AN ABSTRACT OF THE THESIS OF

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Title: EFFECTS OF 2-CHLOROETHYLPHOSPHONIC ACID (ETHREL) AND SELECTED ENVIRONMENTAL FACTORS ON GROWTH OF QUACKGRASS (AGROPYRON REPENS L. (BEAUV.)) AND FIELD BINDWEED (CONVOLVULUS ARVENSIS L.)

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The primary purposes of these studies were to investigate: (1) the effects of air temperature, soil moisture, and supplemental light on sprouting ability of quackgrass (Agropyron repens L. (Beauv.)) rhizome buds; (2) the influence of 2-chloroethylphosphonic acid (Ethrel) on growth, morphology, and regenerative capacity of quackgrass and field bindweed (Convolvulus arvensis L.); and (3) the efficacy of Ethrel in enhancing the phytotoxicity of a mixture of 3-amino-s-triazole and ammonium thiocyanate (amitrol-T) and 2,2-dichloropropionic acid (dalapon) on the regenerative capacity of quackgrass rhizomes. The studies were carried out in a greenhouse or growth chambers.

The percent sprouting of the single-node quackgrass rhizome

buds was decreased if the plants were subjected to 70°F day and 60°F night air temperatures, a reduced level of light intensity, or severe soil moisture stress.

Ethrel applied to mature quackgrass plants effectively induced the rhizome buds to grow and develop into either rhizome branches or into leafless, rhizome-like aerial shoots. The aerial shoots did not develop normal leaves for two to four weeks. Later, as the effect of Ethrel diminished, normal leaves developed on the upper parts of the new shoots. Higher rates of Ethrel (4 to 6 lb/A) were more effective in evoking growth of the rhizome buds than the lower rates, but the resulting shoots remained leafless for a longer time.

A high level of soil-applied nutrients also induced growth of quackgrass rhizome buds. In this regard, the effect of Ethrel and high soil nutrient level was simply additive not synergistic.

Ethrel applied to intact quackgrass plants or to its excised rhizome buds did not increase or decrease the percent sprouting of the single-node rhizome buds. But the excised rhizome buds from quackgrass plants growing at a high level of soil nutrients had a higher percent sprouting.

Over a six-week period, Ethrel (6 lb/A) application doubled the fresh and the dry weight of the leaves plus the newly formed shoots, moderately reduced the dry weight but not the fresh weight of the rhizomes, and inhibited root growth of the treated quackgrass plants in

comparison to the untreated plants.

Pre-treating quackgrass plants with Ethrel did not enhance the effectiveness of amitrol-T, applied subsequently, as measured by the average weight of regrowth produced by the replanted rhizome segments. But Ethrel in combination with amitrol-T completely inhibited the rhizome segments of 60% to 80% of the plants from producing any regrowth. When amitrol-T alone was used, the rhizome segments of 30% to 50% of the plants failed to have any regrowth.

The rhizome pieces from quackgrass plants treated with Ethrel and dalapon produced more regrowth dry weight than the rhizome segments obtained from similar plants treated with dalapon alone. The reason for this antagonistic relation between Ethrel and dalapon was not investigated.

Mature field bindweed plants sprayed with Ethrel sustained severe to complete defoliation. Many of the existing stems also died. The rootstocks of these plants, especially those treated with 1.0 lb Ethrel/A, were stimulated to initiate numerous visible shoot-buds. The initiated buds close to the soil surface emerged and developed into aerial shoots with minute leaves and short internodes.

The rootstocks of field bindweed plants were segmented and replanted to measure their regrowth potential. The segmented rootstocks from Ethrel (1.0 lb/A) treated plants produced three times as many shoots and five times as much regrowth dry weight than the

untreated plants.

The effects of low rates of Ethrel (1/4 to 1.0 lb/A) on shoot and root growth of young field bindweed were similar to those of mechanical defoliation or mowing.

Effects of 2-Chloroethylphosphonic Acid (Ethrel) and Selected Environmental Factors on Growth of Quackgrass (*Agropyron repens* L. (Beauv.)) and Field Bindweed (*Convolvulus arvensis* L.)

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TO MY WIFE KITTY, AND TO MY SONS

AFSHENE,

RAMENE, and

KAMRAN

As ever, they were a constant source of encouragement and inspiration.

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INTRODUCTION

Perennial weeds have always been great impediments to man. They have hampered food production, infringed on recreational facilities and clogged waterways the world over.

The problem of perennial weeds, especially that of the rhizomatous and stoloniferous species, is on the rise. Generally, mechanical, chemical or biological methods for the control of these weeds have in practice proven uneconomical or of limited success.

A readily translocatable, highly toxic, very persistent and selective herbicide is needed to effectively control these weeds. The high degree of phytotoxicity and persistence required of such a herbicide is diametrically opposed to the public demand for minimizing pollution of the environment with pesticides.

An alternate approach in solving the problem of perennial weeds may very well lie in the use of growth regulators to change the normal growth pattern of these weeds. Such changes, in general, should either make the weeds less competitive or make them more susceptible to non-persistent chemicals or cultivation.

The practical ways of achieving such changes using growth regulators ought to be sought vigorously. In the past, several of the promising plant growth regulators have been used to change some of the characteristics of the perennial weeds. Though these attempts have generally been of limited success, they have provided some leads for future investigators.

The ability of ethylene gas to cause many hormone-type physiological and morphological changes in plants has been known for several decades. However, ethylene's low water solubility has hindered its widespread use in agriculture. Recently, 2-chloroethylphosphonic acid (Ethrel), a water-soluble, ethylene-releasing compound, has become available for experimental work.

Quackgrass (Agropyron repens L. (Beauv.)) and field bindweed (Convovulvus arvensis L.) are two of the most persistent and difficult to control perennial weeds. The capacity of these two weeds to regenerate new shoots and rhizomes from their numerous dormant underground buds is their major safeguard against attempts to control or eradicate them.

The research reported in this thesis was conducted in a greenhouse or growth chambers to investigate the following:

1. The effects of supplemental light, soil moisture and temperature on the sprouting ability (bud activity) of quackgrass rhizome buds. The objective was to determine

whether the seasonal dormancy (inactivity) of quackgrass rhizome buds noted by Johnson and Buchholtz (1962) could be induced by subjecting the plants to various levels of light, soil moisture or temperature.

2. The influence of Ethrel on growth and morphology primarily of quackgrass and to a limited extent of field bindweed. The objective was to determine what changes Ethrel would cause in the growth and regenerative capacity of shoots, roots and rhizomes of the two perennial weeds. This information not only delineates the specific physiological influences on these two weeds but also discerns whether Ethrel breaks the dormancy of rhizome buds so that the efficacy of subsequent chemical or physical weed control practices could be enhanced.

3. The performance of several chemical treatments consisting of Ethrel in combination with a mixture of 3-amino-s-triazole and ammonium thiocyanate (amitrol-T) and 2,2-dichloropropionic acid (dalapon) on quackgrass plants. The objective was to investigate the effectiveness of Ethrel in enhancing the phytotoxicity of the herbicides.

LITERATURE REVIEW

Quackgrass (Agropyron repens L. (Beauv.))

Magnitude of Quackgrass Problem

Quackgrass is a persistent perennial weed occurring in much of the temperate humid regions of the world. It is a prevalent pestiferous plant in Europe, Asia, Africa, Australia and America (Palmer and Sagar, 1963). It is capable of establishing and spreading rapidly in arable lands to become a formidable competitor to other plants. It can either directly compete for the available resources or secrete some unidentified toxicant(s) inhibitory to normal growth of other species (LeTourneau, 1957; Kommedahl, Kotheimer, and Bernardini, 1959; Ohman and Kommedahl, 1960, 1964; Welbank, 1963; and Omid, 1964).

Growth and Development of Quackgrass-- Factors Affecting Them

According to Palmer (1958), the growth and development of quackgrass under natural conditions proceeds in an orderly, well-defined pattern. In the fall, the tip of a rhizome which had previously grown horizontally away from the parent plant turns upward and forms a small aerial shoot. In Britain's temperate climate it continues to grow very slowly until the next spring. In colder climate,

most of these newly formed shoots will die in the winter (Hakansson, 1967). Early in the spring the overwintered aerial shoot commences active growth, forms new leaves, elongates its main stem and produces three tillers and from three to four rhizomes from its previously dormant basal buds. Some of these shoots flower and set seeds during the growing season while others remain entirely vegetative (Palmer, 1958). The initiated rhizomes grow underground until fall. At that time, their tips turn upward forming new primary shoots for the subsequent season's growth.

The seven auxilliary buds, on the base of the primary shoots are the origin of both the rhizomes and the tillers. Normally the upper buds develop into tillers and the lower ones into rhizomes (Palmer, 1958).

The initiation and the amount of rhizome growth from parent plants were not associated with flowering of the plants, e.g. flowering shoots produced the same amount of rhizome as the vegetative ones did (Palmer, 1958). The amount of rhizome formed also did not depend on the amount of foliage developed. It was shown, however, that a certain minimum level of light intensity was needed for rhizome growth and at higher levels of light intensity more rhizomes were produced. Rhizome growth ceased by the end of September and cessation was not simply governed by light and temperature factors (Palmer, 1958).

Rhizome branches and aerial shoots originate from the buds located on the base of the parent shoot or tillers (Palmer, 1958). Shoots or rhizome branches could also arise from any of the lateral buds along an already formed rhizome. However, these lateral buds are normally inactive (dormant). They rarely initiate aerial shoots or rhizome branches unless the rhizome is segmented into smaller pieces.

Conceivably, every uninjured, mature rhizome bud is capable of establishing a new plant. However, many factors, e.g. the true physiological dormancy (Johnson and Buchholtz, 1962), the length of the rhizome piece (Turner, 1966; Hakansson, 1968a; Vengris, 1962), the depth at which the rhizome segments are planted (Vengris, 1962; Hakansson, 1968b), the stage of growth of the parent plant (Hakansson, 1967), the carbohydrate reserve of the rhizome (Turner, 1969), and the chemical or the mechanical treatments applied to the plant (Hakansson, 1968c; Turner, 1966, 1969) or to the rhizomes (Grummer, 1963), have profound effects on the ability of the rhizome segments to establish a new plant.

The natural dormancy of quackgrass rhizome buds and the factors influencing dormancy and growth of these buds will be discussed in more detail.

