight

Rhizome fresh weight was obtained in the first fall following application at the same dates as the shoot dry weight sampling, i.e., August 13, 1986, and August 11, 1987, for experiment number one and August 11, 1987, and August 30, 1988, for experiment number two. In order to better evaluate long-term efficacy of quizalofop-ethyl as determined via bud viability studies, a supplemental sampling of rhizomes was performed on August 30, 1988, for the spring 1987 application. A 15-cubic centimeter soil sampler (Gutman and Watson, 1980) was used to retrieve soil and quackgrass rhizomes at three locations selected at random within each plot. The soil sampler was placed on the side of the potato hill for sampling. Each sample was independently bagged and labelled. Separation of rhizomes from the soil in the sample was performed by washing the rhizome/soil agglomerates through three successive sieves of 2.5 cm, 1.0 cm and 2.0 mm respectively.

The freed rhizomes were blotted dry with absorbant paper and left to air dry at ambiant temperature on an aluminum plate for about 15 minutes. Each rhizome sample was then labelled individually and mixed with sterilized moist potting soil in a perforated plastic bag. These samples were then stored in a refrigerator in the dark for 4 to 8 weeks at a temperature of 4°C and subsequently used to determine rhizome bud viability.

6.1.7 Crop marketable and total yields

Crop yields were obtained for both experiments. Experiment number one was harvested on August 20, 1986, and August 17, 1987, and experiment number two was harvested on August 17, 1987, and August 30, 1988. Rows number two and three in each plot were harvested with a two-row commercial potato harvester and all tubers were collected and sized according to the Canadian grading system for potatoes. Potatoes which had a width of 47 mm or more and those with less than 47 mm were separated and weighed with a commercial scale for each plot. Potatoes were then discarded by spreading them over alleys between experiments with the intent of destroying them with a fall ploughing.

6.2 Laboratory studies

6.2.1 Bud emergence studies

6.2.1.1 Rhizome categories

Rhizome samples that had been stored in the refrigerator at 4°C were washed under running water using two successive sieves of 1.0 cm and 2.0 mm respectively. Rhizomes were then separated into three groups based on their appearance and texture. The first group consisted of light- or dark-colored hollow rhizomes which were assumed dead. The second group consisted of rhizomes that had a firm texture but were in part or completely darkened. The third group consisted of rhizomes that had a firm texture, were light in color and presumed normally viable. After washing, the rhizomes were blotted dry with absorbant paper and left in ambiant air for about 15 minutes to allow surface moisture to evaporate. The three groupings in each sample were weighed.

6.2.1.2 *In vitro* emergence study

After weighing, rhizomes from the first group were discarded. Of the remaining two groups, five rhizome buds were selected at random from each. The rhizome sections bearing these buds were cut into lengths of approximately five to seven mm making certain that only one bud per piece was present.

Each rhizome was washed free of any remaining soil particles by rinsing it in distilled water. Adventitious roots and scale leaves present at the nodes were removed using surgical scissors to reduce contamination in the growth medium. The rhizome sections were then placed in water agar (0.8% Difco Bacto agar). The rhizome sections were positioned vertically in the agar by placing the mid point of each rhizome node at the surface level. Plates containing five rhizome pieces each were labelled and sealed with a strip of parafilm to prevent drying while allowing gas exchanges. The plates were incubated at 24°C in the dark for 15 days. These plates were examined and any bud showing evidence of extension (root or shoot) was rated viable. These viable buds were discarded and the others were evaluated with the tetrazolium trichloride technique.

6.2.2 Tetrazolium bud viability studies

To complement the *in vitro* emergence tests, buds that had not emerged were removed from the rhizomes using tweezers and a scalpel under a dissection microscope and then cut longitudinally. Both halves of each bud were then transferred to a 15-mL vial containing five mL of a 0.1% tetrazolium solution and the vials were capped. The 0.1%

tetrazolium solution was prepared by diluting 0.5 g of tetrazolium powder in 500 mL of distilled water. The vials were stored at 24°C for 22 hours in the dark.

After the incubation period, rhizome bud halves were examined under the microscope and a pink or red stain in the meristem region of the buds was recorded as viable while an unstained white or brown meristem was recorded as non-viable.

6.3 Statistical analyses

The data for each parameter in both experiments was first subjected to a standard analysis of variance to determine whether or not there was a significant treatment effect. A test of homogeneity (Ftest) of error mean squares (EMS) was then conducted to determine whether or not data from successive years could be pooled for analysis. It was then decided not to pool data. This was done in order to avoid confusion as all parameters measured were not homogeneous. Also, great differences in growing conditions were seen during subsequent testing years. For maximum clarity and ease of interpretation, the integrity of the data sets was maintained and results from experiments reported together by individual year of testing. For parametric data, when a significant effect was obtained the least significant difference (LSD) was calculated with the help of a computerized statistical analysis system (SAS) and results reported. Shoot density data was first subjected to a square root transformation for normalization. In the case of non-parametric data (injury), a Friedman two-way analysis of variance by ranks test with multiple comparisons was used to identify differences between treatments. These steps were carried out utilizing files in which all seven treatments including the untreated check and the two standards were present. An analysis of variance was then conducted on files in which the standard treatments had been eliminated in order to see whether or not a regression analysis could be performed. When a treatment effect was identified with the variance analysis, the data set was subjected to an analysis of orthogonal polynomials to determine whether or not the regression was cubic, quadratic or simply linear. The appropriate regression analysis was then conducted so as to obtain the value of the regression parameters.

CHAPTER 7

RESULTS FROM A SUMMER APPLICATION

Results for both experiments are presented in graphical form through the text. The analysis of variance tables are presented in appendices I to VIII. Results are also presented in tabular form in appendices IX to XIX. A test of homogeneity of experimental mean squares for each parameter evaluated was conducted between successive years of testing for both experiments. For summer applications, 60% of experimental mean squares were homogeneous between years and 40% heterogeneous. For fall applications, 50% were homogeneous and heterogeneous respectively.

7.1 1986 Application

Quackgrass response

Of all the parameters used to evaluate the efficacy of the herbicides for quackgrass control, shoot dry weight, an objective physical measurement of the quackgrass population, is perhaps the most representative of the actual efficacy achieved. Following a 1986 application, all herbicide treatments significantly reduced quackgrass shoot dry weight, but increasing the rate of quizalofop-ethyl above 96 g/ha did not further improve this reduction (Figure 7.1). Although minor differences were noticed visually among the herbicide treatments, quackgrass shoot density, height and visual injury were significantly reduced by all herbicide treatments when compared to the untreated check (Figures 7.2, 7.3 and 7.4). Regression analyses did not indicate any difference among the quizalofop-ethyl rates for any of the parameters evaluated in 1986. In 1987, quackgrass shoot density, height and visual injury were measured on plots treated the previous year. All herbicide treatments resulted in significantly reduced quackgrass density when compared to the untreated check as was observed the previous year (Figure 7.5). No symptoms of herbicide injury on the quackgrass regrowth were observed for any of the treatments. Differences were noticed however when height was measured. A quadratic effect was obtained when a regression analysis was performed among the quizalofop-ethyl treatments and the untreated check (Figure 7.7). The best treatment was 144 g/ha of quizalofop-ethyl. Higher rates of quizalofop-ethyl resulted in greater heights although they were not significantly different from the 144 g/ha rate. This reduction in height may be an indication that the 96 g/ha rate of quizalofop-ethyl may not always be the optimum rate for quackgrass control as suggested by the evaluation of other parameters. Also, it may indicate that higher rates of quizalofop-ethyl may prevent the complete translocation of quizalofop-ethyl to the rhizomes of quackgrass plants due to faster kill of meristems in the shoot.

Rhizome data, in the figures and tables, are reported as grams per

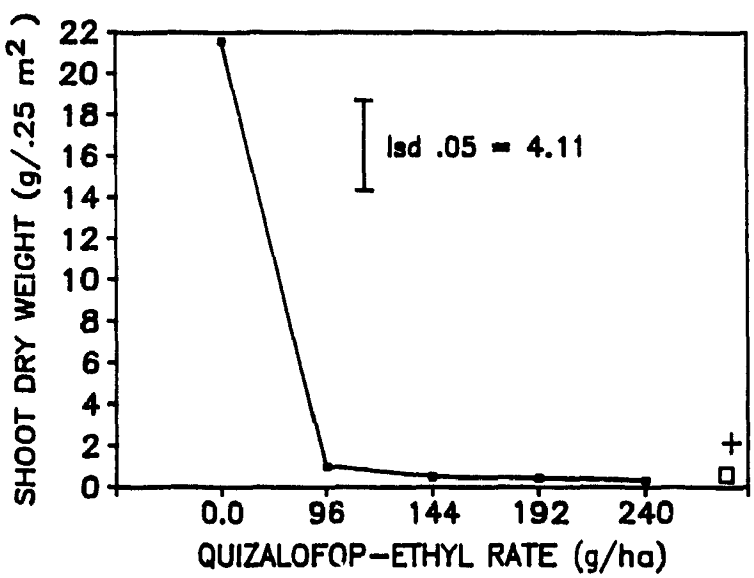

Fig.7.1 Effect of quizalofop-ethyl on quackgrass shoot dry weight following a 1986 summer application (1986 sampling). Standard treatments are sethoxydim (+) and fluazifop-butyl (□).

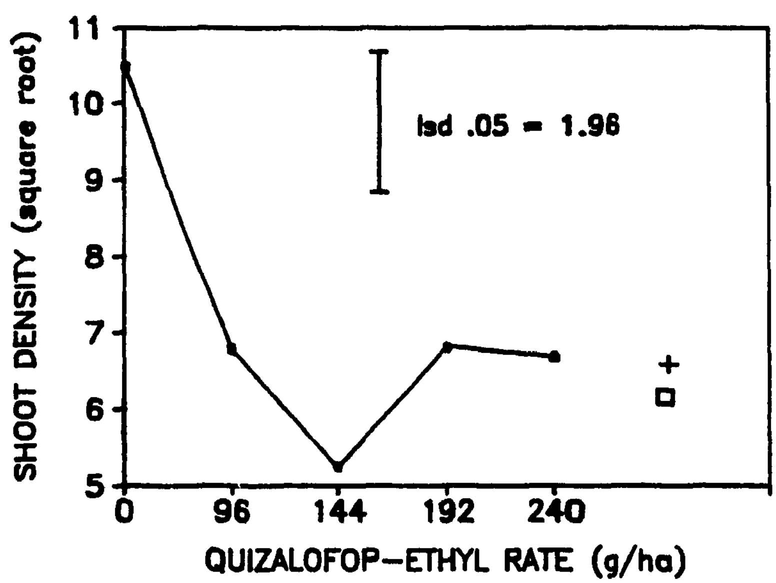

Fig.7.2 Effect of quizalofop-ethyl on quackgrass shoot density following a 1986 summer application (1986 evaluation). Standard treatments are sethoxydim (+) and fluazifop-butyl (□).

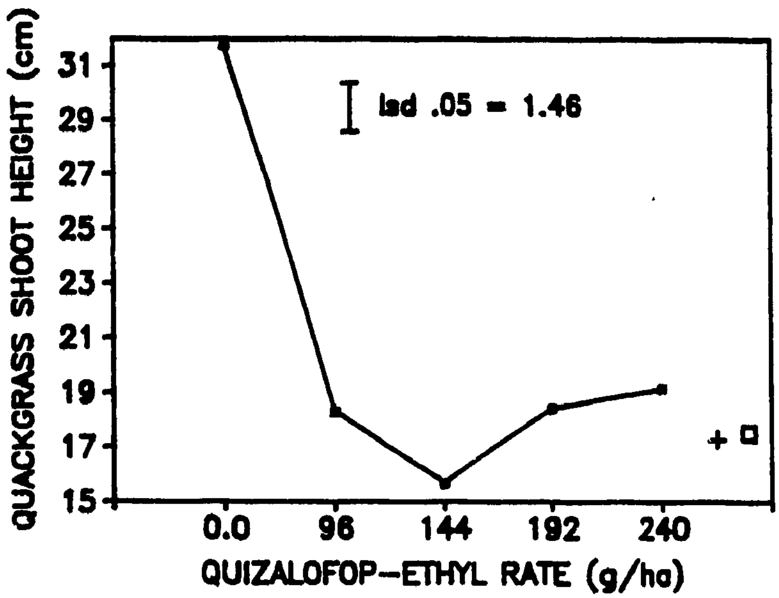

Fig.7.3 Effect of quizalofop-ethyl on quackgrass shoot height following a 1986 summer application (1986 evaluation). Standard treatments are sethoxydim (+) and fluazifop-butyl (□).

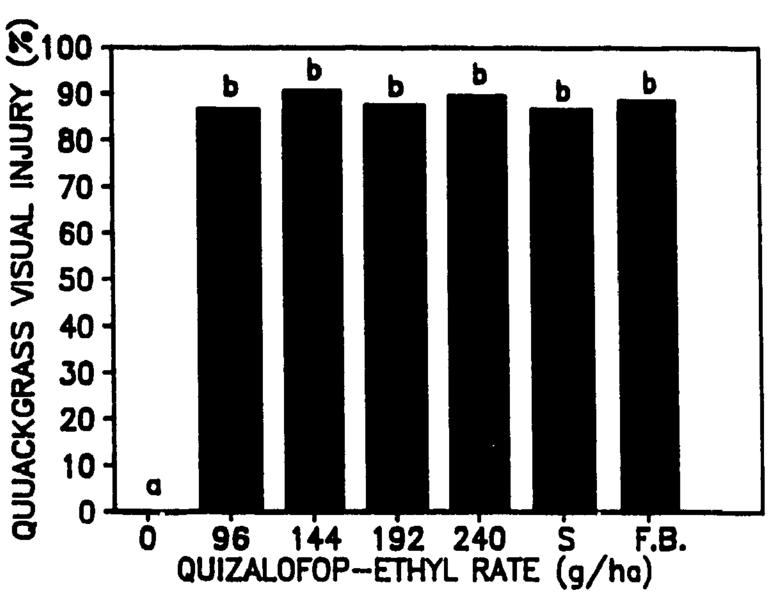

Fig.7.4 Effect of quizalofop-ethyl on quackgrass visual injury following a 1986 summer application (1986 evaluation). Standard treatments are sethoxydim (S) and fluazifop-butyl (F.B.). Means identified by the same letter are not significantly different at the 0.45 experiment wise error rate.

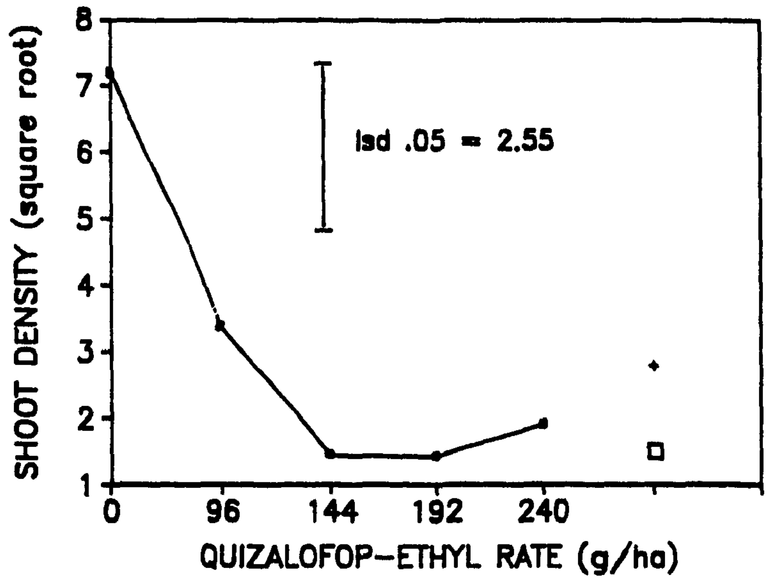

Fig.7.5 Effect of quizalofop-ethyl on quackgrass shoot density following a 1986 summer application (1987 evaluation). Standard treatments are sethoxydim (+) and fluazifop-butyl (□).