Dormancy of Quackgrass Rhizome Buds

Quackgrass rhizome buds exhibit two types of dormancy. First, under favorable growing conditions in the field, most of the buds along an intact rhizome do not initiate any growth. Apical dominance is believed to be involved in this type of dormancy. In the absence of apical dominance, a second type of seasonal dormancy was shown to occur by Johnson and Buchholtz (1962). In Madison, Wisconsin, the investigators found that the percent sprouting (activity) of the excised single buds cultured in agar medium steadily decreased from April to June, stayed at a low level during June and started to rise from July through the rest of the growing season. Previously, Dexter (1942) had shown that the same seasonal variation occurs with respect to the sprouting ability and drought resistance of quackgrass rhizome buds. The hygroscopic capacity of the dried rhizome powder is an indication of the total hydrophilic carbohydrates and proteins of the rhizome (Welch and Veatch, 1962). When this criterion was measured during the growing season, its magnitude also changed similarly to the changes noted in the percentage sprouting of the single-node rhizome segments.

Since the decrease and the increase in sprouting of the excised rhizome buds were gradual, Johnson and Buchholtz (1962) concluded that this dormancy may be due to some gradual physiological changes

taking place in the rhizome and that it was not the result of any distinct change in the environmental conditions.

The seasonal type dormancy of quackgrass rhizome buds has not been demonstrated in Britain's temperate climate. It is possible that the dormancy due to apical dominance is the primary form of dormancy in such a climate (Turner, 1966).

Apical Dominance and Growth of Rhizome Buds

The inhibitory influence of the shoot apex on the growth of lateral buds is a widespread phenomenon in the plant kingdom. But, the nature of the mechanism is not definitely known. Several investigators have shown that the apex controls the growth of lateral buds by producing indole-3-acetic acid (IAA) in the terminal region and transporting it into the lateral buds in sufficiently high levels inhibitory to the growth of the lateral buds (Thimann, 1937; Jacobs et al., 1959; Scott, Case, and Jacobs, 1967).

As more naturally occurring plant growth hormones have been discovered, it has been demonstrated that they are also involved in the process of apical dominance. Gibberellic acid (Jacobs and Case, 1965) and kinetin (Davies, Seth, and Wareing, 1966) were shown to enhance the activity of IAA in restoring apical dominance. Contrary to the above findings, gibberellic acid was found to have an antagonistic effect on the growth inhibition of the auxilliary buds caused by IAA

(Phillips, 1969). Also, kinetin applied to the lateral buds counteracted the inhibitory influence of the intact apex (Sachs and Thimann, 1964).

In recent years, it has become abundantly clear that not only auxins, gibberellins and cytokinins but also abscisic acid, ethylene and possibly other promotive or inhibitory hormones interact in controlling various plant growth processes including apical dominance and dormancy (Galston and Davies, 1969; Addicott and Lyon, 1969). Thus, it has become increasingly more difficult to formulate a generalized hypothesis to account for the varied and at times contradictory results of the action of the known growth hormones in regard to dormancy and apical dominance.

From quackgrass rhizomes, Mudd et al. (1959) obtained an enzyme system capable of oxidizing IAA and an unidentified inhibitor(s) of the enzyme. The total activity of the IAA-oxidase system decreased and the concentration of the enzyme inhibitor(s) increased as the growing season advanced. The dormancy of the rhizome buds also increased as the season advanced (Johnson and Buchholtz, 1962). Consequently, it is possible to postulate that during the early part of the season, while the quackgrass plants are rapidly growing, IAA concentration in the rhizome rises to a sufficiently high level to inhibit the growth of the rhizome buds. There are, however, some criticisms against this explanation of seasonal bud dormancy. For one

thing, although it is doubtful that quackgrass is devoid of IAA, its presence in rhizomes has not been demonstrated. Furthermore, a direct correlation between the level of IAA in the rhizome and the degree of bud dormancy needs to be established.

The growth enhancement or inhibition of lateral buds may also be indirectly associated with the growth hormones. Growth regulators may cause photosynthetic products or inorganic nutrients to move toward and accumulate into a meristematic region inducing its growth. Conversely, the nutritive materials may be transported away from lateral buds inhibiting their growth (Both et al., 1962; Weaver and van Overbeek, 1963; Shindy and Weaver, 1967; and Weaver, Shindy, and Kliewer, 1969).

The effect of growth regulators on conversion, mobilization, and translocation of stored nutrients in quackgrass rhizomes has not been fully investigated. Meyer and Buchholtz (1963) found that the addition of 1-naphthaleneacetic acid (NAA) to an agar medium inhibited growth of single-node quackgrass rhizome buds implanted on the medium. But, IAA, 6-furfuryl aminopurine (kinetin) and gibberellic acid (GA_3) applied similarly, had no effect on the sprouting ability of the buds. When the agar, alone or impregnated with GA_3, NAA or 2, 3, 5-triiodobenzoic acid (TIBA) was applied to the vincinity of the rhizome apices, TIBA slightly reduced the linear growth of the rhizome, while GA_3 slightly increased the growth, and NAA had no appreciable effect.

In TIBA-treated rhizomes, two or three of the buds behind the point of application became active and produced shoots or rhizome branches. Other treatments did not have such an effect.

Some investigators have suggested that the inhibition of lateral bud growth may be due to a nutrient deficiency (Gregory and Veale, 1957) in the lateral buds; and that the apical dominance could simply be explained on the basis of competition between the actively growing points and those in a state of arrest due to a lack of nutrient.

McIntyre (1964, 1965, 1966) observed that the rhizome buds of quackgrass plants growing at a low level of nitrogen remained dormant; wheras those at a higher nitrogen level grew and exhibited no dormancy. It is worthwhile to note that the nitrogen content of the rhizomes from plants growing at the low nitrogen level was similar to the nitrogen content of the rhizomes collected from a field. But the high nitrogen level used in the experiment was 150-fold that of the low nitrogen level. Such a high level of nitrogen seems to be abnormally excessive to have physiological significances.

Also, Dexter (1942) found that both the sprouting ability and the nitrogen content of the rhizomes from quackgrass plants growing in a field decreased from April to June indicating a positive correlation between the two criteria. In contrast Welch and Vealch (1962-W2) observed an increase in the nitrogen content of the rhizomes from May to June, but they did not measure the sprouting ability of the

rhizome buds.

Chanceller (1968) measured the growth of the buds from quackgrass rhizome fragments having 2 to 15 nodes. Most of the buds on each of the rhizome segments made some initial growth. Subsequently, however, one or two shoots re-exerted their dominant effect on the remaining growing buds and stopped their further growth. Addition of KNO_3 to the culture medium did not prevent re-exertion of apical dominance.

Field Bindweed (Convolvulus arvensis L.)

Field bindweed is a persistent broadleaf perennial weed. It is widespread throughout the northern United States, Southern Canada, Europe, and much of Asia.

The species is a very heterogeneous one consisting of many strains and ecotypes. It exhibits considerable differential response to herbicide treatments and plant growth regulators (Whitworth, 1964; Whitworth and Muzik, 1967; and Muzik and Muzik, 1968).

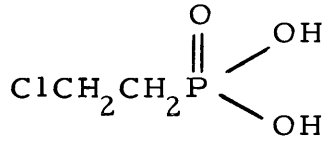
During winter, the aerial part of the plant dies off. In spring, new shoots and roots develop from the over-wintered root systems of the old plants. Both the roots and the shoots originate from the pericycle cells of the roots. Root segments as short as 2.6 mm could develop at least a shoot or a root (Bonnett and Torrey, 1965).

In the field, fragmentation of field bindweed roots by any

implement provides a readily available source of vegetative tissues to re-establish the weed. Only through repeated cultivation and specific cropping systems is it possible to reduce the population of field bindweed (Russ and Anderson, 1960). Several herbicides have been used to control this weed with some degree of success (Wiese and Rea, 1961; Whitworth, 1964; and Agbakoba and Goodin, 1969). The use of herbicide combinations may have some advantage in obtaining better control of field bindweed (Agbakoba and Goodin, 1970).

Ethrel

Ethrel is the brand name for 2-chloroethylphosphonic acid which has the following chemical structure (Amchem Products, Inc., 1968).



The acid is a white crystalline substance, highly soluble in water and other polar solvents. It is stable in a fairly acidic aqueous solution.

An aqueous solution of Ethrel released ethylene in a logarithmic or a linear fashion depending of whether NaOH or excised plant tissues were added to the solution, respectively (Warner and Leopold, 1969). The products of Ethrel disintegration were ethylene gas and phosphate and chloride ions. At a pH above five ethylene evolution

increased rapidly. The breakdown of Ethrel molecules is suggested to proceed via removal of the phosphonate as a salt and a subsequent dehydrohalogenation reaction (Warner and Leopold, 1969; and Cooke and Randall, 1968). Inside the plant cells, suppesedly, the same kind of reaction would take place releasing ethylene directly into the cells.

Ethrel application has been reported to enhance abscission of the leaves and the flower buds of several plant species (Morgan, 1969; Morgan, Meyer, and Merkle, 1969; and Solymosy, 1968).

Cooke and Randall (1968) induced flowering in the pineapple plants by treating them with Ethrel. On or off the vine, tomato fruits were hastened to mature by applying Ethrel to the plants or to the immature fruits (Sims, 1969; Iwahori and Lyons, 1969; and Iwahori, Ben-Yehoshua and Lyons, 1969).

Ethrel is also capable of inducing growth of the vegetative buds of perennial plants. This phenomenon may be brought about by breaking the dormancy of the buds or removing the apical dominance of the terminal growing points. Morgan et al. (1969) noted an enhanced growth of the inactive basal buds of honey mesquite's (Prosopis juliflora var. glandulosa Torr.) subsequent to Ethrel application to the entire plant. Foliar application of Ethrel to johnsongrass (Sorghum halepense L. Pers.) plants effectively stimulated growth of the rhizome's auxilliary buds (Beasley, 1969); whereas a direct

application of Ethrel to the excised rhizome buds of the same species either inhibited bud growth (Beasley, 1969) or was ineffective in promoting growth of the buds (Hull, 1970). Burg and Burg (1967, 1968) showed that ethylene gas effectively inhibited growth of lateral buds in pea (Pisum sativum, var. Alaska) seedlings.

MATERIALS AND METHODS
(General)

The experiments were conducted in a greenhouse or in growth chambers. Depending on the external climatic conditions, the high temperature levels in the greenhouse ranged from 75°F to 90°F and the low levels varied from 60°F to 65°F. The temperature in growth chambers was controlled and will be given later for individual experiments.

The light intensity in the greenhouse was greatly dependent on the external sunlight, which varied over a wide range. The intensity of the supplemental light at the greenhouse bench, provided by fluorescent tubes and incandescent bulbs, was about 700 foot-candles. The lights were on for 14 hours per day regardless of the intensity and the duration of external sunlight. The light source in the growth chambers was also a mixture of fluorescent tubes and incandescent bulbs supplying about 1500 foot-candles at the bench level during 16 hours per day.

The relative humidity in the growth chambers was set at 50% and it fluctuated in the greenhouse.

The quackgrass and the field bindweed plants were always established singly in 4-1/4 x 4-1/4 x 4 inch green plastic pots having drainage holes on the bottom. The soil was a sandy loam soil. In one experiment, where it was necessary to collect and weigh the

quackgrass roots, the plants were grown in washed white sand (El Monte EI20).

Quackgrass plants were consistently established by planting single-node rhizome segments and field binweed plants were grown from pre-soaked seeds. The original supply of quackgrass rhizomes was obtained from a field east of Corvallis, Oregon. Subsequent rhizomes were taken from the first group of established quackgrass plants. Field bindweed plants were trained to climb three-foot cane poles inserted into the soil.

After planting, the pots were set on rectangular galvenized trays for sub-irrigation and left on the greenhouse bench for the plants to grow. Each plant received 150 ml of a complete full-strength Hoagland's nutrient solution every 10 to 15 days.

It generally took three months to obtain well developed plants for each experiment. To speed up the research program, at various times, several groups of plants, each consisting of a few hundred, were established in the greenhouse. Later, as needed, the uniform plants from one of the groups were used in one or more experiments. Consequently, the growing conditions among the groups were not identical; but within each group all the plants were treated alike up to the time of experimentation.

The Ethrel used was prepared from the Amchem 68-62 formulation containing two pounds acid equivalent Ethrel per gallon. The

Ethrel rates mentioned hereinafter will be on an acid equivalent basis. Since Ethrel is not very stable in a neutral solution, the solution for spraying was made fresh and used within 10 to 15 minutes.

The greenhouse sprayer was the stationary type with a variable speed moving nozzle. Depending on the size of the plants to be sprayed, the speed, the size and the height of the nozzle were changed to obtain a 60 to 70 gallons per acre delivery for thorough coverage. All solutions contained 0.5% (v/v) of Triton X-77 surfactant.

For each of the experiments, additional information will be given in the Materials and Methods section.

SECTION I

EFFECTS OF SOME SELECTED ENVIRONMENTAL FACTORS ON SPROUTING ABILITY (BUD ACTIVITY) OF QUACKGRASS RHIZOME BUDS

Experiment 1: Sprouting Ability of Single-Node Quackgrass Rhizome Segments Cultured on Moist Paper, Sand, or Soil

Objective

A simple and quick method for testing the sprouting ability of excised single-node segments of quackgrass rhizomes was needed for some of the future experiments. The method described by Johnson and Buchholtz (1962), using agar for the culture medium of rhizome buds is elaborate and time consuming. It was decided to evaluate the percent sprouting of rhizome buds placed on moist germination-paper, in sand, and in soil to ascertain which of the methods is most satisfactory.

Materials and Methods

Rhizomes from nine 80-day old quackgrass plants were harvested, excised into single-node segments and divided into three groups. Each of the groups was used in triplicate for sprouting test by each of the following three methods:

a. Buds laid on a moist double-sheet germination-paper and

covered with a third sheet. Then the three sheets with the buds between were rolled up, put in a glass tray and covered with a piece of Handi-Wrap plastic film to prevent drying.

b. Buds planted 1/2 inch deep in a sandy loam soil.

c. Buds planted 1/2 inch deep in white sand (El Monte EI20).

For 14 days, all the containers were kept moist in an incubator maintained at a high relative humidity level and with 12 hours of light at 82°F and 12 hours of dark at 72°F. Then the percent sprouting was determined.

Results and Discussion

The sprouting percentages (Table 1) were transformed to arcsin $\sqrt{\%\ \text{sprouting}}$ and statistical analysis carried out on the transformed data. There were no significant differences in sprouting percentages among the three culture-methods used.

The germination-paper method and the conditions mentioned were used in the subsequent sprouting tests.

Experiment 2: Sprouting Ability of Excised Single-Node Rhizome Segments of Quackgrass Plants Grown in Soil or Sand Under Two Different Light Conditions

Objective

To determine whether there is any difference between the sprouting ability of single-node rhizome segments excised from

Table 1. Percent sprouting of excised quackgrass rhizome buds cultured in three different ways.

Excised buds cultured	Percent Sprouting				Transformed means
	I	II	III	Avg.	
In soil	83	76	36	65	54.4
In sand	16	30	50	32	33.7
On paper	48	25	69	47	43.4

Analysis of Variance

Arcsin $\sqrt{\%\ \text{sprouting}}$

Source	df	MS	F
Treatments	2	314.85	1.87 NS
Error	6	168.37	

quackgrass plants grown in soil or in sand, with or without supplemental light, in the greenhouse.

Materials and Methods

The rhizomes from 80-day old quackgrass plants which had been grown under the following three conditions were harvested and segmented into single buds:

a. Plants grown in soil in the greenhouse with natural plus supplemental light.

b. Plants grown as above, but without supplemental light.

c. Plants grown in sand with natural plus supplemental light.

The germinating-paper method described before, was used for testing the percent sprouting of the buds. There were three replications per treatment.

Results and Discussion

The sprouting percentages (Table 2) were transformed to arcsin $\sqrt{\%\ \text{sprouting}}$ and statistical analysis was run on the transformed data.

The rhizome segments from the plants grown without supplemental light showed significantly lower sprouting ability than those from plants receiving natural plus supplemental light. No difference in bud sprouting ability was noticed between the rhizomes from plants

Table 2. Percent sprouting of single-node rhizome segments excised from quackgrass plants grown under three different conditions.

Growth conditions in greenhouse	Percent sprouting				Transformed means
	I	II	III	Avg.	
Grown in soil with natural light	38	19	27	28	31.7**
Grown in soil with natural plus supplemental light	42	61	53	52	46.2
Grown in sand with natural plus supplemental light	64	59	56	60	50.6

LSD (0.05) = 9.9

Analysis of Variance

Arcsin $\sqrt{\%\ \text{sprouting}}$

Source	df	MS	F
Treatments	2	292.0	11.85***
Error	6	24.6	

***Significant at 1% level

grown in sand or in soil, provided that they had received supplemental light.

Experiment 3: The Effects of Soil Moisture Levels on Sprouting Ability of Quackgrass Rhizome Buds

Objective

To determine what effect, if any, variations in soil moisture levels have on the sprouting of the rhizome buds.

Materials and Methods

A four-replicated 4 x 4 factorial experiment was set up as follows:

a. Amount of water added to each pot: Twice a week, 20, 40, 80, or 160 ml of water were added to each potted quackgrass plant.

b. Duration of time from the start of the water-regimes to the time the rhizomes were harvested: Rhizomes were harvested and sprouting tests were conducted on the excised single node segments at 0, 7, 14, and 21 days after the beginning of the watering regimes.

Three-month old quackgrass plants were used for this experiment.

Results and Discussion

Analysis of variance was performed on the transformed sprouting percentages (Table 3).

At each of the four harvest dates, there were no significant differences in sprouting percentages of the rhizome buds from the plants receiving 40, 80, or 160 ml of water twice a week. However, when 20 ml of water was added to each pot twice a week the sprouting percentages of the rhizome buds were reduced significantly in comparison with other watering regimes. For the plants receiving 20 ml water twice a week, the reduction in the sprouting ability became progressively more severe at later harvest dates.

Statistical tests showed no significant difference due to the duration of the watering regimes, from 0 to 21 days, except for the 20 ml water treatment as noted above. The interaction between the amount and duration of the watering regimes was significant only for the lowest watering regime.

In summary, only the quackgrass plants subjected to a severe water stress, to the point where the foliage dried up completely and the rhizomes became dehydrated, showed reduction in the sprouting ability of the rhizome buds. This reduction in the sprouting ability of the buds cannot be termed a true increase in the dormancy of the buds due to soil moisture stress. Physical damage to the buds through

Table 3. Percent sprouting of the single-node rhizome segments harvested at different time intervals from quackgrass plants subjected to four different watering regimes.

Ml of water added to plants twice a week	Days from start of watering regimes to harvest	Percent sprouting				Transformed means
		I	II	III	IV	
20	0	49	84	50	49	50.0
	7	27	72	69	51	47.8
	14	16	55	27	50	43.9
	21	0	53	2	12	18.8**
Mean						40.1**
40	0	50	62	80	62	53.0
	7	49	71	71	60	52.5
	14	50	29	68	67	47.0
	21	53	68	70	68	53.7
Mean						51.6
80	0	59	56	58	36	46.3
	7	28	76	83	48	50.5
	14	76	66	67	66	56.0
	21	41	76	62	84	54.7
Mean						51.9
160	0	47	49	87	53	50.8
	7	32	38	85	46	45.6
	14	38	78	40	54	46.6
	21	65	47	67	68	51.9
Mean						48.7

LSD (0.05) for m/water added = 7.2
LSD (0.05) for m/water x days = 14.4

Analysis of Variance

Arcsin $\sqrt{\%\ \text{sprouting}}$

Source	df	MS	F
Block	3	387.9	3.74**
Ml water added	3	481.8	4.65***
Days from start	3	104.0	1.00 NS
Ml water x days	9	295.2	2.84**
Error	45	103.6	

***Significant at 1% level
**Significant at 5% level

excessive dehydration was in all likelihood the cause of their low sprouting ability.

Experiment 4: The Effects of Low and High Temperature Levels on the Growth of Quackgrass Shoots and the Sprouting Ability of Rhizome Buds

Objectives

To study the effects of prolonged exposure of quackgrass plants to two temperature levels on growth of aerial shoots and rhizome buds.

To determine whether production of new shoots after removal of the old ones has any effect on the seasonal dormancy of the rhizome buds.

To investigate the effects of low and high temperature levels on rhizome-bud dormancy.

Materials and Methods

The foliage of 100 uniform four-month old quackgrass plants was removed at soil level. Half the plants were put in one growth chamber and received a 16-hour light period at 45°F and an eight-hour dark period at 35°F. The other half of the plants were kept in another identical growth chamber maintained at 70°F during 16 hours of light and at 60°F for the remaining eight hours of darkness. The

light intensity in the two chambers was the same.

Every ten days, five plants from each growth chamber were taken out and the dry weight of aerial regrowth, the total number of rhizome buds, and the percent sprouting of the single-node rhizome segments were determined for each plant.

Results and Discussion

The foliage regrowth increased rapidly for the first 40 to 50 days after removal of the old shoots (Table 4). Later the regrowth rate slowed down and during the last 20 to 30 days it tapered off completely. Dry weights of foliage regrowth from the plants at the high temperature level were moderately higher than those of the plants kept at the low temperature level.