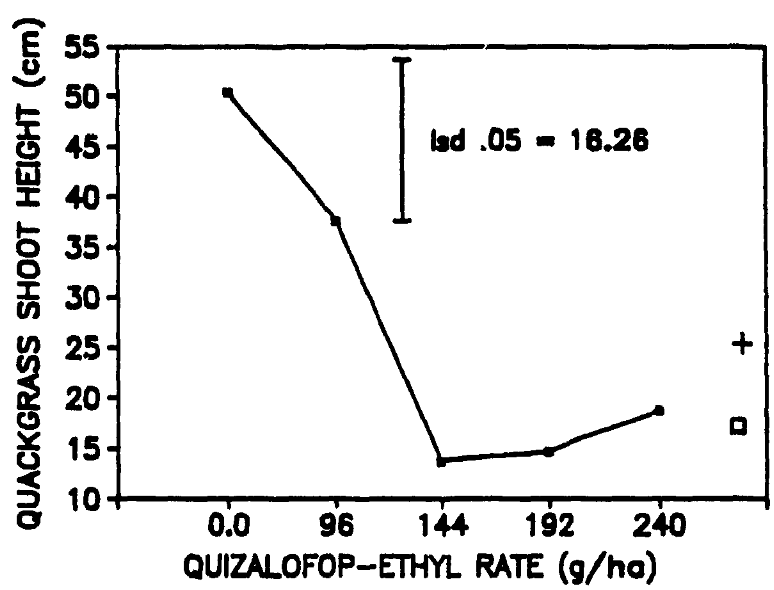

Fig.7.6 Effect of quizalofop-ethyl on quackgrass shoot height following a 1986 summer application (1987 evaluation). Standard treatments are sethoxydim (+) and fluazifop-butyl (□).

15 cm^3 sample. In 1986, all herbicide treatments yielded rhizome fresh weights that were significantly smaller than the untreated checks. The best treatment among those tested was quizalofop-ethyl at 96 g/ha although not significantly different from other quizalofop-ethyl rates or sethoxydim (Figure 7.8). The lowest rate of quizalofop-ethyl was therefore sufficient to provide adequate control of quackgrass. Only fluazifop-butyl was not significantly different from the untreated check. In 1986, rhizome bud viability was not reduced by any of the herbicide treatments, including the standard treatments sethoxydim and fluazifop-butyl (Figure 7.9). It seems this may be the result of high variability in the data obtained within replicates. However, when standard treatments were removed from the data set, the rhizome bud viability of the untreated check was then significantly greater than all quizalofop-ethyl rates.

Crop response

In 1986, crop injury was observed with all quizalofop-ethyl treatments. Only the two higher rates were significantly different from the untreated check however (Figure 7.10). Symptoms were characterized by white spotting and interveinal chlorosis of potato leaves shortly after application. The level of injury was very slight (<1%) and recovery of potato plants was rapid. One year after application, no visual crop injury was noticed with any of the treatments.

In 1986, all herbicide treatments increased total and marketable yields although the lowest and highest rates of quizalofop-ethyl were not significantly different from the untreated check (Figure 7.11). Differences were not detected among quizalofop-ethyl treatments with a

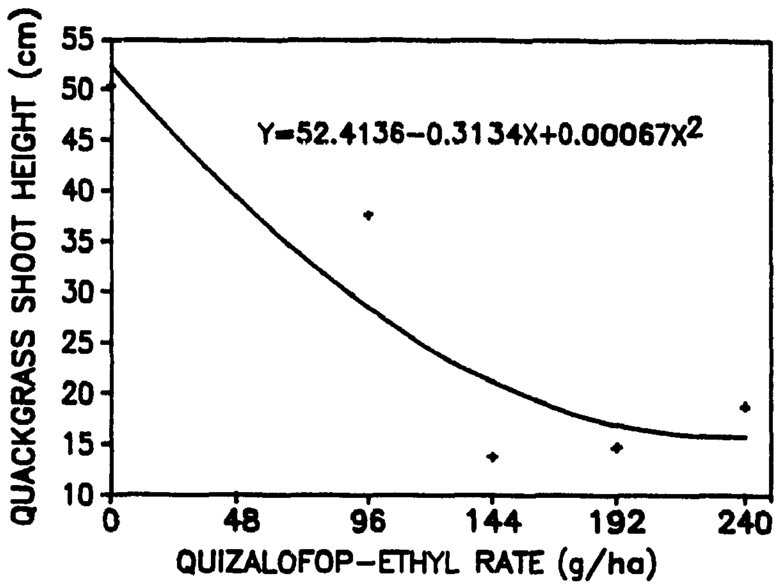

Fig.7.7 Regression effect of quizalofop-ethyl on quackgrass shoot height following a 1986 summer application (1987 evaluation).

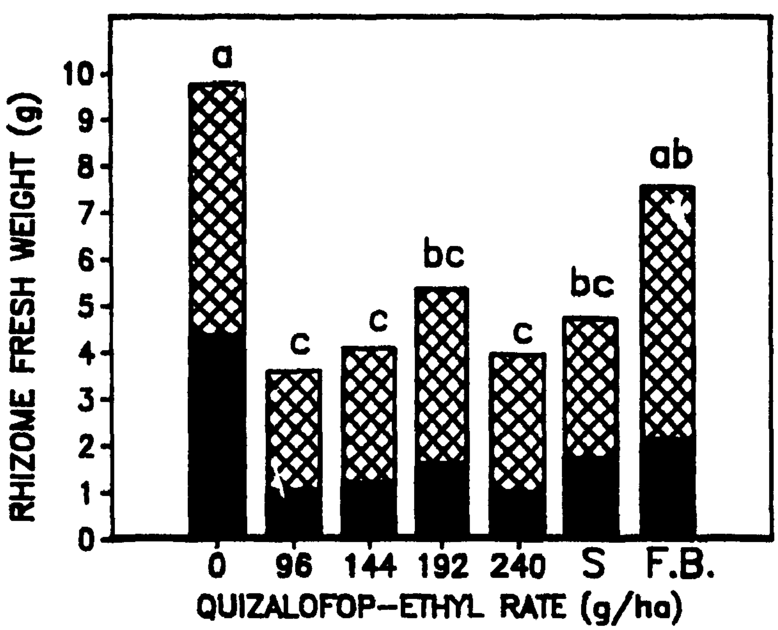

Fig.7.8 Effect of quizalofop-ethyl on quackgrass rhizome fresh weight following a 1986 summer application (1986 sampling). Columns consist of white (⊠) and brown (■) categories. Columns identified with the same letter are not significantly different at the 0.05 level. Standard treatments are sethoxydim (S) and fluazifop-butyl (F.B.).

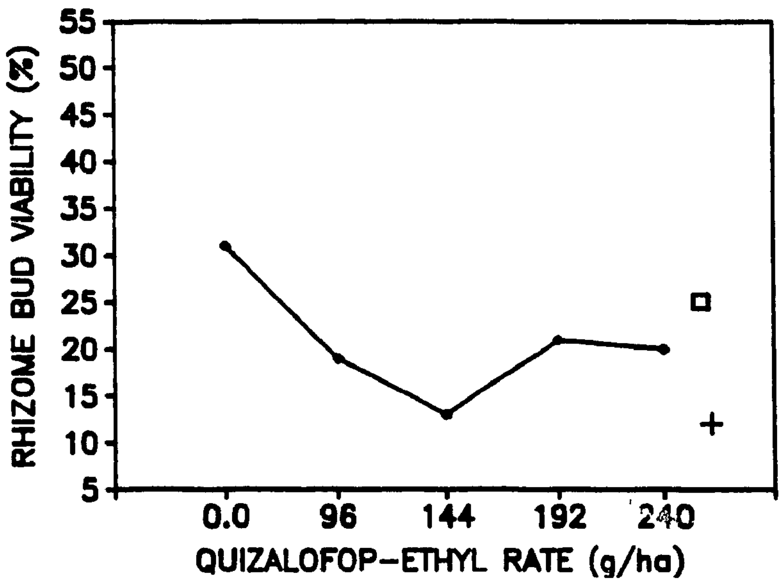

Fig.7.9 Effect of quizalofop-ethyl on quackgrass rhizome bud viability following a 1986 summer application (1986 sampling). Standard treatments are sethoxydim (+) and fluazifop-butyl (□). No significant difference was seen among treatments at the 0.05 level.

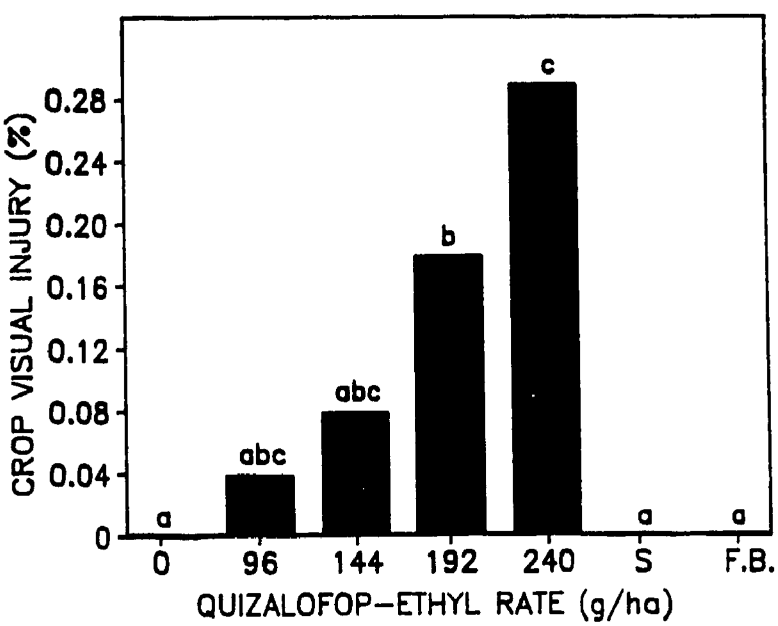

Fig.7.10 Effect of quizalofop-ethyl on potato visual injury following a 1986 summer application (1986 evaluation). Standard treatments are sethoxydim (S) and fluazifop-butyl (F.B.). Means identified by the same letter are not significantly different at the 0.42 experiment wise error rate.

regression analysis. These results suggest that the optimum rate of quizalofop-ethyl with respect to yields is located near the mid-point of the range of rates tested in this experiment. The lowest rate may not have provided adequate suppression of the quackgrass population while the highest rate may have suppressed crop development to a certain extent. Such suggestions are not supported by the quackgrass control data however, nor do visual crop injury data suggest that the highest rate of quizalofop-ethyl could have caused reduced yields.

7.2 1987 Application

Quackgrass response

In 1987, all herbicide treatments reduced quackgrass shoot dry weight and height significantly, but increasing the rate of quizalofop-ethyl above 96 g/ha did not improve efficacy (Figures 7.12 and 7.13). This was also the case for visual injury to quackgrass plants (Figure 7.14). Significant differences were seen between treatments for shoot density (Figure 7.15). Quizalofop-ethyl at 192 g/ha was best but not significantly different from all other herbicide treatments with the exception of fluazifop-butyl. The untreated check was significantly different from all other treatments. There was no effect among quizalofop-ethyl treatments when a regression analysis was conducted.

A subsequent follow-up sampling in 1988 on plots treated in 1987 showed the difference between the untreated check and the herbicide treatment had disappeared as expressed in quackgrass shoot dry weight (Figure 7.16). The 96 g/ha rate of quizalofop-ethyl was the treatment with the smallest weight however. Shoot density and height were still showing significant differences for all herbicide treatments when

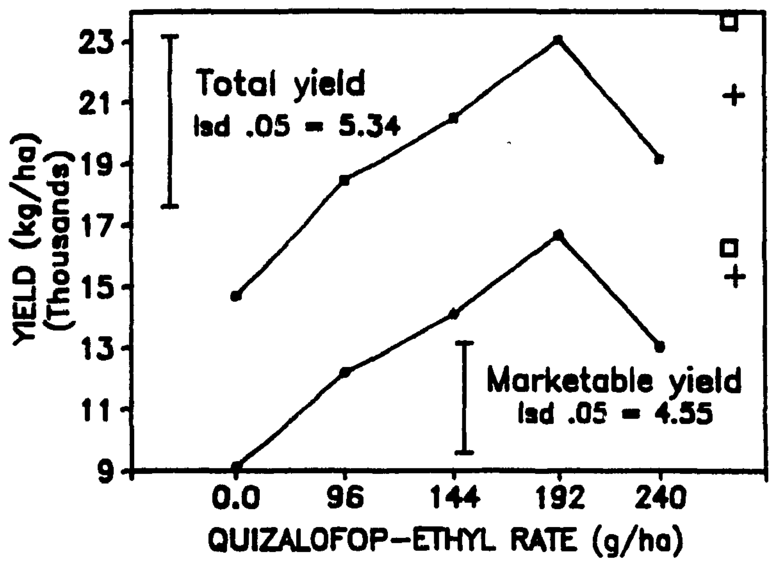

Fig.7.11 Effect of quizalofop-ethyl on potato marketable and total yields following a 1986 summer application (1986 harvest). Standard treatments are sethoxydim (+) and fluazifop-butyl (□).

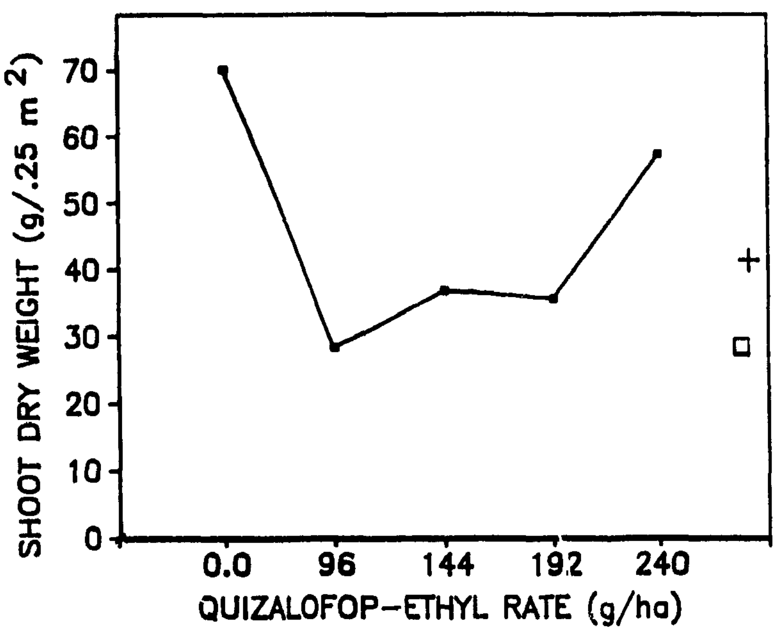

Fig.7.12 Effect of quizalofop-ethyl on quackgrass shoot dry weight following a 1987 summer application (1987 sampling). Standard treatments are sethoxydim (+) and fluazifop-butyl (□). No significant difference was seen among treatments at the 0.05 level of significance.

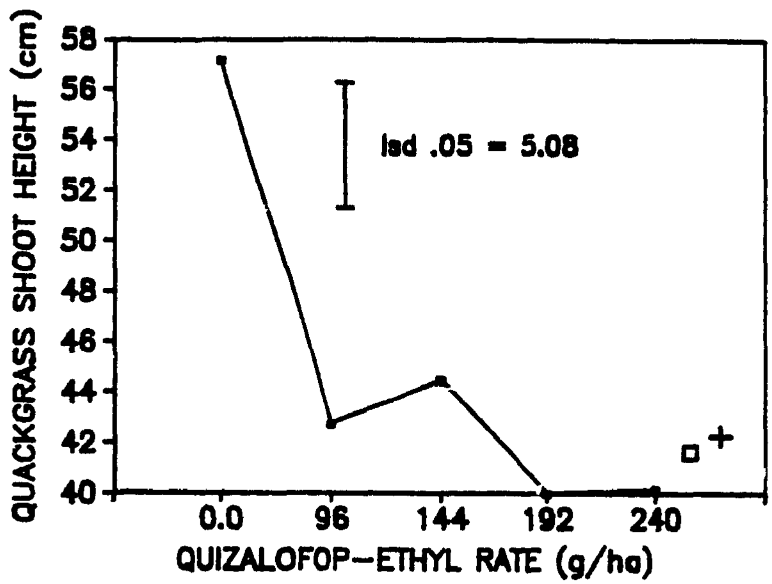

Fig.7.13 Effect of quizalofop-ethyl on quackgrass shoot height following a 1987 summer application (1987 evaluation). Standard treatments are sethoxydim (+) and fluazifop-butyl (□).