The number of rhizome buds per plant slowly increased during the 100-day period. There was no significant difference between the two temperature levels in regard to the formation of new rhizome buds.

The percent sprouting for the high temperature plants drastically decreased from about 65% at the start of the experiment to a low level of about 20% at the end. In contrast, over the 100-day period, the percent sprouting for the low temperature plants increased from about 60% to about 75%.

In Wisconsin, Johnson and Buchholtz (1962) showed that the

Table 4. The influence of two temperature levels over a 100-day period on foliage regrowth, number of rhizome buds and percent sprouting of rhizome buds of quackgrass plants after initial removal of the old shoots.

	Average per plant[1/]								
	Regrowth dry weight (g)			No. of rhizome buds			Arcsine transformed % sprouting		
Days after removal of the old shoots	High temp. 70°-60° F	Low temp. 45°-35° F	Avg.	High temp. 70°-60° F	Low temp. 45°-35° F	Avg.	High temp. 70°-60° F	Low temp. 45°-35° F	Avg.
10	0.03	0.04	0.03	83	67	75	54.0	53.0	53.5
20	0.27	0.25	0.26	61	76	68	54.7	49.4	52.1
30	0.57	0.48	0.52	75	87	81	49.2	61.4	55.3
40	1.27	0.82	1.04	89	80	84	45.8	67.8	56.8
50	1.40	0.90	1.15	100	97	99	33.3	48.4	40.9
60	1.60	1.60	1.57	91	90	91	27.1	59.7	43.4
70	1.90	1.40	1.63	88	79	83	35.9	71.6	53.8
80	1.80	1.50	1.67	110	85	98	23.6	60.0	41.8
90	1.80	1.50	1.67	116	90	103	31.4	61.4	46.4
100	1.60	1.70	1.68	113	106	110	24.1	62.2	43.1
Means	1.22	1.03		93	86		37.9	59.5	
LSD (0.05)									
Temperature	0.16			10			5.4		
Days	0.37			23			12.1		
Temp x Day	0.52			31			17.2		

[1/] Complete data are found in Appendix Table 1.

percent sprouting of the rhizome buds of quackgrass plants in the field decreased from mid-April to the first of June, it stayed at a constant low level during June and it started to increase gradually from July to the end of the growing season. A satisfactory explanation of this phenomenon has not yet been proposed. It is possible that the increase in seasonal temperature from April to August may cause a reduction in percent sprouting of quackgrass rhizome buds as noticed in this experiment.

A hypothesis based on the nutritional drain of the rhizome system due to an increase in the amount of foliage produced by the plants at the high temperature level does not seem to be a valid argument for the reduction in the sprouting ability of the rhizome buds. In the last two sampling dates of this experiment, there was not much difference between the amount of foliage produced by the plants at the low and the high temperature levels. However, the percent sprouting of the rhizome buds of the low temperature plants was two to three times greater than that of the high temperature plants.

SECTION II

EFFECTS OF ETHREL ON GROWTH, MORPHOLOGY, AND REGENERATIVE CAPACITY OF QUACKGRASS AND FIELD BINDWEED PLANTS

Experiment 5: The Effects of Low Temperature Treatment of the Intact Plants and Ethrel on Sprouting Ability of Excised Quackgrass Rhizome Buds

Objectives

To observe whether a direct application of Ethrel to the excised quackgrass rhizome buds would increase their sprouting ability.

To investigate whether a short period of cold temperature imposed on the intact quackgrass plants prior to excision of the rhizome buds would enhance their sprouting capacity.

Materials and Methods

The quackgrass plants were 100 days old. The experiment was designed as a six-replicated 2 x 3 factorial to investigate the effects of two temperature treatments and three levels of Ethrel. For 15 days, 18 plants were subjected to a continuous low temperature level (50^{o}F) and a 12-hour photoperiod in a growth chamber. At the end of this period, the rhizomes from each plant were harvested and dissected into single buds. The excised buds from each of six plants were immersed separately for one hour in an aqueous solution containing 0,

100, or 1000 ppm (w/v) Ethrel. Then they were used for sprouting tests.

The rhizome buds from another 18 quackgrass plants were similarly used for sprouting tests without being subjected to the low temperature level.

Results and Discussion

Pre-exposure of the intact quackgrass plants to cold temperature ($50^{o}F$) for 15 days failed to increase the percent sprouting of the rhizome buds significantly (Table 5). In experiment 4, it was noticed that prolonged exposure of quackgrass plants to a low temperature level increased the percent sprouting of the excised rhizome buds. In the present experiment, the trend is toward an increase in the sprouting ability of the rhizome buds due to a low temperature treatment of the intact plants (Table 5).

A direct application of Ethrel to the excised quackgrass rhizome buds did not increase or decrease their sprouting ability significantly. This result is in agreement with Hull's (1970) results concerning the percent germination of Ethrel-treated single-node rhizome buds of johnsongrass. In contrast, Beasley (1969) noted a reduction in the sprouting ability of excised johnsongrass rhizome buds treated with Ethrel and Burg and Burg (1967) observed an inhibition of the growth of lateral buds of pea seedlings due to the application of ethylene gas.

Table 5. Percent sprouting of quackgrass rhizome buds as influenced by low temperature treatment of the intact plants and direct application of Ethrel to the excised buds.

Days plants subjected to low temperature (50°F)	Buds immersed for one hour in Ethrel (ppmw)	Percent sprouting						Transformed means
		I	II	III	IV	V	VI	
Zero	Zero	36	33	68	41	83	40	45.4
	100	30	35	68	74	58	30	44.5
	1000	55	57	58	38	30	39	41.9
15	Zero	56	60	71	78	68	50	53.2
	100	16	29	46	27	49	75	39.1
	1000	59	56	52	51	63	47	48.8

Analysis of Variance

Arcsin $\sqrt{\%\ \text{sprouting}}$

Source	df	MS	F
Days at low temperature	1	87.11	0.91 NS
Ethrel rate	2	167.36	1.75 NS
Days x rate	2	164.87	1.73 NS
Error	30	95.45	

The discrepancy among these observations may be due to differences in the concentrations of Ethrel or ethylene, duration of exposure, experimental methods, and plant species employed by various investigators. In the works cited, a direct application of Ethrel or ethylene gas to the excised quackgrass or johnsongrass rhizome buds did not cause an increase in the sprouting ability of these buds.

Experiment 6: The Effects of Ethrel and Low Temperature Treatment of the Harvested Rhizomes on the Sprouting Ability of Quackgrass Rhizome Buds

Objectives

To investigate the sprouting ability of single-node segments of quackgrass rhizomes subjected to a chill period.

To observe the effect of a direct application of Ethrel to the excised quackgrass rhizome buds on their sprouting ability.

Materials and Methods

The rhizomes from 24 (100-day old) quackgrass plants were harvested in one day. The rhizomes from 12 plants were used for sprouting test immediately and those from the other 12 plants were put in a refrigerator ($36^{\circ}F$) for 20 days before being tested for sprouting. Ethrel levels and method of application were identical to those of Experiment 5.

Results and Discussion

Keeping the harvested rhizomes at a low temperature level ($36^{o}F$) for 20 days reduced the sprouting ability of the buds significantly (Table 6).

Ethrel applied directly to the excised buds did not significantly promote or inhibit sprouting of the buds. This result was similar to that in Experiment 5.

Experiment 7: The Effects of Ethrel on Shoot and Rhizome Development of Quackgrass Plants Treated at Three Different Stages of Foliage Regrowth

Objectives

To investigate whether Ethrel promotes development of new shoots and rhizome branches of quackgrass plants.

To discern at what stage of foliage development Ethrel application is most effective in promoting bud growth.

To find the approximate rate of Ethrel which would be effective in inducing shoot and rhizome initiation.

To study the relative effectiveness of a single and a split application of Ethrel for promotion of foliage and bud growth.

Materials and Methods

The foliage of four-month old quackgrass plants was removed to

Table 6. Percent sprouting of quackgrass rhizome buds as influenced by low temperature treatment of the harvested rhizomes and Ethrel applied directly to the excised buds.

Days rhizomes stored at low temperature ($36^{\circ}F$)	Buds immersed for one hour in Ethrel (ppmw)	Percent sprouting				Transformed means
		I	II	III	IV	
Zero	Zero	79	65	73	75	58.8
	100	52	38	50	62	45.3
	1000	46	71	45	86	52.6
Mean						52.2**
20	Zero	61	54	51	37	45.4
	100	24	41	70	48	42.4
	1000	48	38	54	52	43.8
Mean						43.9

LSD (0.05) for days at low temperature = 6.8

Analysis of Variance

Arcsin $\sqrt{\%\ \text{sprouting}}$

Source	df	MS	F
Days at low temperature	1	414.42	6.50**
Ethrel rate	2	135.84	2.13 NS
Days x rate	2	55.65	0.87 NS
Error	18	63.76	

**Significant at 5% level

permit regrowth. The plants were sprayed with various rates of Ethrel at three subsequent stages of foliage regrowth. Six plants representing six replications were used for each treatment.

Stage 1. Regrowth was 8 to 14 inches tall and ten days old. Eighteen plants were sprayed with 0, 0.65, or 1.30 lb Ethrel/A as a single application. Another 12 plants received 0.65 or 1.30 lb Ethrel/A initially and the same amount again a week later.

Stage 2. Regrowth was 18 to 26 inches tall and 30 days old. The plants treated as in Stage 1.

Stage 3. Regrowth was 24 to 32 inches tall and 50 days old. The plants treated as in Stage 1.

Before applying Ethrel, the number of regrowth shoots per plant was recorded. Six weeks after the first Ethrel application the number of shoots of each plant was counted, the foliage was removed, and its dry weight determined. Roots were separated from the rhizomes and discarded. The number of rhizome growing points and the dry weight of the rhizomes were also recorded.

Results and Discussion

Plants treated with Ethrel developed long, rhizome-like aerial shoots having minute scaly leaves and short internodes. Hereafter these shoots will be called "ethrel shoots" to distinguish them from normal shoots (Table 7). There were indications, later confirmed in

Table 7. The effects of Ethrel on shoot and rhizome development of quackgrass plants treated at three stages of foliage regrowth development.