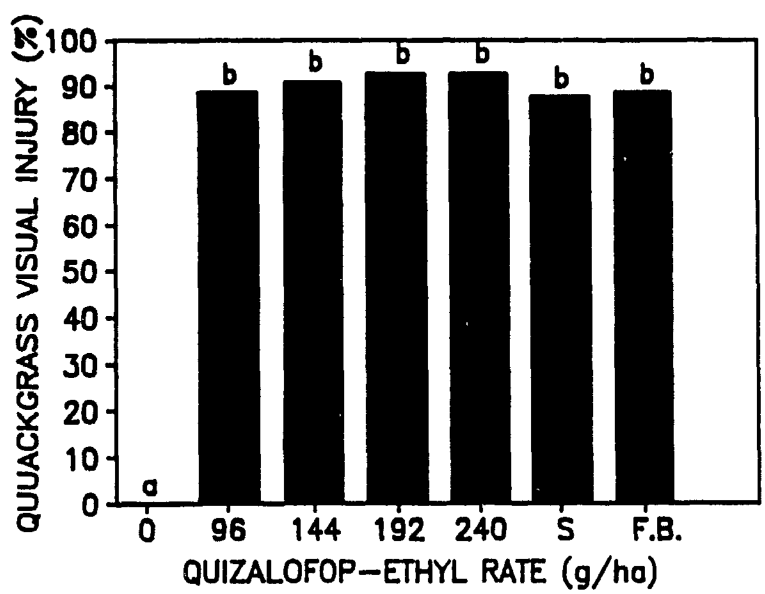

Fig.7.14 Effect of quizalofop-ethyl on quackgrass visual injury following a 1987 summer application (1987 evaluation). Standard treatments are sethoxydim (S) and fluazifop-butyl (F.B.). Means identified by the same letter are not significantly different at the 0.42 experiment wise error rate.

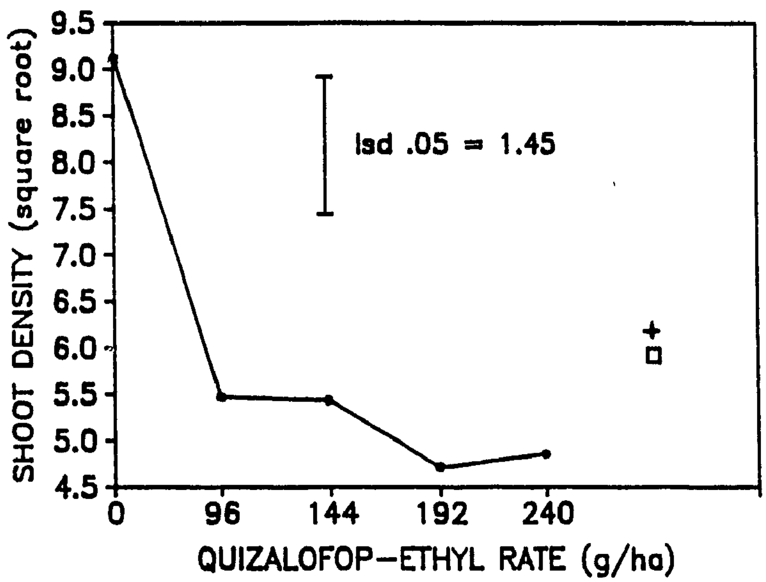

Fig.7.15 Effect of quizalofop-ethyl on quackgrass shoot density following a 1987 summer application (1987 evaluation). Standard treatments are sethoxydim (+) and fluazifop-butyl (□).

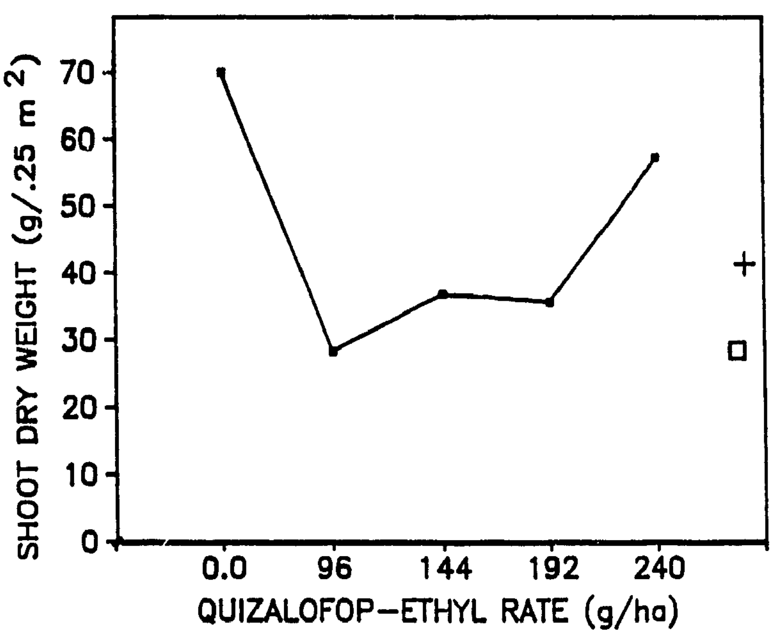

Fig.7.16 Effect of quizalofop-ethyl on quackgrass shoot dry weight following a 1987 summer application (1988 sampling). Standard treatments are sethoxydim (+) and fluazifop-butyl (□). No significant difference was seen among treatments at the 0.05 level.

compared to the untreated check (Figures 7.17 and 7.18). In both cases, the 96 g/ha rate of quizalofop-ethyl was the best treatment although not significantly different from higher quizalofop-ethyl rates. The level of control achieved the previous year was therefore maintained and it seems that the smallest quizalofop-ethyl rate tested was optimum in achieving quackgrass suppression. No visual injury was noticed with any of the treatments on quackgrass plants during the 1988 evaluation.

Rhizome data in 1987 supported shoot data as all treatments, with one exception, were significantly different from the untreated check (Figure 7.19). Only the 192 g/ha rate of quizalofop-ethyl was not significantly different from the check. This is thought to be due to a particularly dense rhizome population for that treatment rather than failure of efficacy as lower rates did perform as expected. In 1988, with another sampling on plots treated the previous year, there was no significant difference among all treatments. This is thought to be the result of high variabililty in the data as differences were impressive, especially between the untreated check and the 96 g/ha rate of quizalofop-ethyl (Figure 7.20).

Rhizome bud viability studies from a 1987 sampling showed that all herbicide treatments were significantly lower than the unteated check. The best treatment was quizalofop-ethyl at 144 g/ha with 0% viability, but it was not significantly different from both standard treatments and the 96 and 240 g/ha rates of quizalofop-ethyl (Figure 7.21). A cubic effect was obtained when a regression analysis was performed (Figure 7.22). Following a 1988 sampling on plots treated in 1987, rhizome bud viability was not significantly different for all treatments including the untreated check (Figure 7.23).

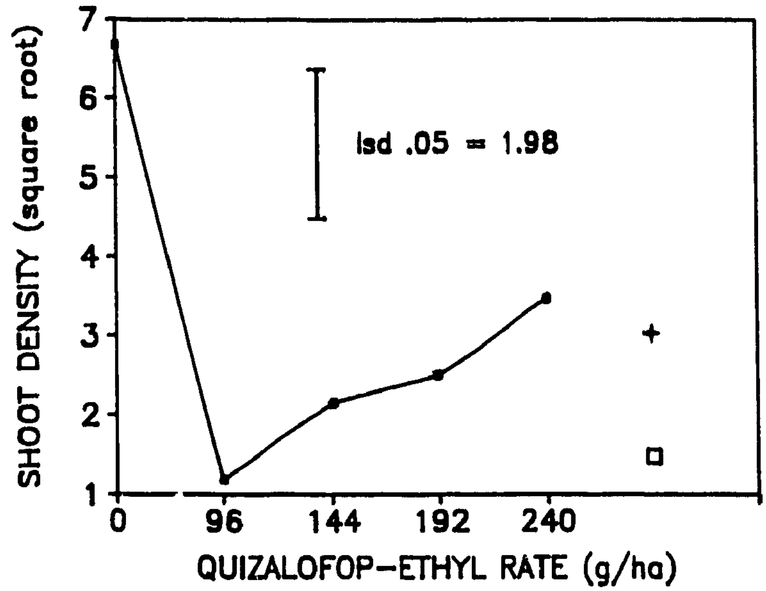

Fig.7.17 Effect of quizalofop-ethyl on quackgrass shoot density following a 1987 summer application (1988 evaluation). Standard treatments are sethoxydim (+) and fluazifop-butyl (□).

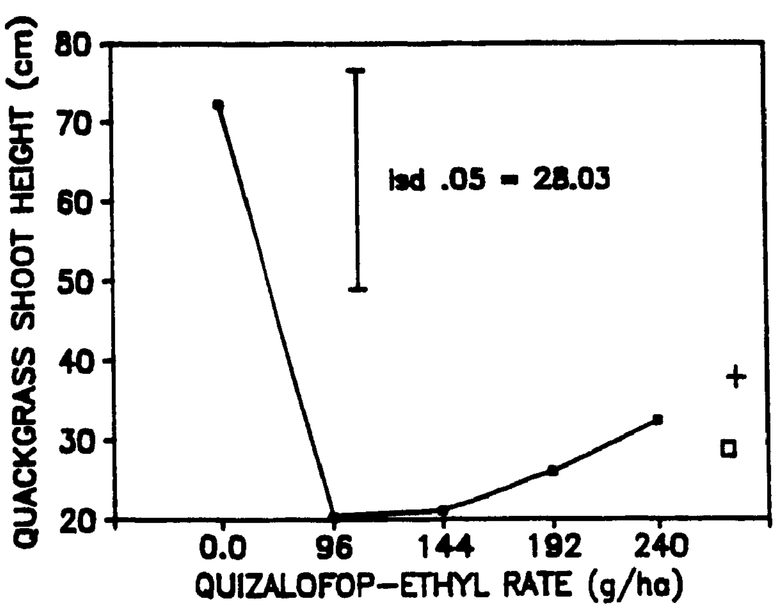

Fig.7.18 Effect of quizalofop-ethyl on quackgrass shoot height following a 1987 summer application (1988 evaluation). Standard treatments are sethoxydim (+) and fluazifop-butyl (□).

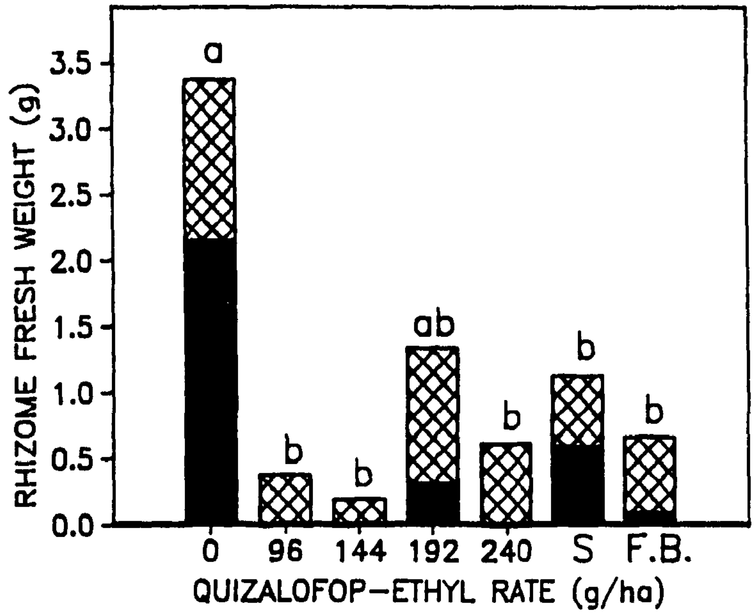

Fig.7.19 Effect of quizalofop-ethyl on quackgrass rhizome fresh weight following a 1987 summer application (1987 sampling). Columns consist of white (⊠) and brown (■) categories. Columns with the same letter are not significantly different at the 0.05 level. Standard treatments are sethoxydim (S) and fluazifop-butyl (F.B.).

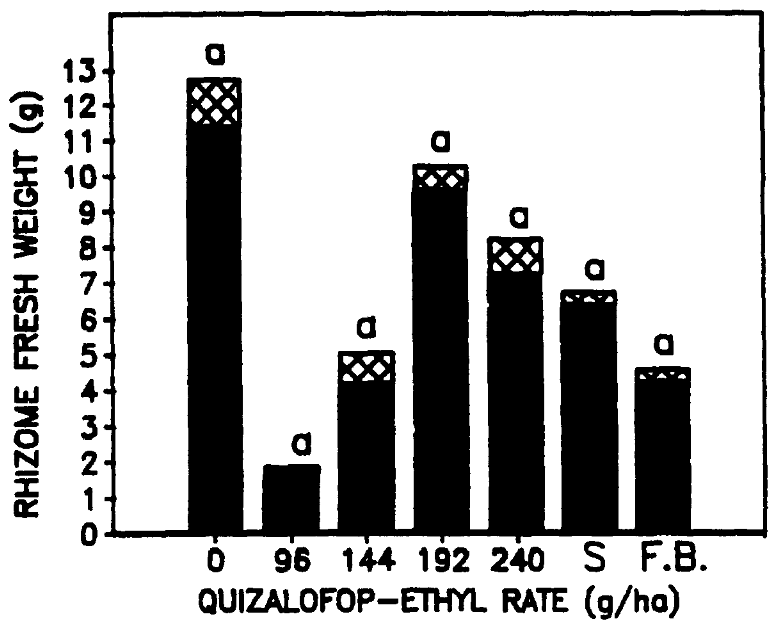

Fig.7.20 Effect of quizalofop-ethyl on quackgrass rhizome fresh weight following a 1987 summer application (1988 sampling). Columns consist of white (⊠) and brown (■) categories. Columns identified with the same letter are not significantly different at the 0.05 level. Standard treatments are sethoxydim (S) and fluazifop-butyl (F.B.).

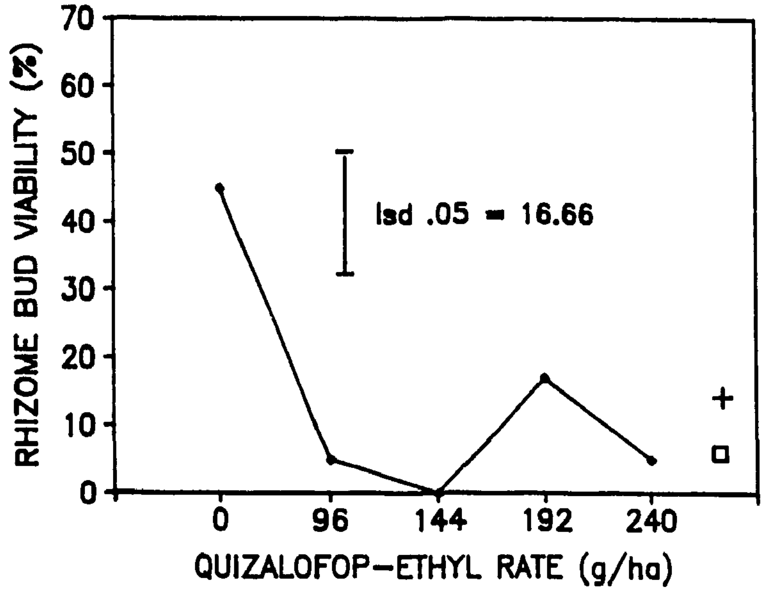

Fig.7.21 Effect of quizalofop-ethyl on quackgrass rhizome bud viability following a 1987 summer application (1987 sampling). Standard treatments are sethoxydim (+) and fluazifop-butyl (□).

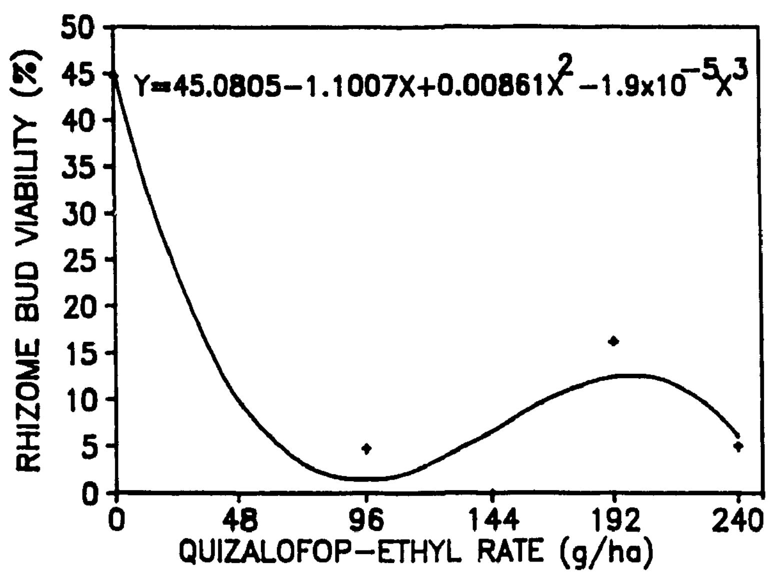

Fig.7.22 Regression effect of quizalofop-ethyl on quackgrass rhizome bud viability following a 1987 summer application (1987 sampling).