Foliage regrowth age at treatment days	Single vs split application	Ethrel rate lb/A	Average of six replications[1/]					
				Six weeks after Ethrel application				
			No. of shoots at treatment	Total no. of shoots	No. of shoots due to Ethrel	No. of rhizome growing points	Foliage DW g	Rhizome DW g
10	Single	Zero	4.2	5.3	0.0	11.3	2.0	2.0
		0.65	5.0	5.8	1.2	6.0	2.0	1.7
		1.30	4.3	4.8	1.2	4.7	1.7	1.8
	Split	1.30	4.0	8.5	5.7	3.3	1.6	1.8
		2.60	3.8	11.5	9.3	5.5	0.8	1.5
Mean				7.2		6.2	1.6	1.8
30	Single	Zero	4.8	5.7	0.0	8.0	2.4	2.4
		0.65	4.5	8.8	4.3	25.2	1.3	2.7
		1.30	5.7	9.5	4.7	20.5	1.3	2.5
	Split	1.30	5.0	10.2	6.0	18.0	1.2	2.6
		2.60	4.7	11.2	6.0	21.5	1.0	1.8
Mean				9.1		18.6	1.5	2.4
50	Single	Zero	4.8	5.3	0.0	9.0	2.7	3.0
		0.65	5.7	7.2	1.5	11.8	2.3	3.1
		1.30	4.8	7.5	2.7	10.0	2.0	2.4
	Split	1.30	6.3	8.8	2.8	13.5	2.2	3.6
		2.60	4.7	7.2	2.7	14.7	2.3	3.0
Mean				7.2		11.8	2.3	3.0
Means of Ethrel Rates								
	Single	Zero		5.4		9.4	2.4	2.5
		0.65		7.3		14.3	1.8	2.5
		1.30		7.3		11.7	1.7	2.3
	Split	1.30		9.2		11.6	1.7	2.7
		2.60		9.9		13.9	1.4	2.1
LSD (0.05) Values								
Regrowth age				1.3		1.8	0.2	0.4
Ethrel rate				1.6		2.3	0.3	0.5
Age x rate				2.8		8.1	0.5	0.9

[1/] Complete data are found in Appendix Table 2

other experiments, that the effect of Ethrel on the "ethrel shoots" would eventually wear off and normal leaves would develop on the upper part of the "ethrel shoots". But, the lower part of the "ethrel shoots" remained devoid of normal leaves. A majority of the "ethrel shoots" were tillers originating from the basal buds of the main shoots. Also, a few of the rhizome buds close to the base of the main shoots and some of the rhizome terminal points grew and emerged above ground as "ethrel shoots".

Unlike the "ethrel shoots", it was not possible to distinguish between rhizome bud growth initiated by Ethrel and those initiated without the influence of Ethrel. As a result, the number of all growing points on the rhizome was determined (Table 7).

Ethrel was effective in removing the inactivity of the rhizome buds forcing them to develop rhizome branches which stayed underground as rhizomes or bent upward and emerged above ground as "ethrel shoots". Usually more of the buds close to the rhizome-apex-end and the shoot-end of the rhizomes grew than the buds in between. Consequently, it seems that Ethrel is able to remove or suppress the inhibitory influence of apices (apical dominance) on growth of lateral buds inducing them to grow.

The number of "ethrel shoots" ranged from 1.2 to 9.3 shoots per plant for the various treatments applied (Table 7). At an equal total rate, a split application of Ethrel (1.30 lb/A) increased the number of

"ethrel shoots" by 775%, 128%, and 104% over that of a single application (1.30 lb/A) for the 10, 30, and 50-day old treated regrowth, respectively (Table 7). It appears that as plants become older, with more foliar area, split application of Ethrel becomes less effective in increasing the number of "ethrel shoots".

The total number of shoots per plant was highest for the 30-day old regrowth treated plants and it was the same for the other two stages of regrowth. Compared with the untreated plants, all rates of Ethrel significantly increased the total number of shoots per plant (Table 7). However, the two Ethrel rates applied singly (0.65 and 1.30 lb/A) were of the same order of effectiveness in promoting shoot initiation. Although the same was true for the two Ethrel rates (1.30 and 2.60 lb/A) in split application, the total number of shoots produced per plant was significantly higher for the split application treatments than for the single application of Ethrel.

As compared with the control plants, the application of Ethrel to 10, 30, and 50-day old regrowth, respectively, reduced, increased significantly, and increased slightly the number of rhizome growing points. Considering the 30-day old regrowth treated plants, treatments involving single or split application of Ethrel at 0.65 to 2.60 lb/A were generally comparable in effectiveness to promote growth of rhizome buds.

Compared with untreated plants, Ethrel application reduced the

foliage dry weight of the treated plants. In general, higher rates of Ethrel were only slightly more effective in reducing foliage dry weight. Older plants with more foliage, were less subject to reduction in foliage growth than the younger ones.

Ethrel application did not reduce rhizome dry weights.

Experiment 8: The Effects of Ethrel on Shoot and Rhizome Growth of Young Quackgrass Plants

Objective

To determine whether Ethrel applied to young quackgrass plants just starting to form new rhizomes will promote shoot growth to such an extent as to retard growth and development of rhizomes.

Materials and Methods

Ethrel at three rates, 0, 2, and 4 lb/A, was applied to young quackgrass plants which had just started to form new rhizomes. Immediately and 30 and 60 days after Ethrel application the plants were harvested. At each harvest date, the number of shoots per plant, the height of each shoot, the number of rhizome growing points, and the fresh weight of shoots and rhizomes (excluding roots) were determined.

A completely randomized design with 3 x 3 factorial arrangement was set up in the greenhouse. There were five replications and three

plants per replication for each of the treatments.

Results and Discussion

Thirty days after Ethrel application, both the two and the four pound rates approximately doubled the number of shoots per plant compared with the untreated plants (Table 8). However, 60 days after Ethrel application, plants receiving 0 or 2 lb Ethrel/A had approximately the same number of shoots; whereas the plants sprayed with four lb Ethrel/A formed about 30% more shoots per plant than the other two treatments. It seems that as the time interval between Ethrel application and harvest increased, the ability of Ethrel to induce aerial shoot growth diminished. In this respect, the effective period seems to be a function of Ethrel rate used initially, i.e. the effect of the higher Ethrel rate lasted longer than that of the lower rate.

The same trend was noted for Ethrel's ability in increasing the number of rhizome growing points per plant.

It should be noted, however, that both rates of Ethrel were able to induce rhizome bud growth only in the first 30 days after application. At 30 days after spraying, plants treated with two or four pounds Ethrel/A had three times more rhizome growing points than the untreated plants (Table 8).

Ethrel application both increased the number of shoots and

Table 8. The effects of three Ethrel rates on the number and growth of shoots and rhizomes of young quackgrass plants treated at the time of rhizome formation and harvested at three different times. (Each figure is the mean of five replications with three plants per treatment per replication[1/].)

Harvest time days after Ethrel application	Ethrel rate lb/A	No. of shoots	Height of shoots inch	No. of rhizome growing points	Foliage Fresh weight g	Rhizome Fresh weight g
Zero	0	11	177	4	8.0	0.9
	2	10	161	5	7.9	1.2
	4	10	157	5	7.7	1.4
Mean		10	165	5	7.9	1.2
30	0	12	227	11	11.4	6.6
	2	22	195	29	9.4	7.0
	4	21	194	33	9.7	6.9
Mean		18	205	24	10.2	6.8
60	0	18	288	30	14.2	19.5
	2	20	331	25	15.9	15.1
	4	27	272	33	12.3	15.0
Mean		22	297	29	14.1	16.5
Means of Ethrel Rates						
	0	14	231	15	11.2	9.0
	2	17	229	20	11.0	7.8
	4	19	208	24	9.9	7.8
LSD (0.05) Values						
Harvest time		3	96	4	1.1	1.3
Ethrel rate		3	96	4	1.1	1.3
Rate x time		6	166	8	1.9	2.2

[1/] Complete data are found in Appendix Table 3

inhibited elongation of the sprayed shoots. Consequently, the average height per shoot decreased as the result of Ethrel application. But, the total height of all shoots per plant increased during the two-month period (Table 8).

The fresh weight of rhizomes produced during the first 30 days after Ethrel application was the same for all treatments. At 60 days after Ethrel application, the untreated plants had about 30% more rhizomes by weight than the plants which had received 2 or 4 lb Ethrel/A. The foliage fresh weight increased at each of the successive harvest dates (Table 8). Ethrel application only slightly reduced foliage fresh weight.

In regard to an increase in the total number of shoots and rhizome growing points and a decrease in the foliage and rhizome fresh weights, the best treatment was an application of 4 lb Ethrel/A to the young quackgrass plants. However, even this rate of Ethrel only retarded rhizome growth, but did not completely arrest it.

Experiment 9: The Effect of Ethrel on the Distribution of Shoots, Roots, and Rhizomes Weights of Quackgrass Plants

Objectives

To measure the changes in the fresh and the dry weights of various quackgrass organs after Ethrel application to mature plants, in an effort to determine whether Ethrel is capable of shifting the growth

pattern such that more foliage is formed at the expense of underground organs.

Materials and Methods

Three-month old quackgrass plants grown in white sand were sprayed with zero or six pounds Ethrel per acre and harvested at 0, 3, and 6 weeks after spraying. At each harvest date, the number of shoots, the height of each shoot, the number of rhizome growing points and the fresh and the dry weights of leaves, stems, roots, rhizomes, and "ethrel shoots" for each plant were determined. "Ethrel shoots" are the shoots formed under the influence of Ethrel.

The experiment was conducted in the greenhouse. The design was completely randomized with a 2 x 3 factorial treatment. There were five replications and three plants per replication for each of the treatments.

Results and Discussion

Compared with the untreated plants, Ethrel application tripled the number of aerial shoots during the six-week period (Table 9). At the end of this period, Ethrel-treated plants had only about 10% more growing rhizome buds than the untreated plants. This small difference between the treated and untreated plants might be interpreted as Ethrel's ineffectiveness to promote growth of rhizome buds. Such

Table 9. The effects of two Ethrel rates on the number and the weight of various organs of quackgrass plants sprayed once and harvested at three different times.

Harvest time weeks after Ethrel application	Ethrel rate lb/A	No. of shoots	No. of rhizome growing tips	Average per three plants[1/] Fresh weights - grams					Dry weights - grams				
				Leaves	Stems	Roots	Rhizomes	"Ethrel shoots"	Leaves	Stems	Roots	Rhizomes	"Ethrel shoots"
Zero	Zero	10	13	9.9	11.5	10.2	6.3	0.0	1.9	2.5	1.1	1.2	0.0
	Six	10	17	10.2	10.9	9.7	6.6	0.0	2.0	2.2	1.3	1.3	0.0
Mean		10	15	10.0	11.2	9.9	6.5	0.0	2.0	2.4	1.2	1.2	0.0
3	Zero	28	79	16.8	16.2	10.8	19.8	0.0	4.4	4.5	1.7	4.0	0.0
	Six	50	105	9.3	11.2	7.5	24.4	6.8	2.6	3.0	1.4	3.8	1.1
Mean		39	92	13.1	13.7	9.2	22.0	3.4	3.5	3.8	1.6	3.9	0.6
6	Zero	39	90	24.1	19,5	12.3	39.1	0.0	6.8	5.8	2.7	9.1	0.0
	Six	97	99	6.0	7.4	7.5	34.1	40.6	2.6	2.1	1.7	5.7	6.5
Mean		68	94	15.0	13.5	9.0	36.6	20.3	4.7	4.0	2.2	7.4	3.2
Means of Ethrel rates													
	Zero	26	61	16.9	15.8	11.1	21.7	0.0	4.4	4.3	1.8	4.8	0.0
	Six	52	73	8.5	9.8	8.2	21.7	23.7	2.4	2.4	1.5	3.6	2.5
LSD (0.05) for some of the criteria													
Harvest time		8	11	1.1	1.4	2.2	3.7						
Ethrel rate		6	9	0.9	1.1	1.8	3.0						
Time x rate		11	16	1.5	1.9	3.1	5.2						

[1/] Complete data are found in Appendix Table 4

a conclusion is erroneous. Because, Ethrel promoted the growth of rhizome buds; but once the shoot from a growing rhizome bud emerged above the ground it was counted as an aerial shoot rather than a rhizome growing point.

The leaves collected from the untreated plants represented all the leaves originally present on the plants plus those which were formed during the six-week period. But, the leaves from the treated plants were only those present at the time of Ethrel application; and the new growth was called "ethrel shoots" and was recorded separately (Table 9). Over the six-week period, the leaf fresh weight of the untreated plants increased gradually; but that of the Ethrel-treated plants somewhat decreased. The decrease was due to partial chlorosis and dehydration of the leaves caused by Ethrel. The fresh weight of the "ethrel shoots" increased from zero at the time of Ethrel application to 6.8 grams/three plants three weeks later; and at a much quicker pace it reached to 40.6 grams/three plants in the next three weeks. Consequently, the total fresh weight of the old leaves plus the new "ethrel shoots" of the treated plants at the end of the six-week period was almost double the leaf fresh weight of the untreated plants. Dry weights of the leaves and the "ethrel shoots" followed the same pattern as the fresh weights.

Both the dry weight and the fresh weight of the stems of the untreated plants increased gradually during the six-week period. But

Ethrel caused a cessation of stem growth.

During the six-week period the root fresh weight of the untreated plants increased steadily; but that of the treated plants reduced drastically during the first three weeks and remained constant thereafter. However, the root dry weight of the treated plants did not reduce, indicating that the reduction in the fresh weight was due to dehydration of the roots. As compared with the untreated plants, Ethrel application greatly retarded root growth.

There was no significant difference between the rhizome fresh weight of the treated plants and that of the untreated plants at each harvest date. Considering the rhizome dry weight (Table 9), it is evident that Ethrel retarded accumulation of dry matter in the rhizomes from the third week to the sixth week. In other words, Ethrel caused formation of more succulent rhizomes.

In six weeks, Ethrel did not change the total fresh weight of the plants and only slightly reduced plants' dry weight.

In conclusion, it seems that Ethrel changed the metabolic activities of quackgrass plants diverting part of the plant's resources from root, rhizome, and stem formation to leaf and new shoot development. Also, the rhizomes formed by the Ethrel-treated plants were more succulent than those produced by the untreated plants.

The increase in the amount of the foliage produced by the

Ethrel-treated plants could weaken the rhizome system of the plants and provide extra surface area for the deposition of subsequently applied herbicide. In addition, the more succulent rhizomes of the Ethrel treated plants may be less resistant to frost, drought, or mechanical disturbance than the rhizomes of the untreated plants.

Experiment 10: The Effects of Ethrel and Soil Nutrient Levels on Shoot and Rhizome Bud Growth and Percent Sprouting of Excised Rhizome Buds of Quackgrass

Objectives

To investigate the effects of Ethrel on shoot growth, rhizome bud development, and sprouting ability of the rhizome buds from quackgrass plants grown under high, medium, and low soil nutrient levels. The primary objective was to determine whether a low rate of applied Ethrel in combination with medium to high rates of added soil nutrient could produce synergistic effects in promoting growth of rhizome buds.

Materials and Methods

A six-replicated 3 x 3 factorial experiment was set up in the greenhouse to investigate the objectives. Fifty-four uniform plants (four months old) were selected and randomly divided into three groups. The plants of one group received no additional nutrient.

One hundred ml of a nutrient solution containing 20 mg N + 16 mg P_2O_5 + 15 mg K_2O were added to the pot of each of the plants of the second group (medium nutrient). Each plant of the third group (high nutrient) received a level of fertilizer five times greater than the level of the medium nutrient plants. Three weeks later, the 18 plants of each group were divided into three sub-groups which were sprayed with 0, 0.5, or 1.0 lb Ethrel/A. Five weeks later the total number of shoots, the number of "ethrel shoots", the number of rhizome growing points, the foliage dry weight, and the percent sprouting of excised rhizome buds were determined.

Results and Discussion

The number of shoots due to Ethrel, the "ethrel shoots", produced by the plants at the medium or the high nutrient levels was twice that formed by the low nutrient plants (Table 10).

Compared with the plants receiving no Ethrel, the application of either 0.5 or 1.0 lb Ethrel/A to the plants at the low nutrient level did not appreciably increase the total number of shoots formed per plant (Table 10).

For the plants at the medium soil nutrient level, one-half pound Ethrel/A was ineffective in increasing the total number of shoots; but when one pound of Ethrel/A was used, the total number of shoots increased significantly over that of the untreated plants (Table

Table 10. The effects of Ethrel and soil nutrients on shoot and rhizome-bud growth and percent sprouting of excised rhizome buds of quackgrass.

Nutrient level mg nutrient added to each plant three weeks before Ethrel	Ethrel rate lb/A	Average per plant based on six replications[1/]						
			Five weeks after Ethrel application					
		No. of shoots at the time of Ethrel application	Total no. of shoots	No. of "Ethrel shoots"	No. of rhizome growing points	Foliage Dry weight g	Total no. of rhizome buds	Arcsine transformed percent sprouting
LOW	0	6.0	6.7	0	7.3	2.6	90	23.9
No nutrient	0.5	6.0	7.0	1.2	7.3	2.0	88	35.4
added	1.0	6.0	7.5	1.3	13.0	2.0	87	24.6
Mean		6.0	7.1	0.8	9.2	2.2	88	27.9
MEDIUM								
20 mg N	0	6.7	8.0	0.	5.2	3.4	82	37.7
16 mg P_2O_5	0.5	6.5	7.3	0.8	11.3	2.2	78	33.2
15 mg K_2O	1.0	6.7	11.2	4.8	11.2	2.4	87	28.7
Mean		6.6	8.8	1.9	9.2	2.7	82	33.2
HIGH								
100 mg N	0	7.7	13.0	0	13.3	3.9	74	59.6
80 mg P_2O_5	0.5	8.7	16.2	2.0	13.2	3.2	108	50.1
75 mg K_2O	1.0	7.5	12.5	3.2	18.0	3.0	121	54.2
Mean		8.0	13.9	1.7	14.8	3.4	101	54.7
Means of Ethrel rates								
	0	6.8	9.2	0.0	8.6	3.3	82	40.4
	0.5	7.1	10.2	1.3	10.6	2.5	91	39.5
	1.0	6.7	10.4	3.1	14.1	2.4	98	35.9
LSD (0.05) Values for some of the criteria								
Nutrient level			1.4		3.5	0.25	17	7.4
Ethrel rate			1.4		3.5	0.25	17	7.4
Nutrient x Ethrel			2.4		6.1	0.43	29	12.8

[1/] Complete data are found in Appendix Table 5

10). At the high nutrient level, however, the application of 0.5 lb Ethrel/A produced the highest number of shoots per plant.

The number of rhizome growing points per plant increased as the level of soil nutrient or the rate of Ethrel application increased. The interaction between nutrient levels and Ethrel rates was insignificant. This indicates that the effect of Ethrel and soil nutrient in increasing the number of rhizome growing points were simply additive.

An increase in the level of soil nutrient increased the foliage dry weights of the plants. In contrast, an application of either one-half pound or one pound Ethrel/A reduced the foliage dry weights. The interaction between the soil nutrient levels and Ethrel rates was again insignificant, indicating that the effect of nutrient levels and that of the Ethrel rates on foliage dry weights were additive but in an opposite direction.

Neither nutrient levels nor Ethrel rates significantly increased the total number of rhizome buds per plant.

At all three nutrient levels, Ethrel had no significant effect on increasing the percent sprouting of the single-node rhizome segments. But, excised rhizome buds from the plants at the high nutrient level had significantly higher percent sprouting than those obtained from the plants at the low or the medium soil nutrient levels.

If the total number of shoots and the number of rhizome growing

points for each of the treatments in Table 10 are added up, the magnitude of the sum of the two numbers is an overall indication of the ability of each of the treatments to induce growth of quackgrass rhizome buds. Considering these calculated sums, it was noted that there was no significant interaction between Ethrel rates and nutrient levels. But there was an additive effect between the two main factors, especially at the medium nutrient level.

In summary, both Ethrel and soil nutrients, especially nitrogen, can induce quackgrass rhizome buds to grow, developing into either aerial shoots or rhizome branches. Furthermore, Ethrel and soil nutrient, each at the levels used in this experiment, increased the number of growing rhizome buds additively rather than synergistically.

Ethrel applied to the intact plants was incapable of increasing the percent sprouting of the excised rhizome buds of the treated plants. But, the rhizome buds from the high nutrient plants showed a significantly higher percent sprouting than those obtained from the low or the medium nutrient level plants.

Experiment 11: The Effects of Three Ethrel Rates on Foliage Growth and Regeneration Capacity of Field Bindweed

Objectives

To investigate the effects of Ethrel on a perennial broadleaf

weed in contrast to a perennial grass weed (quackgrass).

To obtain some preliminary information concerning the feasibility of using Ethrel as an aid to the control of field bindweed by studying the effects of Ethrel on shoot development and root regeneration capacity of the weed.