Crop response

In 1987, all quizalofop-ethyl treatments resulted in significant crop injury when compared to the untreated check and the standard treatments. Injury was highest with 240 g/ha of quizalofop-ethyl but was only 1% and not of concern as the crop recovered quickly (Figure 7.24). In 1988, no crop injury was observed where any of the herbicides had been applied the previous year.

All treatments but one resulted in marketable and total yields that were significantly greater than the untreated check in 1987 (Figure 7.25). Only the 240 g/ha rate of quizalofop-ethyl was not significantly different from the untreated check although it was not significantly different from all other herbicide treatments. As was the case in 1986, the data suggests that the highest quizalofop-ethyl rate tested may have an effect on crop development although visual symptoms were at a low level.

In 1988, significant differences were no longer seen between treatments, but marketable and total yields were lower with 192 and 240 g/ha of quizalofop-ethyl than they were with the untreated check (Figure 7.26). It is unlikely that residual activity of quizalofop-ethyl is responsible for such results as the diphenyl ether herbicides show very short residual activity (Rick et al., 1983). It is may be the result of a greater amount of decaying rhizomes resulting from the use of higher rates of quizalofop-ethyl and an increase in the production of allelochemic toxins from decaying quackgrass rhizomes (Gabor and Veatch, 1981).

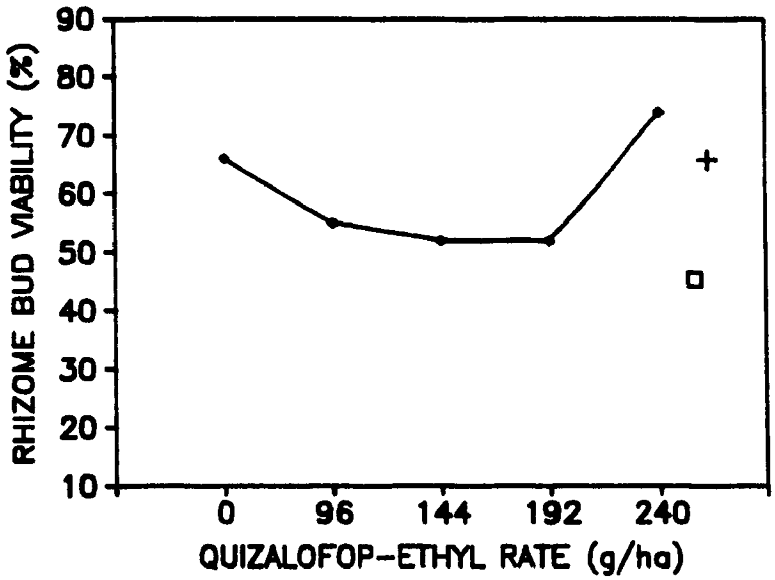

Fig.7.23 Effect of quizalofop-ethyl on quackgrass rhizome bud viability following a 1987 summer application (1988 sampling). Standard treatments are sethoxydim (+) and fluazifop-butyl (□). No significant difference was seen among treatments at the 0.05 level.

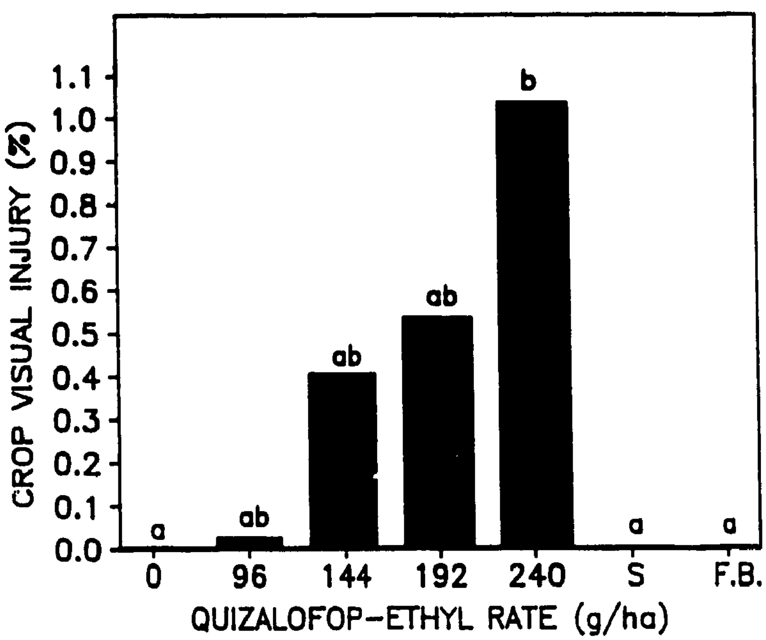

Fig.7.24 Effect of quizalofop-ethyl on potato visual injury following a 1987 summer application (1987 evaluation). Standard treatments are sethoxydim (S) and fluazifop-butyl (F.B.). Means identified by the same letter are not significantly different at the 0.42 experiment wise error rate.

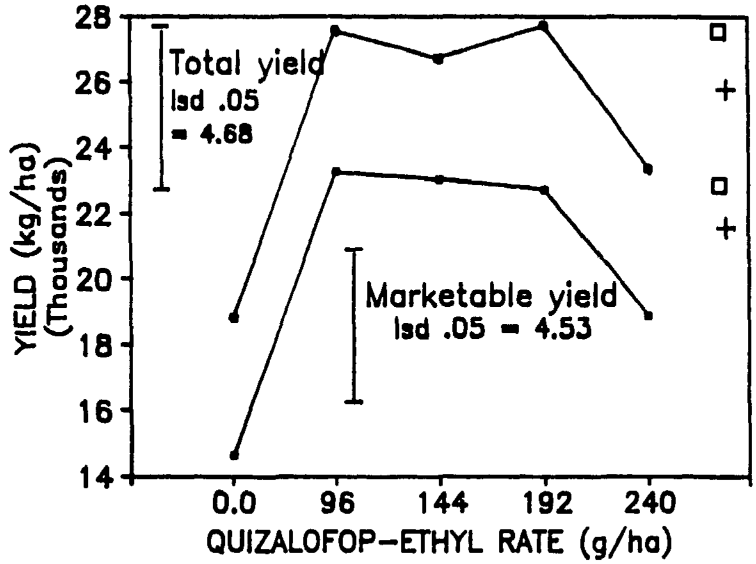

Fig.7.25 Effect of quizalofop-ethyl on potato marketable and total yields following a 1987 summer application (1987 harvest). Standard treatments are sethoxydim (+) and fluazifop-butyl (□).

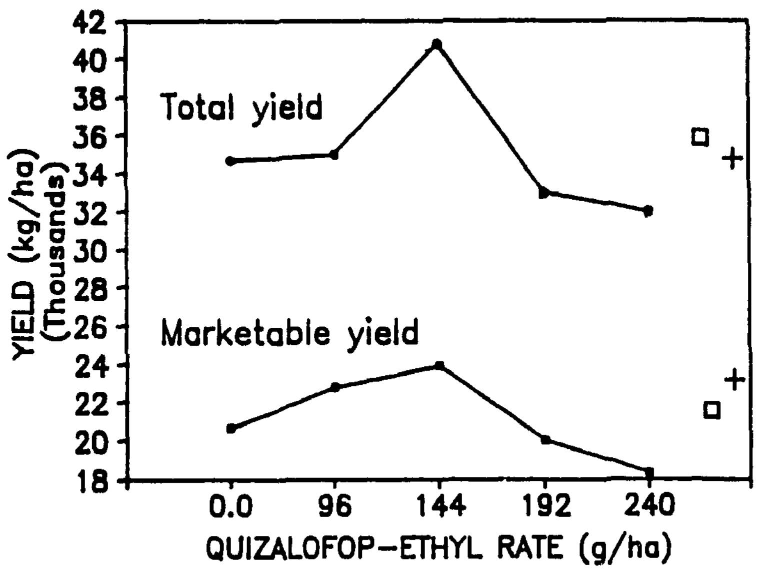

Fig.7.26 Effect of quizalofop-ethyl on potato marketable and total yields following a 1987 summer application (1988 sampling). Standard treatments are sethoxydim (+) and fluazifop-butyl (□). No significant difference was seen among treatments for both marketable and total yields at the 0.05 level.

CHAPTER 8

RESULTS FROM A FALL APPLICATION

8.1 1986 Application

Quackgrass response

Following a 1986 fall application, no significant differences were seen among all treatments including the untreated check for shoot dry weight (Figure 8.1). Only the 240 g/ha rate of quizalofop-ethyl and glyphosate were significantly different from the untreated check for shoot density (Figure 8.2). When shoot height was measured, the 96 and 192 g/ha rates of quizalofop-ethyl as well as glyphosate were the only treatments that performed better than the untreated check (Figure 8.3). Glyphosate therefore did perform as expected with reduced shoot density and height. It is recognized as perhaps the best fall treatment for quackgrass control. Glyphosate's failure to be significantly different from the untreated check for shoot dry weight may be due to the selection of a low rate of the compound which resulted in suppression rather than a rate at the high end of the recommended scale which would have resulted in control of fall-treated quackgrass. This is also reflected in rhizome fresh weight data where no significant differences were seen among all treatments including the untreated check (Figure

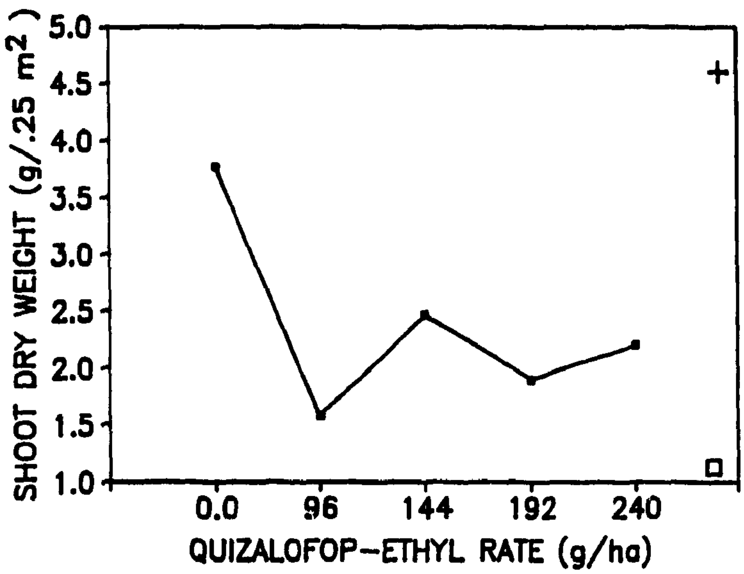

Fig. 8.1 Effect of quizalofop-ethyl on quackgrass shoot dry weight following a 1986 fall application (1987 sampling). Standard treatments are sethoxydim (+) and glyphosate (□). No significant difference was seen among treatments at the 0.05 level.

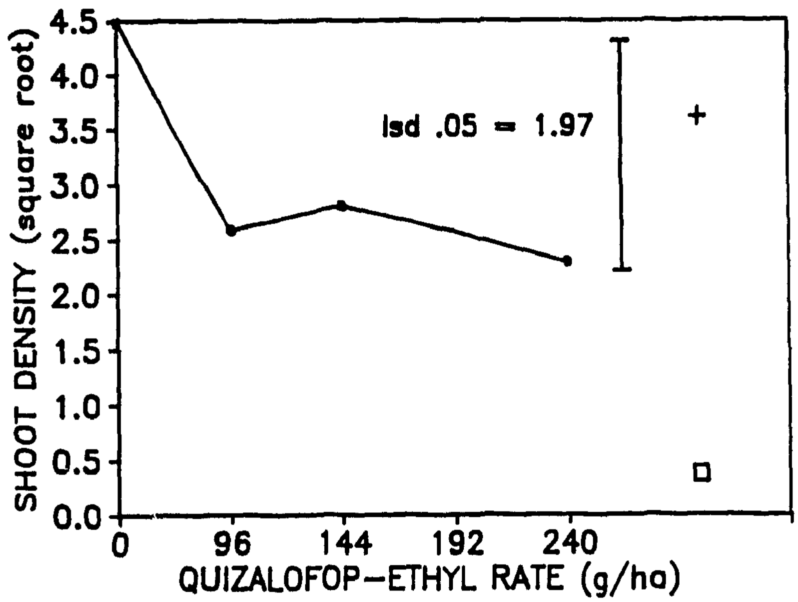

Fig.8.2 Effect of quizalofop-ethyl on quackgrass shoot density following a 1986 fall application (1987 evaluation). Standard treatments are sethoxydim (+) and glyphosate (□).

8.4). However, despite this lack of significant difference, the best treatment was glyphosate for all parameters tested. This was also true for rhizome bud viability (Figure 8.5). Quackgrass plants did not display visual symptoms following a fall application with any of the herbicide treatments.

<u>Crop reponse</u>

In 1987, all herbicide treatments were not significantly different from the untreated check with the exception of the 192 g/ha rate of quizalofop-ethyl which resulted in yields that were lower than those obtained with the untreated check (Figure 8.6). The 144 and 240 g/ha rates of quizalofop-ethyl also resulted in yields lower than the untreated check. Such results support data obtained in 1988 following a 1987 summer application. It is suspected that allelopathy caused by more decaying quackgrass rhizomes may be a possible cause for lower yields obtained with high rates of quizalofop-ethyl. A quadratic effect was obtained for both marketable and total yields when regression analyses of the data were performed (Figures 8.7 and 8.8). No visual injury to crop plants could be detected with any of the herbicide treatments.

8.2 1987 Application

<u>Quackgrass response</u>

Following a 1987 fall application, no significant differences were seen among all treatments including the untreated check for shoot dry weight as was the case for 1986. All quizalofop-ethyl treatments yielded shoot dry weights that were smaller than glyphosate however

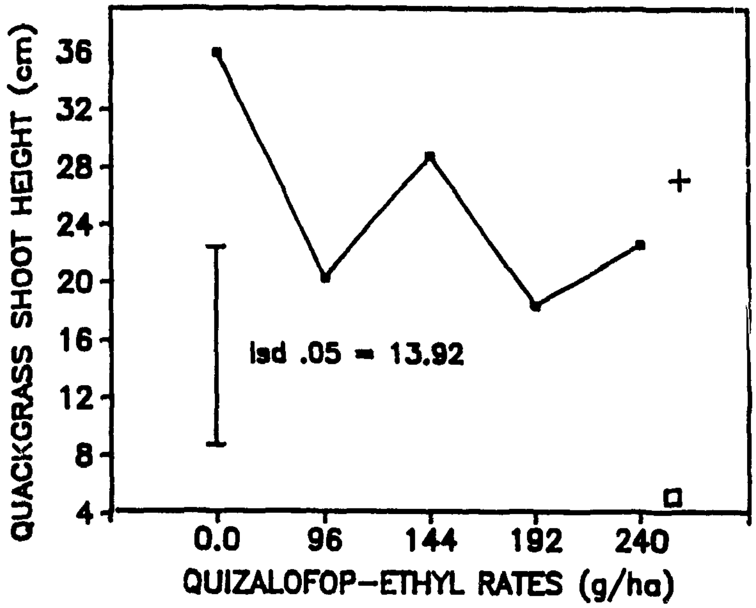

Fig.8.3 Effect of quizalofop-ethyl on quackgrass shoot height following a 1986 fall application (1987 evaluation). Standard treatments are sethoxydim (+) and glyphosate (□).

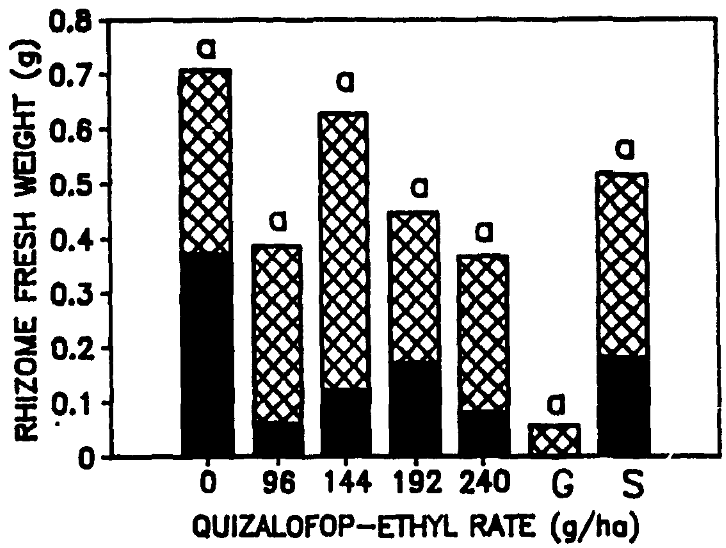

Fig.8.4 Effect of quizalofop-ethyl on quackgrass rhizome fresh weight following a 1986 fall application (1987 sampling). Columns consist of white (□) and brown (■) categories. Columns identified with the same letter are not significantly different at the 0.05 level. Standard treatments are sethoxydim (S) and glyphosate (G).