Materials and Methods

Field bindweed plants, 100 days old and trained to climb cane poles, were sprayed with zero, one, or five pounds Ethrel/A. Prior to spraying, the number of branches of the main shoot and the number of secondary shoots arising from the rootstock of each plant were recorded. Six weeks after Ethrel application, the number and the dry weight of the living secondary shoots and the living branches of the main shoot were determined. The rootstock of each plant was cleaned from soil, cut into two-inch segments, replanted one-half inch deep in fresh soil, and left on a lighted greenhouse bench to regenerate. Four weeks after replanting, the number and the dry weight of regrown shoots were determined.

There were six replications per treatment and four plants per replication per treatment.

Results and Discussion

Field bindweed was much more sensitive to Ethrel than

quackgrass. Within three to four days after Ethrel application, field bindweed leaves started to turn yellow and soon they became completely chlorotic and started to shed. The plants were thoroughly defoliated in 10 to 15 days. All the existing stems of the plants sprayed with Ethrel at the 5 lb/A rate and most of those receiving 1.0 lb Ethrel/A also died off (Table 11). As the result of defoliation and death of the stems, the amount of living shoots six weeks after Ethrel application was greatly reduced.

The number of secondary shoots arising from the rootstocks of the plants treated with 1.0 lb Ethrel/A was about three times greater than the number of the secondary shoots from the untreated plants or the plants treated with 5 lb Ethrel/A. It seems, then, that Ethrel, especially at 1.0 lb/A, stimulated the rootstocks to form many shoot buds which emerged and developed into the secondary shoots. However, these shoots, having been developed under Ethrel influence, had very minute leaves and very short internodes--an effect very similar to that observed on the Ethrel treated quackgrass plants.

Four weeks after the segmented rootstocks were replanted, the number of regrowth shoots from the plants treated with 1.0 lb Ethrel/A was three times more than that produced by the untreated plants and one and one-half times more than the number of regrowth shoots from plants treated with 5 lb Ethrel/A (Table 11). The regrowth dry weights were 530, 330, and 110 mg per four plants for the

Table 11. The effect of three Ethrel rates on shoot growth and shoot regeneration from rootstocks of field bindweed plants.

	Average per four plants[1/]						
	At Ethrel application		Six weeks after Ethrel application			Four weeks after replanting segmented rootstock	
Ethrel rate lb/A	No. of main branch	No. of secondary branch	No. of living main branch	No. of living secondary branch	Living shoots DW g	No. of regrowth shoots	Regrowth DW 10^{-2} g
Zero	12	2	12.5	5.3	7.1	17.2	10.7
1	13	3	4.5	17.8	1.1	60.3	53.0
5	13	2	0.0	7.0	0.1	38.8	33.2
LSD (0.05) for some of the criteria							
Ethrel rates			1.8	5.2	0.3	11.4	10.6

[1/] Complete data are found in Appendix Table 6

plants treated with 1.0, 5.0, and zero lb Ethrel/A, respectively. As far as it could visually be determined, there was no morphological difference between the regrowth shoots of the treated and the untreated plants. However, the regrowth shoots from the replanted rootstock segments of the plants treated with 1.0 lb/A Ethrel emerged quicker and grew faster and taller than those from the untreated plants. The emergence time and the growth of the regrowth shoots were intermediate for the plants treated with 5.0 lb/A Ethrel.

When the rootstocks of the plants were being cleaned for replanting, it was noted that numerous buds along the rootstocks of the plants treated with 1.0 lb/A Ethrel had commenced growth and many of them had already produced minute shoots underground. This was not the case for the untreated plants. The number of growing buds from rootstocks was much less for the plants treated with 5 lb Ethrel/A than for those sprayed with 1.0 lb Ethrel/A. Presence of these minute shoots on the rootstocks at the time of replanting was undoubtedly responsible for quick and profuse emergence of regrowth shoots from the rootstocks of the Ethrel-treated plants--especially those treated with 1.0 lb/A Ethrel.

Ethrel caused a drastic reduction in the amount of existing foliage and at the same time forced the rootstock buds to commence growth. Consequently, Ethrel seems to have some potential as a defoliating agent, as a chemical speeding up starvation of the plants, and

as a chemical inducing the mobilization of reserves for new growth providing susceptible tissue for herbicidal eradication of field bindweed.

Experiment 12: The Effects of Several Low Rates of Ethrel on Shoot and Root Growth of Young Field Bindweed Plants

Objectives

To investigate the effects of several low rates of Ethrel on shoot and root growth of young field bindweed plants over an eight-week period.

To determine whether an application of Ethrel to young field bindweed plants could prevent or suppress root formation at the expense of shoot formation.

To determine a low rate of Ethrel which would not cause extensive defoliation and death of the treated plants. Such a low rate of Ethrel could then be used in field experiments to study the synergistic effects, if any, of Ethrel in combination with other herbicides.

Materials and Methods

Young field bindweed plants were sprayed with 0, 1/4, 1/2, 1.0, and 2.0 lb Ethrel/A. At zero, four, and eight weeks after Ethrel application eight plants of each of the Ethrel rates were harvested.

The number of the living shoots and the dry weights of the living shoots and the roots of each plant were determined.

Results and Discussion

With the exception of the untreated plants, four days after Ethrel application, all rates of Ethrel caused yellowing of the field bindweed leaves. This effect was more pronounced on the lower leaves and more severe at the higher rates of Ethrel. Most of the chlorotic leaves were eventually shed. Defoliation was slight for the lowest Ethrel rates, and it progressively became more severe as the rate of Ethrel applied was increased.

Based on these observations, even the lowest rate of applied Ethrel (1/4 lb/A) did not seem to be sufficiently low enough to be used prior to a foliar-applied herbicide in order to investigate the interaction effect of the two chemicals. Most of the translocatable foliar-applied herbicides are better absorbed and more extensively translocated by an actively growing foliage than by a partially chlorotic one. Ethrel application, however, caused slight to severe chlorosis, rapid senescence and abscission of the leaves--conditions which would hinder the absorption and translocation of a foliar-applied herbicide used subsequent to Ethrel application. However, these results do not necessarily exclude a study of the simultaneous application of a herbicide plus Ethrel.

Ethrel application, especially at higher rates, killed the entire stem or stem apex of many plants. The plants with stems completely killed started new growth from the rootstocks. On plants where only the stem apex was killed, new growth originated from the auxiliary buds on the living portion of the stem.

As compared with the untreated plants, the reduction in the amount of living shoots four weeks after Ethrel application, was about 25%, 50%, and 75% for the low Ethrel rates (1/4 and 1/2 lb/A), the medium Ethrel rate (1.0 lb/A), and the high Ethrel rate (2.0 lb/A), respectively (Table 12). During the next four weeks, the difference between the amount of living shoots produced by the untreated plants and that formed by the Ethrel-treated plants narrowed considerably.

In the first four weeks subsequent to Ethrel treatment, the roots of the plants sprayed with 1.0 or 2.0 lb Ethrel/A did not grow to any extent (Table 12). Also, the amount of roots formed by the plants treated with 1/4 or 1/2 lb Ethrel/A as indicated by dry weight was reduced by about 35% compared with the amount of roots harvested from the untreated plants.

The dry weight of roots produced by the plants sprayed with 0, 1/4 or 1/2 lb Ethrel/A was the same eight weeks after treatment. During this period, root growth of the plants treated with 1.0 and 2.0 lb Ethrel/A as indicated by dry weight was respectively, 20% and 33% less than that of the untreated plants.

Table 12. The effects of five rates of Ethrel on shoot and root growth of young field bindweed plants. 1/

Time of harvest weeks after Ethrel application	Ethrel rates lb/A	Dry weight: Living shoots 10^{-2} g	Dry weight: Roots 10^{-2} g	Root/ Shoot ratios	No. of living shoots
Zero	Zero	7.6	15.8	2.0	1.0
	1/4	8.9	16.4	1.8	1.0
	1/2	10.6	15.0	1.4	1.0
	1.0	7.6	13.9	1.8	1.0
	2.0	7.5	16.4	2.0	1.0
Mean		8.4	15.5		1.0
4	Zero	16.2	41.0	2.6	2.4
	1/4	11.0	26.5	2.4	2.9
	1/2	12.4	26.6	2.2	2.8
	1.0	8.1	17.8	2.2	2.6
	2.0	3.9	16.2	4.0	1.8
Mean		10.3	25.6		2.5
8	Zero	56.4	53.8	1.0	5.2
	1/4	48.8	53.6	1.1	4.5
	1/2	47.4	51.9	1.1	6.0
	1.0	46.1	42.6	0.9	4.8
	2.0	34.8	36.2	1.0	4.2
Mean		46.7	47.6		5.0
Means of Ethrel rates					
	Zero	26.8	36.8		2.9
	1/4	22.9	32.2		2.8
	1/2	23.4	31.2		3.2
	1.0	20.6	24.8		2.8
	2.0	15.4	23.0		2.3
LSD (0.05) values					
Harvest time		4.4	4.7		0.5
Ethrel rate		5.6	6.1		0.6
Time x rate		9.8	10.6		1.1

1/ Complete data are found in Appendix Table 7
Each figure is an average of eight replications

In conclusion, the effect of Ethrel on growth of young field bindweed plants' roots and shoots was temporary and very similar to effects caused by mechanical defoliation or mowing. The higher the concentration of Ethrel applied, the more severe was the initial shock to the plants. Depending on the extent of defoliation and death of the stems which was related to the amount of Ethrel applied, root growth was reduced or stopped over a period of time. In this period the resources of the plants were mainly being used for foliage production. Later, both roots and shoots proceeded to grow. Eight weeks after Ethrel application, the plants treated with 1.0 or 2.0 lb Ethrel/A still had an appreciably lower amount of roots and shoots than the untreated plants.

SECTION III

EFFECTS OF ETHREL IN COMBINATION WITH AMITROL-T OR DALAPON ON GROWTH AND REGENERATIVE CAPACITY OF QUACKGRASS PLANTS

Experiment 13: The Influence of Nutrient Stress, Pre-Treatment with Ethrel and Subsequent Application of Amitrol-T on the Growth and Regeneration Capacity of Quackgrass Plants

Objectives

To investigate the effects of pre-treatment with Ethrel and subsequent application of amitrol-T on the growth of shoots and rhizome buds and the regeneration capacity of the segmented rhizomes of quackgrass plants.

To compare the effects of the treatments on two groups of quackgrass plants, one group growing at a normal level of vigor and the second group growing at a sub-normal level of vigor.

To determine whether an application of Ethrel to quackgrass plants would enhance the action of amitrol-T applied to the same plants three weeks later.

Materials and Methods

Forty-eight mature, well-developed, potted quackgrass plants were divided randomly into two groups. For eight weeks, the plants

of one of the two groups did not receive any fertilizer (low vigor plants), thus being kept under a nutrient stress condition. The plants of the second group were given just enough fertilizer to keep them at a normal level of vigor (normal vigor plants).