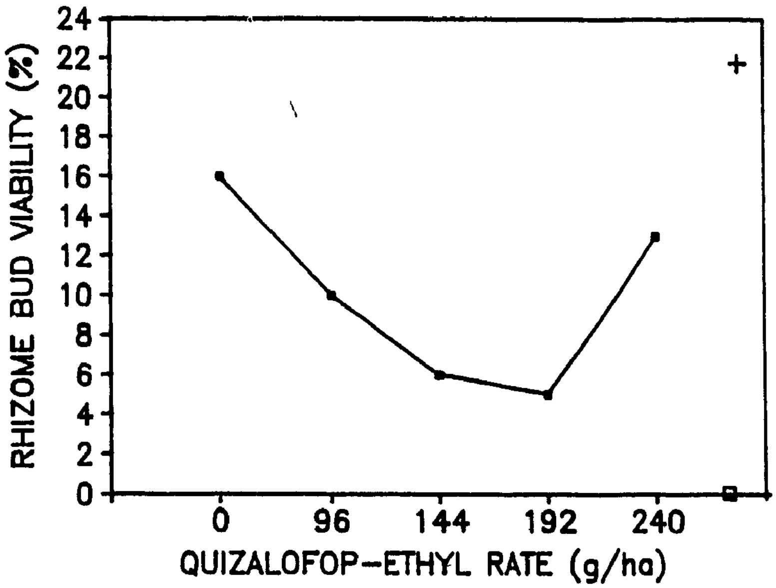

Fig.8.5 Effect of quizalofop-ethyl on quackgrass rhizome bud viability following a 1986 fall application (1987 sampling). Standard treatments are sethoxydim (+) and glyphosate (□). No significant difference was seen among treatments at the 0.05 level.

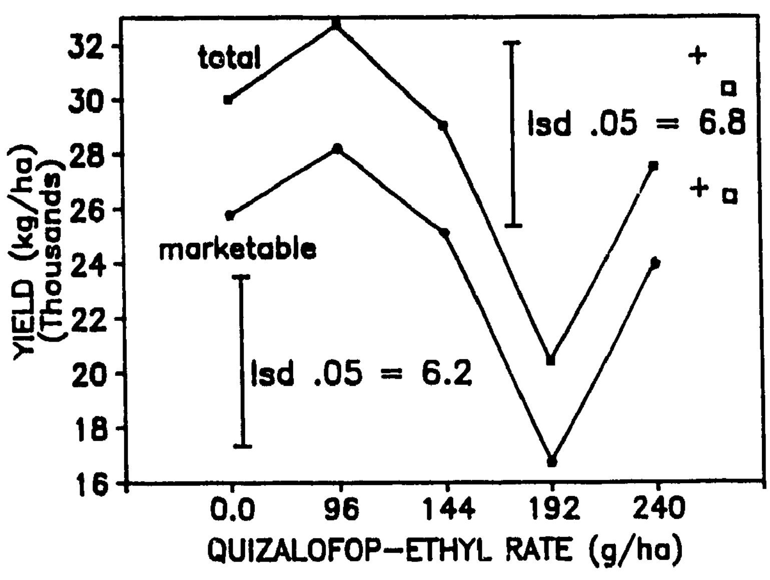

Fig.8.6 Effect of quizalofop-ethyl on potato marketable and total yields following a 1986 fall application (1987 harvest). Standard treatments are sethoxydim (+) and glyphosate (□). No significant difference was seen among treatments for both marketable and total yields at the 0.05 level.

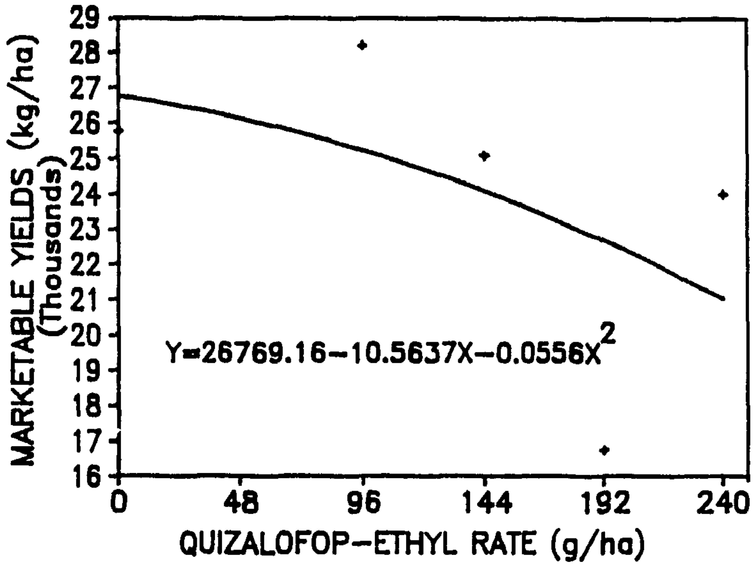

Fig.8.7 Regression effect of quizalofop-ethyl on potato marketable yields following a 1986 fall application (1987 harvest).

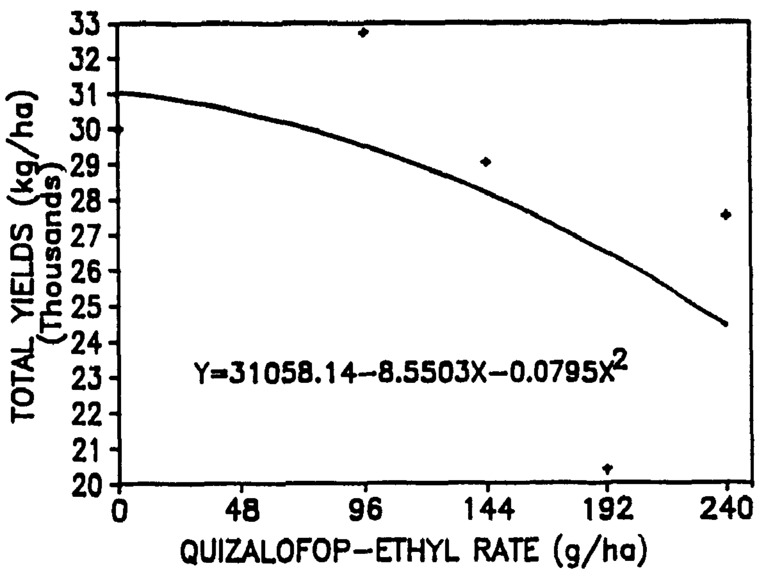

Fig.8.8 Regression effect of quizalofop-ethyl on potato total yields following a 1986 fall application (1987 harvest).

(Figure 8.9). When shoot density was evaluated, quizalofop-ethyl treatments with rates of 144 g/ha or higher were the only herbicide treatments that were significantly better than the untreated check (Figure 8.10). All quizalofop-ethyl treatments were better than the check for quackgrass shoot height (Figure 8.11). Quizalofop-ethyl therefore performed better than glyphosate in 1987 which was not the case in 1986. However, rhizome fresh weight was similar in 1986 and 1987 as no difference was seen among all treatments including the untreated check (Figure 8.12).

As was the case in 1987, there was no difference among treatments including the untreated check for rhizome bud viability (Figure 8.13). However, 0% viability was observed with quizalofop-ethyl at 144 and 240 g/ha compared to 26.5% for the untreated check. No visual injury to quackgrass plants was noticed with any of the herbicide treatments in 1988.

Crop response

No visual crop injury was noticed on potato plants in 1988 following a 1987 fall application with any of the herbicide treatments. Marketable and total yields were not significantly different for all treatments including the untreated check (Figure 8.14). Unlike 1987 results following a fall application and 1988 results following a summer application, yields were lowest with the lowest rate of quizalofop-ethyl, 96 g/ha, rather than higher rates.

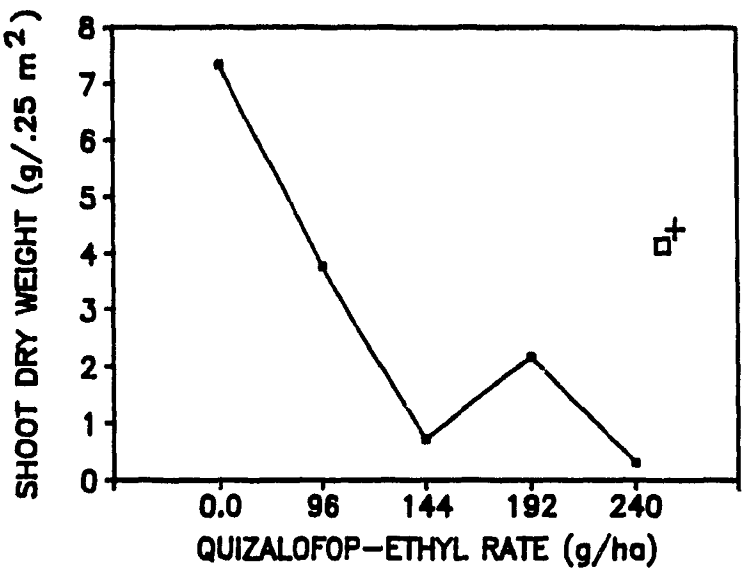

Fig.8.9 Effect of quizalofop-ethyl on quackgrass shoot dry weight following a 1987 fall application (1988 sampling). Standard treatments are sethoxydim (+) and glyphosate (□). No significant difference was seen among treatments at the 0.05 level.

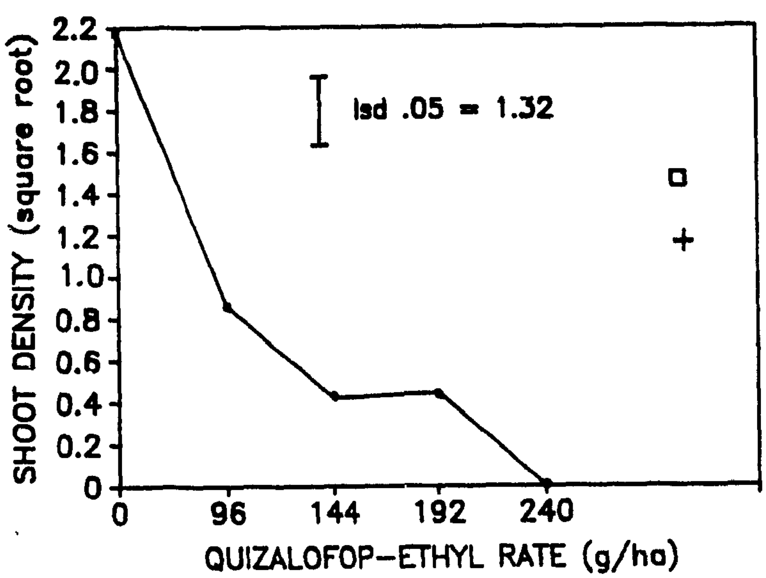

Fig.8.10 Effect of quizalofop-ethyl on quackgrass shoot density following a 1987 fall application (1988 evaluation). Standard treatments are sethoxydim (+) and glyphosate (□).

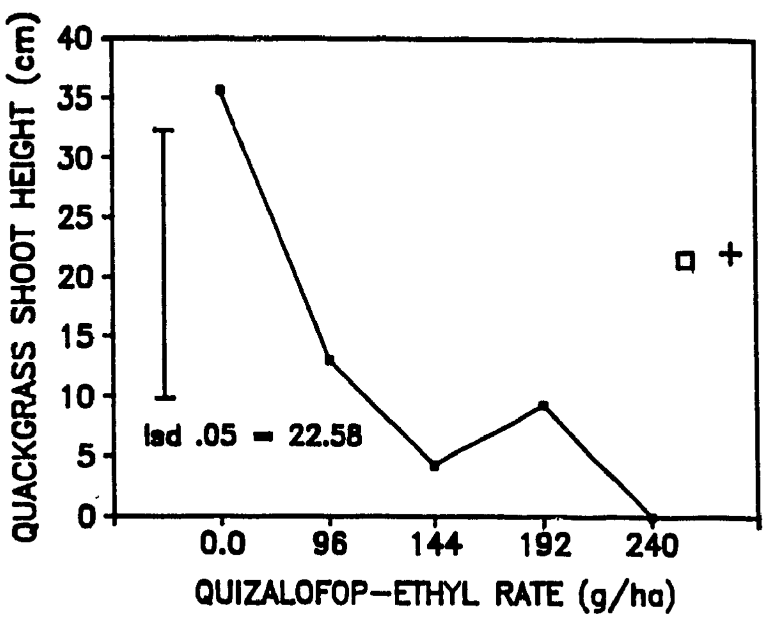

Fig.8.11 Effect of quizalofop-ethyl on quackgrass shoot height following a 1987 fall application (1988 evaluation). Standard treatments are sethoxydim (+) and glyphosate (□).

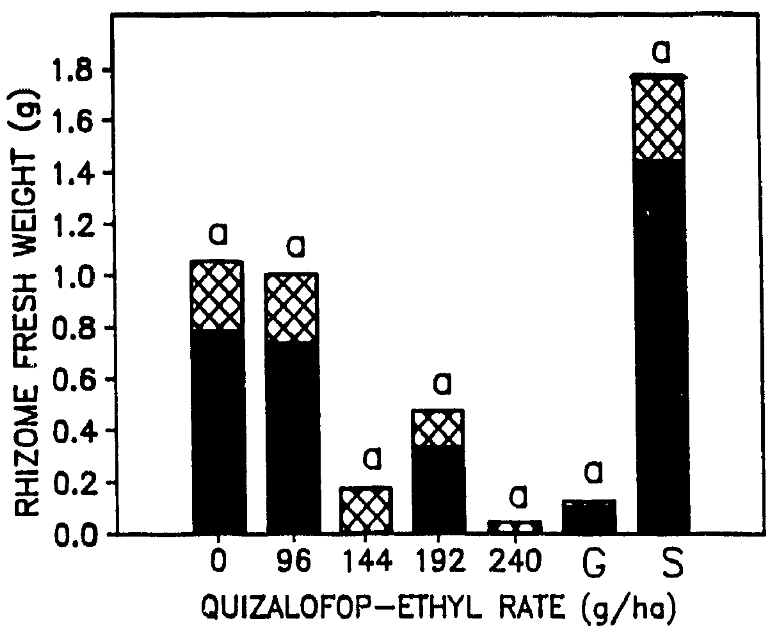

Fig.8.12 Effect of quizalofop-ethyl on quackgrass rhizome fresh weight following a 1987 fall application (1988 sampling). Columns consist of white (⊠) and brown (■) categories. Columns identified by the same letter are not significantly different at the 0.05 level. Standard treatments are sethoxydim (S) and glyphosate (G).

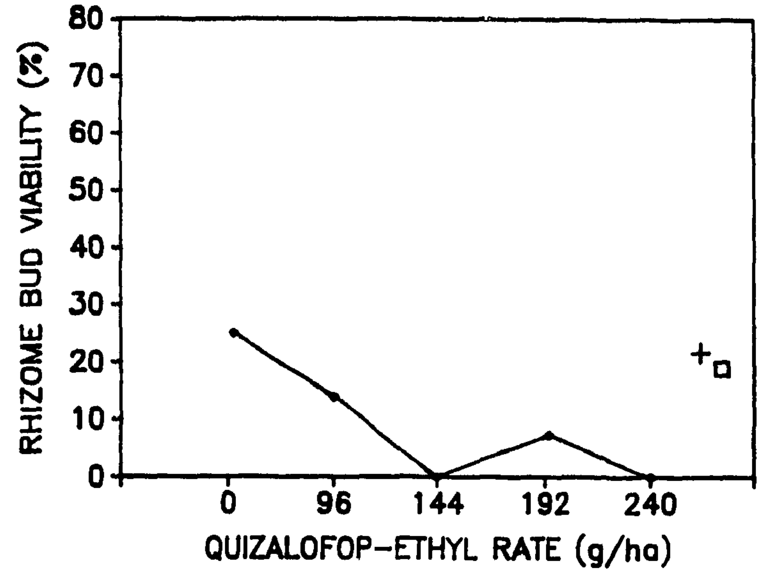

Fig.8.13 Effect of quizalofop-ethyl on quackgrass rhizome bud viability following a 1987 fall application (1988 sampling). Standard treatments are sethoxydim (+) and glyphosate (□). No significant difference was seen among treatments at the 0.05 level.

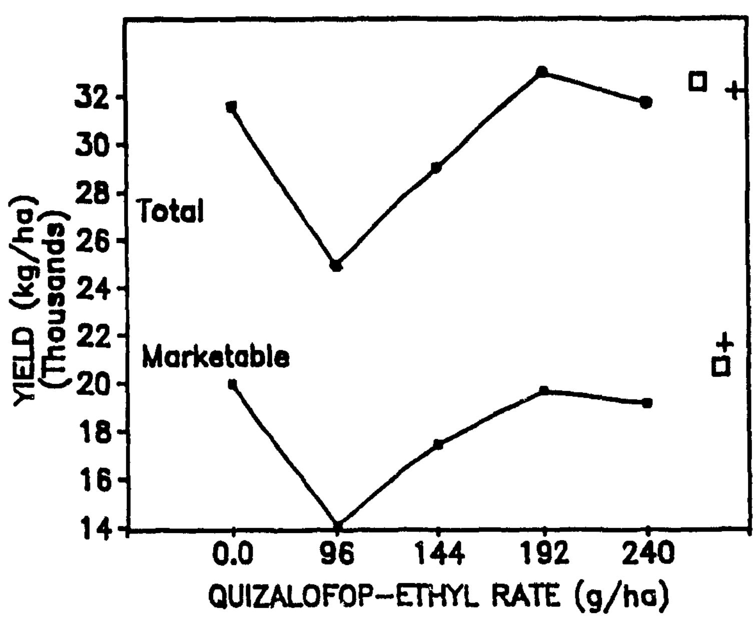

Fig.8.14 Effect of quizalofop-ethyl on potato marketable and total yields following a 1987 fall application (1988 harvest). Standard treatments are sethoxydim (+) and glyphosate (□). No significant difference was seen among treatments for both marketable and total yields at the 0.05 level.

CHAPTER 9

CONCLUSION AND SUGGESTIONS

The evaluation of quackgrass control using parameters such as shoot dry weight, density, height, rhizome fresh weight and visual injury showed that quizalofop-ethyl at the lowest rate tested, 96 g/ha, gave results similar to the standard treatments, sethoxydim and fluazifop-butyl, when applied in the summer and assessed in the fall of that same season. Increasing the rate of quizalofop-ethyl did not appear to improve quackgrass control.

In this study, fall applications did not provide consistent results when the same parameters were assessed the season following application. In the two years of testing, rhizome fresh weight, rhizome bud viability and shoot dry weight gave similar results for the untreated check and herbicide treatments while shoot density and height responded inconsistently between the two years. Also, in 1987, glyphosate, a standard treatment, always was the best treatment for all parameters tested although significance was not always expressed whereas in 1988, one of the quizalofop-ethyl rates was always better than glyphosate. Such inconsistencies were also reported by the manufacturer of quizalofop-ethyl and commercial development of this compound for fall application was subsequently stopped after the initiation of this study.

Those inconsistent results may also partly be due to the use of commercial farm practices to cultivate, plant and harvest the half hectare needed for this research although methods employed were designed to minimize interplot movement of rhizomes, some has undoubtedly occurred.

Potato yields following a summer application did not allow for a treatment to be selected as "best" based on the 1986 and 1987 harvests. The data suggests, however, that rates of quizalofop-ethyl higher than 192 g/ha may result in yield reductions. This was especially evident when interpreting the yield data from fall application. In the two years of testing, marketable yields from plots treated with rates of quizalofop-ethyl greater or equal to 144 g/ha were below those of the untreated check although significance was only seen in the first year with quizalofop-ethyl at 192 g/ha. This may partly be due to allelochemic toxins produced by decaying quackgrass rhizomes as discussed earlier. However, yields in plots treated with the standards were not below those of the untreated check for both years of testing.

It is possible that reductions noticed in quackgrass control and crop yields with higher rates of quizalofop-ethyl may have been the result of physiological interference with crop plants although not visually noticed. The competitive ability of the crop may have been reduced enough to allow the weed to display some recovery. This may in part explain reductions in quackgrass control and crop yields with higher rates of quizalofop-ethyl one year after application for summer applications and the season following application for fall applications. Also, lack of control may be responsible and quackgrass populations recolonizing the test area would explain erratic and inconsistent results obtained in both cases.

Further work with quizalofop-ethyl for quackgrass control should concentrate on a range of rates below 96 g/ha. This rate, which was the lowest tested in this study, was as effective as higher rates. Studies should be designed using plots that are completely isolated from one another by a buffer zone so that each plot can be individually cultivated, planted and harvested so as to eliminate any chance of rhizome movement between plots. If such requirements are met, it would also be desirable to reduce the size of research plots. This would reduce acreage requirements for further studies to a more manageable level and help reduce variability in results by ensuring a more uniform quackgrass stand. The uniformity of soil characteristics within each research plot would also be improved.

Laboratory studies on rhizome bud viability would also benefit from using smaller individual field plots. The accuracy of the tests would improve if emergence and tetrazolium tests were performed immediately after emergence. Reducing the length or eliminating storage of rhizomes between harvest and the execution of laboratory tests may greatly improve the precision of such studies in indicating the extent and long-term potential of herbicides for quackgrass or other rhizomatous weed control.

Finally, one cannot have gone through this exercise without having realized that research involving perennial weeds and their response to various stimuli, whether natural or synthetic, has more chance of being successful in revealing differences, especially if subtle, between treatments if it is conducted and repeated in an environment where growing conditions can be controlled such as a growth chamber or a greenhouse. Field studies such as those conducted for the purpose of this research nevertheless remain essential in confirming other more basic studies before recommendations can be made to producers.

Based on results obtained in my studies, I would recommend quizalofop-ethyl at 96 g/ha applied in the summer to actively growing quackgrass postemergence to the crop for season-long control of quackgrass. Higher rates will not improve control. Fall applications of quizalofop-ethyl are discouraged as quackgrass control was inconsistent the following season. Marketable and total yields following a summer application of quizalofop-ethyl at 96 g/ha are similar to those of the standard treatments, sethoxydim and fluazifop-butyl at recommended rates.

REFERENCES

Anonymous. 1970. Tetrazolium testing handbook for agricultural seeds. 45 p.

Anonymous. 1985. Mauvaises herbes. Répression. Conseil des production végétales du Québec. Agdex 640. 130 p.

Anonymous. 1986. Guide to chemical weed control-1986. Ontario Min. Agric. Food Publ. 75. 168 p.

Ashton, F.M., and A.S. Crafts. 1981. Mode of action of herbicides. 2nd ed. John Wiley and Sons, New York. 525 p.

Asare-Boamah, N.K., and R.A. Fletcher. 1983. Physiological and cytological effects of bas 9052 OH on corn (Zea mays). Weed Sci. 31:49-55.

Bandeen, J.D., and K.P. Buchholtz. 1967. Competitive effects of quackgrass upon corn as modified by fertilization. Weeds 15:220-224.

Blair, A.M., R.J. Chancellor, G.W. Cussans, K. Holly, J. Holroyd, and W.G. Richardson. 1970. The evaluation of herbicides on perennial weeds with special reference to Agropyron repens. Proc. 10th Br. Weed Cont. Conf.:126-133.

Blair, A.M., and J. Holroyd. 1970. Herbicides for the control of Agropyron repens and Agrostis gigantea. Proc. 10th Br. Weed Cont. Conf.:326-330.

Bowden, W.M. 1965. Cytotaxonomy of the species and interspecific hybrids of the genus Agropyron in Canada and neighboring areas. Can. J. Bot. 43:1421-1448.

Buhler, D.D., and O.C. Burnside. 1984. Herbicidal activity of fluazifop-butyl, haloxyfop-methyl, and sethoxydim. Weed Sci. 32:824-831.

Buhler, D.D., B.A. Swisher, and O.C. Burnside. 1985. Behavior of haloxyfop-methyl in intact plants and cell cultures. Weed Sci. 33:291-299.

Campbell, J.R., and D. Penner. 1985. Sethoxydim metabolism in monocotyledonous and dicotyledonous plants. Science 33:771-773.

Carr, J.E., A.H. Davies, A.H. Cobb, and K.E. Pallett. 1985. The metabolic activity of fluazifop acid in excised apical meristem sections. Br. Crop Prot. Conf. Weeds: 155-162.

Carr, J.E., A.H. Davies, A.H. Cobb, and K.E. Pallett. 1986. Uptake, translocation and metabolism of Fluazifop-butyl in Setaria viridis. Ann. Appl. Biol. 108:115-123.

Caseley, J.C. 1970. The effect of temperature on the performance of five herbicides used to control Agropyron repens. Proc. 10th Br. Weed Cont. Conf.:320-325.

Caseley, J.C. 1972. The use of plant growth regulators in the control of Agropyron repens. Proc. 11th Br. Weed Cont. Conf.:736-743.

Chancellor, R.J., and R.B. Leakey. 1972. The effect of plant growth regulators on dominance in Agropyron repens (L.) Beauv. rhizomes. Proc. 11th Br. Weed Cont. Conf.:778-783.

Chancellor, R.J. 1974. The development of dominance amongst shoots arising from fragments of _Agropyron repens_ rhizomes. Weed Res. 14:29-38.

Chandrasena, N.R., and G.R. Sagar. 1986. Uptake and translocation of C_{14} fluazifop by quackgrass (_Agropyron repens_). Weed Sci. 34:676-684.

Claus, J.S., and R. Behrens. 1976. Glyphosate translocation and quackgrass rhizome bud kill. Weed Sci. 24:149-152.

Courtney, A.D. 1972. A study on the persistence of a natural infestation of _Agropyron repens_ and _Agrostis gigantea_ in association with tetraploid Italian ryegrass. Proc. 11th Br. Weed Cont. Conf.:57-63.

Courtney, A.D. 1980. A comparative study of management factors likely to influence rhizome production by _Agropyron repens_ and _Agrostis gigantea_ in perennial ryegrass swards. Proc. 1980 Br. Crop Prot. Conf-Weeds:469-475.

Cussans, G.W. 1970. Biological background to the control of rhizomatous grasses. Proc. 10th Br. Weed Cont. Conf.:1101-1107.

Cussans, G.W., and B.J. Wilson. 1970. Cultural and chemical treatments for the control of _Agropyron repens_ and _Agrostis gigantea_ in barley. Proc. 10th Br. Weed Cont. Conf.:344-351.

Cussans, G.W. 1970. A study of the competition between _Agropyron repens_ (L.) Beauv. and spring sown barley, wheat and field beans. Proc. 10th Br. Weed Cont. Conf.:337-351.

Cusssans, G.W. 1971. Biological background to the control of rhizomatous grasses. Proc. 10th Brit. Weed Cont. Conf.:1101-1107.

Dekker, J. 1983. Long-term effects of atrazine, several graminicides and non selective herbicides on quackgrass. Proc. North. Cent. Weed Cont. Conf.:45.

Dekker, J.H., and K. Chandler. 1985 Herbicide effect on the viability of quackgrass (Agropyron repens) rhizome buds. Can. J. Plant Sci. 65:57-64.

Derr, J.F., T.J. Monaco, and T.J. Sheets. 1985. Uptake and translocation of fluazifop by three annual grasses. Weed Sci. 33:612-617.

Deschênes, J.M., et D. Doyon. 1982. Importance des mauvaises herbes dans les cultures au Québec. Bull. soc. bot. Québec. no.3p.25-26.

Devine, M.D., and J.D. Bandeen. 1983. Fate of glyphosate in Agropyron repens (L.) Beauv. grown under low temperature conditions. Weed Res. 23:69-75.

Doyon, D. 1984. Importance du chiendent dans les cultures au Québec. C.P.V.Q. Rapport de la journée d'information en malherbologie. 6 mars 1984. pp.7-19.

Evans, N.W., and J.E. Ely. 1935. The rhizomes of certain species of grasses. Amer. Soc. Agron. J. 27:791-797.

Fail, H. 1956. The effect of rotary cultivations on rhizomatous weeds. J. Agric. Eng. Res. 1:68-80.

Forde, B.J. 1966. Translocation in grasses. II. Perennial ryegrass and couchgrass. N. Z. J. Bot 4:496-514.

Gabor, W.E., and C. Veatch. 1981. Isolation of a phytotoxin from quackgrass (Agropyron repens) rhizomes. Weed Sci. 29:155-158.

Glick, H.L. (ed.) 1987. Technical proceedings. Quackgrass Action Committee Workshop. March 10 and 11, 1987. Winnipeg. Agriculture Canada, Ottawa.

Gibbard, M., M.R. Smith, and G.B. Stoddart. 1982. Annual and perennial grass weed control with fluazifop-butyl in oilseed rape, potatoes and other broadleaved crops. Proc. 1982 Br. Crop Prot. Conf-Weeds:819-825.

Gronwald, J.W. 1986. Effect of haloxyfop and haloxyfop-methyl on elongation and respiration of corn (Zea mays) and soybean (Glycine max) roots. Weed Sci. 34:196-202.

Gutman, J., and A.K. Watson. 1980. Collection and separation of yellow nutsedge tubers. Can. J. Plant Sci. 60:755-757.

Hakansson, S. 1970. Factors influencing the effect of TCA on gramineous species, with special reference to the effect on Agropyron repens (L.) Beauv. Proc. 10th Br. Weed Cont. Conf.:331-336.

Hakansson, S. 1971. Experiments with Agropyron repens (L.) Beauv. X. Individual and combined effects of division and burial of the rhizomes and competition from a crop. Swed. J. Ag. Res. 1:239-246.

Harris, P. 1971. Current approaches to biological control of weeds. Pages 67-76. Biological control programmes against insects and weeds in Canada 1959-1968. Tech. Commun. Commonw. Inst. Biol. Control 4. 261 p.

Harris, P. 1973. Weed vulnerability to damage by biological control agents. Proc. 2nd Int. Symp. Biol. Contr. Weeds. Rome, 1971. Commonw. Inst. Biol. Contr. Commonw. Agr. Bur., Slough, U.K., 225 p.

Harrison, S.K., and L.M. Wax. 1986. Adjuvant effects on absorption, translocation, and metabolism of haloxyfop-methyl in corn (Zea mays). Weed Sci. 34:185-195.

Hendley, P., J.W. Dicks, T.J. Monaco, S.M. Slyfield, O.J. Tummon, and J.C. Barrett. 1985. Translocation and metabolism of pyridinyloxyphenoxypropionate herbicides in rhizomatous quackgrass (Agropyron repens). Weed Sci. 33:11-24.

Hicks, C.P., and T.N. Jordan. 1984. Response of bermudagrass (Cynodon dactylon), quackgrass (Agropyron repens), and wirestem muhly (Muhlenbergia frondosa) to postemergence grass herbicides. Weed Sci. 32:835-841.

Holm, L.G., D.L. Plucknett, J.V. Pancho, and J.P. Herberger. 1977. The World's Worst Weeds: Distribution and Biology. University Press, Hawaii, Honolulu. 609 p.

Hustitch, I. 1971. The introduced flora element in central Quebec-Labrador peninsula. Natur. Can. 98:425-441.

Ikai, T., K. Suzuki, and H. Igarashi. 1985. The site of action of quizalofop-ethyl, NCI-96683. Proc. Br. Conf. Weeds 1985 163-169.

Ivany, J.A. 1978. Effect of quackgrass competition on silage corn yield. Can. J. Plant Sci. 58:539-542.

Johnson, B.G., and K.P. Buchholtz. 1962. Natural dormancy on vegetative buds on the rhizomes of quackgrass. Weeds 19:53-57.

Kells, J.J., W.F. Meggitt, and D. Penner. 1984. Absorption, translocation, and activity of fluazifop-butyl as influenced by plant growth stage and environment. Weed Sci. 32:143-149.

Kells, J.J., W.F. Meggitt, and D. Penner. 1985. Activity of selective postemergence grass herbicide in soil. Weed Sci. 34:62-65.

King, L. 1966. Weeds of the World. Biology and Control. Interscience, New York. 526 p.

Kommedahl, T., J.B. Kotheimer, and J.W. Bernardini. 1959. The effects of quackgrass on germination and seedling development of certain crop plants. Weeds 7:1-12.

Leaky, R.R.B., and R.J. Chancellor. 1972. The effects of gravity and temperature upon the reassertion of dominance in fragmented rhizomes of Agropyron repens (L.) Beauv. Proc. 11th Br. Weed Cont. Conf.:50-56.

Leaky, R.R.B., R.J. Chancellor, and D. Vince-Prue. 1975. Parental factors in dominance of lateral buds on rhizomes of Agropyron repens (L.) Beauv. Planta 123:267-274.

Leaky, R.R.B., R.J. Chancellor, and D. Vince-Prue. 1978. Regeneration from rhizome fragments of Agropyron repens (L.) Beauv. III. Effects of nitrogen and temperature on the development of dominance amongst shoots of multi-node fragments. Ann. Bot. (London), 42:197-204.

Leaky, R.R.B., R.J. Chancellor, and D. Vince-Prue. 1978b. Regeneration from rhizome fragments of Agropyron repens (L.) Beauv. IV. Effects of light on bud dormancy and development of dominance amongst shoots on multi-node fragments. Ann. Bot. (London) 42:205-212.

Leroux, G. 1984. Méthodes recommandées de répression du chiendent. C.P.V.Q. Rapport de la journée d'information en malherbologie. 6 mars 1984. pp. 27-61.

Linscott, D.L. 1970. The ten worst weeds of field crops-quackgrass. Crops and Soils 23:8-9.

Majek, B.A., C. Erickson, and W.B. Duke. 1984. Tillage effects and environmental influence on quackgrass (Agropyron repens) rhizome growth. Weed Sci. 32:376-381.

Maltais, B., G. Leroux, and A. Watson. 1984. Evaluation des nouveaux herbicides contre le chiendent et les graminées annuelles. C.P.V.Q. Rapport de la journée d'information en malherbologie. 6 mars 1984. pp. 97-109.

McIntyre, G.I. 1965. Some effects of the nitrogen supply on the growth and development of Agropyron repens (L.) Beauv. Weed Res. 5:1-12.

McIntyre, G.I. 1967. Environmental control of bud and rhizome development in the seedling of Agropyron repens (L.) Beauv. Can. J. Bot. 45:1315-1325.

McIntyre, G.I. 1969. Apical dominance in the rhizome of Agropyron repens. Evidence of competition for carbohydrates as a factor in the mechanism of inhibition. Can. J. Bot. 47:1189-1197.

McIntyre, G.I. 1970. Studies on bud development in the rhizome of Agropyron repens. 1. The influence of temperature, light intensity, and bud position on the pattern of development. Can. J. Bot. 48:1903-1909.

McIntyre, G.I. 1981. Apical dominance in the rhizome of Agropyron repens: the influence of humidity and light on the regenerative growth of isolated rhizomes. Can. J. Bot. 59:549-555.

McIntyre, G.I., and A.I. Hsiao. 1982. Influence of nitrogen and humidity on rhizome bud growth and glyphosate translocation in quackgrass (Agropyron repens). Weed Sci. 30:655-660.

McMahon, D.J., and A.M. Mortimer. 1980. The prediction of couch infestation - A modelling approach. Proc. 1980 Brit. Crop Prot. Conf-Weeds:601-608.

Meyer, R.E., and K.P. Buchholtz. 1960. Some factors affecting the activity and growth of buds on quackgrass rhizomes. Proc. North Central Weed Control Conf. 17:37.

Murphy, H.J., and L.S. Monrow. 1985. Effect of DPX Y6202 and DPX F6025 herbicides on weed control in Maine potatoes. Proc. 39th Ann. Meet. N.E. Weed Sci. Soc. pp 181-183.

Nigam, J.N., and G.I. McIntyre. 1977. Apical dominance in the rhizome of Agropyron repens. The relation of amino acid composition to bud activity. Can. J. Bot. 55:2001-2010.

Novakova, J., and J. Zacha. 1975. [Contribution to the knowledge of Tilletia contraversa Kuhn. on Agropyron repens (L.) P.B.J.] (In Russian, English summary) Ceska Mycol. 29:83-89.

Ontario Ministry of Agriculture and Food. 1985. Vegetable production recommendations. Publication 363. Potato. pp. 55-58.

Palmer, J.H. 1958. Studies in the behavior of the rhizomes of Agropyron repens (L.) Beauv. 1. The seasonal development and growth of the parent plant rhizome. New Phytol. 57:145-159.

Palmer, J.H. 1962. Studies in the behavior of the rhizome of Agropyron repens (L.) Beauv. II. Effect of soil factors on the orientation of the rhizome. Physiol. Planta 15:445-451.

Palmer, J.H., and G.R. Sagar. 1963. Biological flora of the British Isles. Agropyron repens (L.) Beauv. (Triticum repens (L.) Nevski.). J. Ecol. 51:783-794.

Parsells, A.J., M.M. Fawzi, J.S. Claus, and J.C. Summers. 1983. DPX Y6202 - A new postemergence grass herbicide for soybeans, cotton and other broadleaf crops. Proc. North Cent. Weed Cont. Conf. 38:14-15.

Perez-Trejo, F., D.D. Dwyer, and K.H. Asay. 1979. Forage yield, phenological development, and forage quality of an Agropyron repens * A. spicatum hybrid. J. Range Manag. 32:387-389.

Plowman, R.E., W.C. Stonebridge, and J.N. Hawtree. 1980. Fluazifop-butyl - A new selective herbicide for the control of annual and perennial grass weeds. Proc. 1980 Br. Crop Prot. Conf-Weeds:29-38.

Poliquin, B., D. Turcotte, and P. Lanoie. 1986. Postemergence quackgrass control in potatoes. Expert committee on weeds. Eastern Canada section. Research report. p. 530.

Poliquin, B., and D. Turcotte. 1987. Quackgrass control in potatoes following a late fall application. Expert committee on weeds. Eastern Canada section. Research report. p. 435.

Poliquin, B., and D. Turcotte. 1987. Postemergence quackgrass control in potatoes. Expert committee on weeds. Eastern Canada section. Research report p. 435.

Poliquin, B., and D. Turcotte. 1987. Quackgrass control one year after application. Expert committee on weeds. Eastern Canada section. Research report. p. 436.

Poliquin, B., and D. Turcotte. 1988. Répression du chiendent dans les pommes de terre un an après une application de printemps. Expert committee on weeds. Eastern Canada section. Research report p. 450.

Poliquin, B., and D. Turcotte. 1988. Répression du chiendent dans les pommes de terre un an après une application d'automne. Expert committee on weeds. Eastern Canada section. Research report. p. 451.

Pooswang, W., P.A. Huxley, and W.R. Buckley. 1972. Differences in growth of four clones of Agropyron repens (L.) Beauv. Proc. 11th Br. Weed Cont. Conf.:38-49.

Qureshi, F.A., and G.I. McIntyre. 1979. Apical dominance in the rhizome of Agropyron repens: the influence of nitrogen and humidity on the translocation of C_{14}-labelled assimilates. Can. J. Bot. 57:1229-1235.

Rick, S.K., F.W. Slife, and W.L. Banwart. 1983. Residual activity of selective grass herbicides by soil. Proc. North. Cent. Weed Control Conf. 38:1.

Rick, S.K., F.W. Slife, and W.L. Banwart. 1984. Absorption of selective grass herbicides by soil. Abstract Weed Sci. Soc. Am. p. 97

Rioux, R., J.D. Bandeen, and G.W. Anderson. 1974. Effect of growth stage on translocation of glyphosate in quackgrass. Can. J. Plant Sci. 54:397-401.

Rogan, P.G., and D.L. Smith. 1974. Patterns of translocation of C_{14}-labelled assimilates during vegetative growth of Agropyron repens (L.) Beauv. Z. Pflanzenphysiol. 73:405-414.

Rogan, P.G., and D.L. Smith. 1975a. The effect of temperature and nitrogen level on the morphology of Agropyron repens (L.) Beauv. Weed Res. 15:93-99.

Rogan, P.G., and D.L. Smith. 1975b. Rates of leaf initiation and leaf growth in Agropyron repens (L.) Beauv. J. Exp. Bot. 26:70-78.

Rogan, P.G., and D.L. Smith. 1976. Experimental control of bud initiation in rhizomes of Agropyron repens (L.) Beauv. Z. Pflanzenphysiol. 78:113-121.

Rousseau, C. 1968. Histoire, habitat et distribution de 220 plantes introduites au Québec. Natur. Can. 95:49-169.

Ruizzo, M.A., and S.F. Gorski. 1985. Vegetable susceptibility to DPX Y6202. Proc. 39th Ann. Meet. Northeast. Weed Sci. Soc. p. 122.

Sagar, G.R. 1961. Agropyron repens - An introduction. Proc. 5th Br. Weed Cont. Conf.:259-263.

Sampson, M.G. 1983. Pathogens associated with Agropyron repens (L.) Beauv. in Eastern Canada. M.Sc. thesis, McGill University, Montreal. 185 p.

Sampson, M.G., and A.K. Watson. 1985a. Host range of Puccinia coronata, Puccinia graminis and Puccinia recondita isolates from Agropyron repens. Can. J. Plant Path. 7:417-420.

Sampson, M.G., and A.K. Watson. 1985c. Host specificity of Urocystis agropyri isolated from Agropyron repens. Can. J. Plant Path. 7:52-54.

Sampson, M.G., and A.K. Watson. 1985b. Host specificity of five leaf spotting pathogens of Agropyron repens. Can. J. Plant Path. 7:161-164.

Sarpe, N., and C. Dinu. 1981. The control of *Sorghum halepense* and *Agropyron repens* in potato crops with fluazifop-butyl, alloxydim-sodium and sethoxydim. Proc. 1981 Br. Crop Prot. Conf-Weeds:919-925.

Schroeder, D. 1983. Biological control of weeds. Pages 41-78 *in* W.W. Fletcher (ed.). Recent advances in weed research. Commonw. Agric. Bur., Slough. 266 p.

Sprankle, P., W.F. Meggitt, and D. Penner. 1975. Absorption, mode of action, and translocation of glyphosate. Weed Sci. 23:235-240.

Steel, R.G.D., and J.H. Torrie. 1980. Principles and procedures of statistics - A biometrical approach. 2nd ed. McGraw Hill Book Co., New York. 633 pp.

Stoltenberg, D.E., and D.L. Wyse. 1986. Regrowth of quackgrass (*Agropyron repens*) following postemergence applications of haloxyfop and sethoxydim. Weed Science 34:664-668.

Swisher, B.A., and F.T. Corbin. 1982. Behaviour of BAS-9052 OH in soybean (*Glycine max*) and Johnsongrass (*Sorghum halepense*) plant and cell cultures. Weed Sci. 30:640-650.

Trimmer, M.C., and D.L Linscott. 1985. Effects of DPX Y6202, haloxyfop and PP005 on moisture uptake by quackgrass. Proc. 39th Ann. Meet. Northeast. Weed Sci. Soc. p. 30.

Turner, D.J. 1969. The effects of shoot removal on the rhizome carbohydrate reserves of couch grass (*Agropyron repens* (L.) Beauv.). Weed Res. 9:27-36.

Van Hiele, F.J.H., and M. De Boer. 1972. Chemical repression of *Agropyron repens* clones without soil cultivation. Proc. 11th Br. Weed Cont. Conf.:1243:1247.

Vengris, J. 1962. The effect of rhizome length and date of planting on the mechanical and chemical control of quackgrass. Weeds 10:71-74.

Weed Science Society of America. 1983. Herbicide handbook. Fifth edition. 515 pp.

Welbank, P.J. 1961. A study of the nitrogen and water factors in competition with Agropyron repens (L.) Beauv. Ann. Bot. (Lond.) 25:110-137.

Werner, P.A., and R. Rioux. 1977. The biology of Canadian weeds. 24. Agropyron repens (L.) Beauv. Can. J. Plant Sci. 57:905-919.

Westra, P.H., D.L. Wyse, and E.F. Cook. 1981. Weevil (Notaris bimaculatus) feeding reduces effectiveness of glyphosate on quackgrass (Agropyron repens). Weed Sci. 29:540-547.

Westra, P.H., and D.L. Wyse. 1981. Growth and development of quackgrass (Agropyron repens) biotypes. Weed Sci. 29:44-52.

Wilhm, J.L., and W.F. Meggitt. 1983. Quackgrass (Agropyron repens (L.) Beauv.) control in soybeans. Proc. North. Cent. Weed Cont. Conf.:7-8.

Williams, E.D. 1970a. Effects of decreasing the light intensity on the growth of Agropyron repens (L.) Beauv. in the field. Weed Res. 10:360-366.

Williams, E.D. 1970b. Studies on the growth of seedlings of Agropyron repens (L.) Beauv. and Agrostis gigantea Roth. Weed Res. 10:321-330.

Williams, E.D. 1971. Effect of light intensity, photoperiod and nitrogen on the growth of seedlings of Agropyron repens (L.) Beauv. and Agrostis gigantea Roth. Weed Res. 11:159-170.

Williams, E.D., and P.J. Attwood. 1971. Seed production of Agropyron repens (L.) Beauv. in arable crops in England and Wales in 1969. Weed Res. 11:22-30.

Williams, E.D. 1972. Growth of Agropyron repens seedlings in cereals and field beans. Prot. 11th Br. Weed Cont. Conf.:32-37.

Williams, E.D. 1973. Variation in growth of seedlings and clones of Agropyron repens (L.) Beauv. Weed Res. 13:24-41.

Williams, E.D. 1973. A comparison of the growth and competition behaviour of seedlings and plants from rhizomes of Agropyron repens (L.) Beauv. and Agrostis gigantea Roth. Weed Res. 13:422-429.

Williams, E.D. 1975. Growth of seedlings of Agropyron repens (L.) Beauv. and Agrostis gigantea Roth. in cereal crops. Weed Res. 15:299-306.

Wilson, C.L. 1969. Use of plant pathogens in weed control. Ann. Rev. Phytopathol. 7:411-434.

Wyse, D.L. 1976. Quackgrass control in field crops. North Cent. Weed Cont. Conf. 31:152-153.

Appendix I. Analysis of variance for the effect of herbicides on quackgrass and potato parameters.
(Summer 1986 application / 1986 evaluation)

Parameter	Source of Variation	DF	SS	Pr>F	C.V.
Shoot density (square root)	Replicates (R)	3	23.31	*	18.91
	Treatments (T)	6	66.25	**	
Height	R	3	49.37	N.S.	18.66
	T	6	708.36	**	
Shoot biomass	R	3	43.23	N.S.	
	T	6	7241.58	**	
Rhizome biomass	R	3	76.29	*	43.86
	T	6	138.39	**	
Rhizome bud viability	R	3	2100.86	**	54.56
	T	6	1093.50	N.S.	
Yields marketable	R	3	258445097.9	**	22.15
	T	6	165244370	*	
Yields total	R	3	405211764	**	17.78
	T	6	233167757	*	

Where ** is significant at the 1% level
* is significant at the 5% level
N.S. is not significant at the 5% level

Appendix II. Friedman's two-way analysis of variance by ranks for non-parametric evaluations of the effect of herbicides on quackgrass and potato parameters.
(Summer 1986 application / 1986 evaluation)

Parameter	Source of Variation	DF	X^2r	$Pr>X^2r$
Quackgrass Visual injury	Treatments	6	12.57	*
Crop Visual injury	Treatments	6	22.62	**

Where ** is significant at the 1% level
* is significant at the 5% level
N.S. is not significant at the 5% level

Appendix III. Analysis of variance for the effect of herbicides on quackgrass parameters.
(Summer 1986 application / 1987 evaluation)

Parameter	Source of Variation	DF	SS	Pr>F	C.V.
Shoot density (square root)	Replicates (R)	3	35.47	*	61.05
	Treatments (T)	6	104.88	**	
Height	R	3	2659.49	**	42.82
	T	6	4516.78	**	

Where ** is significant at the 1% level
* is significant at the 5% level
N.S. is not significant at the 5% level

Appendix IV. Analysis of variance for the effect of herbicides on quackgrass and potato parameters.
(Summer 1987 application / 1987 evaluation)

Parameter	Source of Variation	DF	SS	Pr>F	C.V.
Shoot density (square root)	Replicates (R)	3	2.24	N.S.	15.32
	Treatments (T)	6	49.20	**	
Height	R	3	210.77	**	7.31
	T	6	789.31	**	
Shoot biomass	R	3	22.66	N.S.	72.44
	T	6	1483.06	**	
Rhizome Biomass	R	3	1.35	N.S.	107.52
	T	6	24.03	*	
Rhizome bud viability	R	3	1531.73	*	77.79
	T	6	5389.71	**	
Yields marketable	R	3	23267394	N.S.	13.73
	T	6	238236620	**	
Yields total	R	3	22276044	N.S.	11.75
	T	6	248349320	**	

Where ** is significant at the 1% level
* is significant at the 5% level
N.S. is not significant at the 5% level

Appendix V. Friedman's two-way analysis of variance by ranks for non-parametric evaluations of the effect of herbicides on quackgrass and potato parameters.
(Summer 1986 application / 1986 evaluation)

Parameter	Source of Variation	DF	X^2r	Pr>F
Quackgrass Visual injury	Treatments	6	13.86	*
Crop Visual injury	Treatments	6	12.33	*

Where * is significant at the 5% level

Appendix VI. Analysis of variance for the effect of herbicides on quackgrass and potato parameters.
(Summer 1987 application / 1988 evaluation)

Parameter	Source of Variation	DF	SS	Pr>F	C.V.
Shoot density (square root)	Replicates (R)	3	6.33	N.S.	43.06
	Treatments (T)	6	81.50	**	
Height	R	3	1233.78	N.S.	51.47
	T	6	7583.34	*	
Shoot biomass	R	3	1974.89	N.S.	48.23
	T	6	5868.84	N.S.	
Rhizome Biomass	R	3	176.09	N.S.	81.89
	T	6	324.32	N.S.	
Rhizome bud viability	R	3	2632.68	*	27.09
	T	6	2282.07	N.S.	
Yields marketable	R	3	$2.58x10^8$	N.S.	31.89
	T	6	$9.52x10^7$	N.S.	
Yields total	R	3	$1.68x10^8$	N.S.	25.68
	T	6	$1.89x10^8$	N.S.	

Where ** is significant at the 1% level
* is significant at the 5% level
N.S. is not significant at the 5% level

Appendix VII. Analysis of variance for the effect of herbicides on quackgrass and potato parameters.
(Fall 1986 application / 1987 evaluation)

Parameter	Source of Variation	DF	SS	Pr>F	C.V.
Shoot density (square root)	Replicates (R)	3	6.33	N.S.	43.06
	Treatments (T)	6	81.50	**	
Height	R	3	1416.69	**	41.32
	T	6	2248.95	**	
Shoot biomass	R	3	46.76	**	110.53
	T	6	38.29	**	
Rhizome Biomass	R	3	0.50	N.S.	99.12
	T	6	0.95	N.S.	
Rhizome bud viability	R	3	973	N.S.	172.26
	T	6	1203.5	N.S.	
Yields marketable	R	3	3.65×10^8	**	16.81
	T	6	3.38×10^8	*	
Yields total	R	3	3.47×10^8	**	15.82
	T	6	3.93×10^8	*	

Where ** is significant at the 1% level
* is significant at the 5% level
N.S. is not significant at the 5% level

Appendix VIII. Analysis of variance for the effect of herbicides on quackgrass and potato parameters.
(Fall 1987 application / 1988 evaluation)

Parameter	Source of Variation	DF	SS	Pr>F	C.V.
Shoot density (square root)	Replicates (R)	3	0.33	N.S.	94.86
	Treatments (T)	6	13.03	*	
Height	R	3	168.59	N.S.	99.45
	T	6	3637.19	N.S.	
Shoot biomass	R	3	5.69	N.S.	129.11
	T	6	141.89	N.S.	
Rhizome Biomass	R	3	5.01	N.S.	223.77
	T	6	9.76	N.S.	
Rhizome bud viability	R	3	1585.57	N.S.	185.67
	T	6	2568.36	N.S.	
Yields marketable	R	3	1.23×10^{9}	**	36.19
	T	6	1.49×10^{8}	N.S.	
Yields total	R	3	1.95×10^{9}	**	24.36
	T	6	2.29×10^{8}	N.S.	

Where ** is significant at the 1% level
* is significant at the 5% level
N.S. is not significant at the 5% level

Appendix IX. The effect of herbicides on quackgrass parameters. (Summer 1986 application / 1986 evaluation)

Treatment Number	Treatment	Rate (g/ha)	Visual Injury (0-100)	Shoot Density ($/.25m^2$)	Height (cm)	Shoot dry weight ($g/.25m^2$)	Rhizome fresh weight ($g/15cm^3$)	Rhizome Bud Viability (%)
1	quizalofop-ethyl + Canplus 411	96 0.5%	87 b[a]	47.7 b[b]	18.31 b[b]	3.42 b[b]	3.32 c[b]	19
2	quizalofop-ethyl + Canplus 411	144 0.5%	91 b	28.5 b	15.69 b	1.64 b	3.79 c	13
3	quizalofop-ethyl + Canplus 411	192 0.5%	88 b	48.4 b	18.44 b	1.59 b	4.58 bc	21
4	quizalofop-ethyl + Canplus 411	240 0.5%	90 b	45.9 b	19.19 b	1.68 b	3.99 c	20
5	sethoxydim + Assist	810 2.0%	87 b	47.4 b	17.25 b	2.41 b	4.37 bc	12
6	fluazifop-butyl + Agral 90	750 0.25%	89 b	39.9 b	17.25 b	0.90 b	7.58 ab	25
7	untreated	-	0 a	111.4 a	31.75 a	47.85 a	9.79 a	31
		LSD:	X^2r	1.96 [c]	5.46	4.11	3.48	N.S.

[a]Means followed by the same letter are not significantly different at the 0.42 experiment-wise error rate.
[b]Means followed by the same letter are not significantly different at the 0.05 level of significance.
[c]Analysis of variance was performed on square root transformed data.
N.S. Not significant at the 0.05 level.

Appendix X. The effect of herbicides on the potato crop. (Summer 1986 application / 1986 evaluation)

Treatment Number	Treatment	Rate (g/ha)	Crop Injury (0-100)	Yields Total (kg/ha)	Yields Marketable (kg/ha)
1	quizalofop-ethyl + Canplus 411	96 0.5%	<1	18484 bc[a]	12210 ab[a]
2	quizalofop-ethyl + Canplus 411	144 0.5%	<1	20512 ab	14136 a
3	quizalofop-ethyl + Canplus 411	192 0.5%	<1	23083 ab	16707 a
4	quizalofop-ethyl + Canplus 411	240 0.5%	<1	19188 abc	13063 ab
5	sethoxydim + Assist	810 2.0%	0	21613 ab	15339 a
6	fluazifop-butyl + Agral 90	750 0.25%	0	23937 a	16230 a
7	untreated	-	0	14729 c	9173 b
		LSD:	-	5340	4553

[a]Means followed by the same letter are not significantly different at the 0.05 level of significance

Appendix XI. The effect of herbicides on quackgrass and potato parameters. (Summer 1986 application / 1987 evaluation)

Treatment Number	Treatment	Rate	Visual Injury	Shoot Density	Height	Crop Injury
		(g/ha)	(0-100)	(/.25m^2)	(cm)	(0-100)
1	quizalofop-ethyl + Canplus 411	96 0.5%	0	13.3 b[a]	37.69 ab[a]	0
2	quizalofop-ethyl + Canplus 411	144 0.5%	0	3.6 b	13.81 c	0
3	quizalofop-ethyl + Canplus 411	192 0.5%	0	2.3 b	14.81 c	0
4	quizalofop-ethyl + Canplus 411	240 0.5%	0	3.9 b	18.88 c	0
5	sethoxydim + Assist 2.0%	810	0	10.5 b	25.81 bc	0
6	fluazifop-butyl + Agral 90	750 0.25%	0	4.6 b	17.50 c	0
7	untreated	-	0	65.8 a	50.44 a	0
		LSD:	-	2.55 [b]	16.26	-

[a]Means followed by the same letter are not significantly different at the 0.05 level of significance.
[b]Analysis of variance was performed on square root transformed data.

Appendix XII. The effect of herbicides on quackgrass parameters. (Summer 1987 application / 1987 evaluation)

Treatment Number	Treatment	Rate (g/ha)	Visual Injury (0-100)	Shoot Density (/.25m^2)	Height (cm)	Shoot dry weight (g/.25m^2)	Rhizome fresh weight (g/15cm^3)	Rhizome Viability (%)
1	quizalofop-ethyl + Canplus 411	96 0.5%	89 a[a]	30.2 bc[b]	42.75 b[b]	1.03 b[b]	0.39 b[b]	5 bc[b]
2	quizalofop-ethyl + Canplus 411	144 0.5%	91 b	30.7 bc	44.50 b	0.51 b	0.16 b	0 c
3	quizalofop-ethyl + Canplus 411	192 0.5%	93 b	22.3 c	40.00 b	0.33 b	1.58 ab	17 b
4	quizalofop-ethyl + Canplus 411	240 0.5%	93 b	24.0 c	40.17 b	0.33 b	0.63 b	5 bc
5	sethoxydim + Assist	810 2.0%	88 a	39.4 b	42.06 b	2.35 b	1.05 b	15 bc
6	fluazifop-butyl + Agral 90	750 0.25%	89 a	35.3 bc	41.69 b	0.64 b	0.68 b	7 bc
7	untreated	-	0 a	83.9	57.19 a	21.58 a	3.10 a	45 a
		LSD:	X^2r	1.45 [c]	5.08	4.11	1.73	16.66

[a]Means followed by the same letter are not significantly different at the 0.42 experiment-wise error rate.
[b]Means followed by the same letter are not significantly different at the 0.05 level of significance.
[c]Analysis of variance was performed on square root transformed data.
N.S. Not significant at the 0.05 level.

Appendix XIII. The effect of herbicides on the potato crop.
Summer 1987 application / 1987 evaluation

Treatment Number	Treatment	Rate (g/ha)	Crop Injury (0-100)	Yields Total (kg/ha)	Yields Marketable (kg/ha)
1	quizalofop-ethyl + Canplus 411	96 0.5%	<1	27568 b[a]	23284 b[a]
2	quizalofop-ethyl + Canplus 411	144 0.5%	<1	26727 b	23051 b
3	quizalofop-ethyl + Canplus 411	192 0.5%	<1	27736 b	22750 b
4	quizalofop-ethyl + Canplus 411	240 0.5%	1	23388 ab	18890 ab
5	sethoxydim + Assist	810 2.0%	0	25779 b	21502 b
6	fluazifop-butyl + Agral 90	750 0.25%	0	27719 b	22985 b
7	untreated	-	0	18858 a	14644 a
		LSD:	-	4676	4531

[a]Means followed by the same letter are not significantly different at the 0.5 level of significance.

Appendix XIV. The effect of herbicides on quackgrass parameters.
(Summer 1987 application / 1987 evaluation)

Treatment Number	Treatment	Rate (g/ha)	Visual Injury (0-100)	Shoot Density (/.25m^2)	Height (cm)	Shoot dry weight (g/.25m^2)	Rhizome fresh weight (g/15cm^3)	Rhizome Viability (%)
1	quizalofop-ethyl + Canplus 411	96 0.5%	0	2.0 c[a]	20.45 b[a]	28.26	1.91	55
2	quizalofop-ethyl + Canplus 411	144 0.5%	0	4.8 bc	21.20 b	36.89	5.08	52
3	quizalofop-ethyl + Canplus 411	192 0.5%	0	7.6 bc	26.10 b	35.64	10.32	52
4	quizalofop-ethyl + Canplus 411	240 0.5%	0	14.8 b	32.53 b	57.35	8.28	74
5	sethoxydim + Assist	810 2.0%	0	9.9 bc	38.80 b	40.31	6.78	65
6	fluazifop-butyl + Agral 90	750 0.25%	0	4.2 c	28.83 b	28.17	4.63	46
7	untreated	-	0	46.1 a	72.40 a	69.99	12.77	66
		LSD:	-	14.4	28.03	N.S.	N.S.	N.S.

[a]Means followed by the same letter are not significantly different at the 0.05 level of significance.
N.S. Not significant at the 0.05 level.

Appendix XV. The effect of herbicides on the potato crop.
(Summer 1987 application / 1987 evaluation)

Treatment Number	Treatment	Rate	Crop Injury	Yields Total	Yields Marketable
		(g/ha)	(0-100)	(kg/ha)	(kg/ha)
1	quizalofop-ethyl + Canplus 411	96 0.5%	0	35011	22805
2	quizalofop-ethyl + Canplus 411	144 0.5%	0	40838	23942
3	quizalofop-ethyl + Canplus 411	192 0.5%	0	33019	20029
4	quizalofop-ethyl + Canplus 411	240 0.5%	0	31991	18331
5	sethoxydim + Assist	810 2.0%	0	34726	23277
6	fluazifop-butyl + Agral 90	750 0.25%	0	35611	21210
7	untreated	-	0	34699	20667
		LSD:	-	N.S.	N.S.

N.S. Not significant at the 0.05 level.

Appendix XVI. The effect of herbicides on quackgrass parameters.
(Fall 1986 application / 1987 evaluation)

Treatment Number	Treatment	Rate (g/ha)	Visual Injury (0-100)	Shoot Density ($/.25m^2$)	Height (cm)	Shoot dry weight ($g/.25m^2$)	Rhizome fresh weight ($g/15cm^3$)	Rhizome Viability (%)
1	quizalofop-ethyl + Canplus 411	96 0.5%	0	8.4 ab[a]	20.31 b[a]	1.58	0.39	10
2	quizalofop-ethyl + Canplus 411	144 0.5%	0	9.6 ab	28.81 ab	2.47	0.63	6
3	quizalofop-ethyl + Canplus 411	192 0.5%	0	9.4 ab	18.44 bc	1.90	0.45	5
4	quizalofop-ethyl + Canplus 411	240 0.5%	0	9.6 bc	22.69 ab	2.21	0.39	13
5	glyphosate	890	0	0.6 c	5.25 c	1.00	0.06	0
6	sethoxydim + Assist	810 2.0%	0	19.1 ab	27.31 ab	4.61	0.51	22
7	untreated	-	0	20.6 a	35.94 a	3.77	0.65	16
		LSD:	-	1.97 [b]	13.92	N.S.	N.S.	N.S.

[a]Means followed by the same letter are not significantly different at the 0.05 level of significance.
[b]Analysis of variance performed on square root transformed data.
N.S. Not significant at the 0.05 level.

Appendix XVII. The effect of herbicides on the potato crop. (Fall 1987 application / 1987 evaluation)

Treatment Number	Treatment	Rate (g/ha)	Crop Injury (0-100)	Yields Total (kg/ha)	Yields Marketable (kg/ha)
1	quizalofop-ethyl + Canplus 411	96 0.5%	0	32725 a[a]	28215 a[a]
2	quizalofop-ethyl + Canplus 411	144 0.5%	0	29034 a	25098 a
3	quizalofop-ethyl + Canplus 411	192 0.5%	0	20412 b	16756 b
4	quizalofop-ethyl + Canplus 411	240 0.5%	0	27532 a	24020 a
5	glyphosate	890	0	30212 a	26223 a
6	sethoxydim + Assist	810 2.0%	0	31533 a	26896 a
7	untreated	-	0	30009 a	25779 a
		LSD:	-	6762	6172

[a]Means followed by the same letter are not significantly different at the 0.5 level of significance.

Appendix XVIII. The effect of herbicides on quackgrass parameters.
(Fall 1987 application / 1988 evaluation)

Treatment Number	Treatment	Rate	Visual Injury	Shoot Density	Height	Shoot dry weight	Rhizome fresh weight	Rhizome Viability
		(g/ha)	(0-100)	(/.25m^2)	(cm)	(g/.25m^2)	(g/15cm^3)	(%)
1	quizalofop-ethyl + Canplus 411	96 0.5%	0	1.3 abc	13.08 bc[a]	3.77	1.01	14
2	quizalofop-ethyl + Canplus 411	144 0.5%	0	0.7 bc	4.25 bc	0.72	0.18	0
3	quizalofop-ethyl + Canplus 411	192 0.5%	0	0.8 bc	9.33 bc	2.18	0.48	9.5
4	quizalofop-ethy[illegible] + Canplus 411	[illegible] [illegible]%	0	0.0 c	0.0 c	0.31	0.05	0
5	glyphosate	890	0	2.4 ab	21.70 abc	4.21	0.13	20
6	sethoxydim + Assist	810 2.0%	0	2.0 abc	22.88 ab	4.42	1.77	21
7	untreated	-	0	5.8 a	35.65 a	7.34	1.06	26.5
		LSD:	-	1.32 [b]	22.56	N.S.	N.S.	N.S.

[a]Means followed by the same letter are not significantly different at the 0.05 level of significance.
[b]Analysis of variance performed on square root transformed data.
N.S. Not significant at the 0.05 level.

Appendix XVIX. The effect of herbicides on the potato crop. (Fall 1987 application / 1988 evaluation)

Treatment Number	Treatment	Rate (g/ha)	Crop Injury (0-100)	Yields Total (kg/ha)	Yields Marketable (kg/ha)
1	quizalofop-ethyl + Canplus 411	96 0.5%	0	24940	14088
2	quizalofop-ethyl + Canplus 411	144 0.5%	0	29015	17450
3	quizalofop-ethyl + Canplus 411	192 0.5%	0	32987	19685
4	quizalofop-ethyl + Canplus 411	240 0.5%	0	31718	19143
5	glyphosate	890	0	32857	20868
6	sethoxydim + Assist	810 2.0%	0	33929	21424
7	untreated	-	0	31565	19986
		LSD:	-	N.S.	N.S.