At the end of the eight-week period, Ethrel at 0, 1.5, or 2.5 lb/A was applied to each one-third of the normal and low vigor plants. Three weeks later, amitrol-T at 0 or 1/2 lb/A was applied to each of four plants. This resulted in a 2 x 3 x 2 factorial treatment design.

Seven weeks after amitrol-T application, the dry weight of shoots was determined. The rhizomes from each plant were cut into two-inch segments and the segments were replanted one inch deep in fresh soil. Eight weeks after replanting, the dry weight of regrowth was determined.

Results and Discussion

The number of "ethrel shoots" per plant was recorded three weeks after Ethrel application. The plants maintained at the normal vigor level formed significantly more "ethrel shoots" than those kept under the nutrient stress condition, the low vigor plants (Table 13). There was a significant interaction between the Ethrel rates and the plant's vigor. The number of "ethrel shoots" produced by the normal vigor plants was statistically the same as that formed by the low vigor plants when 1.25 lb of Ethrel/A was used. Increasing the rate of

Table 13. The influence of pretreatment with Ethrel and subsequent application of Amitrol-T on the growth of shoots and rhizome buds and the regeneration capacity of the segmented rhizomes of quackgrass plants maintained at two levels of vigor.

			Average per plant based on four replications[1/]				
				Seven weeks after Amitrol-T application			
Plants' vigor	Ethrel rate lb/A	Amitrol-T applied three weeks after Ethrel Lbai/A	No. of "Ethrel shoots" at Amitrol-T application	No. of "Ethrel shoots"	No. of rhizome growing points	Foliage dry weight g	Regrowth dry weight 8 weeks after replanting rhizomes 10^{-2} g
Normal	Zero	Zero	0.0	0.0	7.5	2.1ab	18.8
		1/2	0.0	0.0	11.2	2.0ab	17.5
	1.25	Zero	1.0	2.0	16.0	1.9bc	15.0
		1/2	1.5	1.5	13.2	1.0d	15.8
	2.50	Zero	3.0	5.0	15.0	2.1ab	12.5
		1/2	1.8	2.2	14.0	1.1d	16.0
Low	Zero	Zero	0.0	0.0	was not	2.5a	9.5
		1/2	0.0	0.0	determined	1.6b	12.8
	1.25	Zero	0.5	1.2	"	1.8b	7.5
		1/2	1.2	1.2	"	1.8b	14.0
	2.50	Zero	0.8	2.2	"	1.6b	8.5
		1/2	0.5	0.5	"	1.4cd	14.2
Means for:							
Vigor:	Normal		1.2a	1.8a		1.7	16.0a
	Low		0.5b	0.9b		1.8	11.1b
Ethrel:	0		0.0c	0.0c		2.0a	14.6
	1.25		1.1a	1.5b		1.6b	13.1
	2.50		1.5a	2.5a		1.5b	12.9
Amitrol-T:	0		0.9	1.8a		2.0a	12.0b
	1/2		0.8	0.9b		1.5b	15.1a

[1/] Means designated with different letters are significantly different at the 5% level; where no letters are used, the "F" test was not significant. Complete data are found in Appendix Table 8

applied Ethrel from 1.25 lb/A to 2.50 lb/A did not increase the number of "ethrel shoots" developed by the low vigor plants, but it doubled that of the normal vigor plants. These results indicate that it is not possible to obtain a higher number of "ethrel shoots" just by applying more Ethrel to the plants. The maximum number of "ethrel shoots" which could be obtained is limited both by the rate of Ethrel and the vigor of the plants which depends on the nutrient status of the soil.

Seven weeks after amitrol-T application, all the three factors studied, vigor, Ethrel rates, and amitrol-T, significantly influenced the number of "ethrel shoots" produced per plant (Table 13). Plants receiving no amitrol-T doubled their number of "ethrel shoots" in the seven-week period; whereas those sprayed with 1/2 lb amitrol-T/A ceased to form any new "ethrel shoots" in the same period. Also the growth of "ethrel shoots" which had already been formed at the time of amitrol-T application was stopped. Since amitrol-T inhibits photosynthesis, it is evident that the development of "ethrel shoots" is not only dependent on the vigor of the plants at the time of Ethrel application, but also it depends on a continuous supply of photosynthetic products from a vigorously growing plant.

The foliage dry weight of the plants was reduced significantly by amitrol-T or Ethrel application. The interaction among plants' vigor, Ethrel rates, and amitrol-T was significant. The greatest reduction

in the foliage dry weight occurred when normal vigor plants were sprayed with a combination of Ethrel (1.25 or 2.50 lb/A) plus 1/2 lb/A amitrol-T (Table 13). On the other hand, the normal vigor plants which received no Ethrel or amitrol-T generally produced the highest foliage dry weight. It seems that the Ethrel plus amitrol-T combination treatments were more effective in reducing foliage dry weight of the normal vigor plants than that of the low vigor plants. More vigorous plants probably absorbed and translocated a greater portion of the applied chemicals than the less vigorous plants, thus were more severely injured.

The regrowth dry weight from the rhizome segments of the more vigorous plants was higher than that produced by the replanted rhizome segments of the less vigorous plants. The rhizome from the Ethrel-treated plants produced slightly, but not significantly, less regrowth than the untreated plants. A surprising result was that with or without Ethrel the rhizomes from the amitrol-T-treated plants, especially those at the low level of vigor, produced more regrowth dry weight than the plants receiving no amitrol-T (Table 13).

Experiment 14: The Effects of Initial Ethrel Treatment and Subsequent Amitrol-T or Dalapon Application to Quackgrass Plants on the Regeneration Ability of the Rhizomes

Objectives

To determine whether an initial application of Ethrel to quackgrass plants would enhance the effectiveness of subsequently applied amitrol-T or dalapon in reducing the regeneration ability of the rhizomes.

Materials and Methods

Ethrel at 0, 3, or 6 lbs/A was applied to well-developed potted quackgrass plants. Ten days later, amitrol-T (3 lb a.i./A) or dalapon (9 lb a.e./A) was applied to one-third of each group of the Ethrel-treated plants and the remaining one-third of the plants receiving no herbicide. The experimental design was completely randomized with a 3 x 3 factorial treatment arrangement. There were five replications and three plants per replication per treatment.

Five weeks after herbicide application, the rhizomes from each plant were cut into two-inch pieces and replanted in fresh soil to determine regrowth capacity of the rhizomes. One month after replanting, the number and the dry weight of the regrowth shoots were determined.

Results and Discussion

When no herbicide was used, the application of Ethrel at 3 lb/A increased the number and the dry weight of the regrowth shoots (Table 14). Increasing the amount of applied Ethrel from 3 lb/A to 6 lb/A did not cause any further increase in the number or the dry weight of the regrowth from the replanted rhizome segments. Ethrel application initiated growth of many quackgrass rhizome buds during the eight-week period prior to the replanting of the rhizome segments. Once these segments were planted, more of their buds than those of the plants not treated with Ethrel were primed to grow and they did quickly emerge. The increase in the dry weight of the regrowth shoots from the Ethrel-treated plants over that of the untreated plants was due to an increase in the number of regrowth shoots in the former case.

The application of amitrol-T (3 lb/A) alone reduced the number and the dry weight of regrowth shoots to the same degree as it was accomplished through the application of amitrol-T plus Ethrel. Stated in other words, pretreating quackgrass plants with Ethrel did not significantly increase the effectiveness of amitrol-T applied subsequently. It should be noted, however, that the rhizomes from a certain number of the amitrol-T-treated plants did not produce any regrowth (Table 14). The failure percentages were 53% for amitrol-T

Table 14. The effects of initial Ethrel treatment and subsequent application of Amitrol-T or dalapon on the number and the dry weight of the regrowth shoots produced by the segmented quackgrass rhizomes one month after replanting.

		Total per three plants					
		No herbicide		Dalapon 9 lb a.e./A		Amitrol-T 3 lb a.i./A[1/]	
Ethrel rate lb/A	Rep.	No. of regrowth shoots	Regrowth dry weight 10^{-2} g	No. of regrowth shoots	Regrowth dry weight 10^{-2} g	No. of regrowth shoots	Regrowth dry weight 10^{-2} g
Zero	I	22	8	24	20	6	2
	II	20	14	30	32	8	5
	III	20	8	31	29	1	1
	IV	34	10	55	74	5	2
	V	18	5	40	30	1	1
	Avg.	22.8	9.0	36.0	37.0	3.6	2.8
3	I	16	14	42	42	0	0
	II	28	20	57	58	7	4
	III	42	12	7	8	5	3
	IV	46	12	40	50	5	1
	V	53	13	43	42	2	1
	Avg.	37.0	14.2	37.8	39.8	3.2	2.4
6	I	15	19	22	24	0	0
	II	40	21	20	25	6	3
	III	29	14	28	34	0	0
	IV	59	17	54	54	0	0
	V	40	4	12	24	7	2
	Avg.	36.6	15.0	27.2	32.2	2.6	1.0
Herbicide means:		32.1	12.7	33.7	36.3	3.1	2.1
Ethrel means:							
	Zero	20.8	16.3				
	3	26.1	18.8				
	6	22.1	16.1				

[1/] Dalapon and Amitrol-T were applied 10 days after Ethrel application.

ANOV - No. of Regrowth Shoots

Source	df	MS	F
Ethrel rate	2	112.5	0.79 NS
Herbicides	2	4449.8	31.25***
Ethrel x herb.	4	190.4	1.34 NS
Error	36	142.4	

LSD (0.05) Herbicides = 8.7 shoots

***Significant at the 1% level

ANOV - Regrowth Dry Weight

Source	df	MS	F
Ethrel rate	2	34.8	0.29 NS
Herbicides	2	4612.4	38.58***
Ethrel x herb.	4	48.3	0.40 NS
Error	36	119.6	

LSD (0.05) Herbicides = 8.1 x 10^{-2} g

***Significant at the 1% level

alone, 67% for amitrol-T plus three pounds Ethrel/A, and 80% for amitrol-T plus 6 lb Ethrel/A.

Dalapon was much less effective than amitrol-T in reducing regrowth potential of the treated quackgrass rhizomes. With or without Ethrel, the regrowth dry weights of the dalapon-treated plants were significantly higher than those obtained from the plants receiving Ethrel alone (Table 14). The regrowth shoots of the dalapon-treated plants were longer, healthier, and heavier than those produced by the rhizome segments of the plants treated with or without Ethrel or amitrol-T.

Experiment 15: The Effects of Ethrel Applied Before or After Amitrol-T or Dalapon Application on the Regenerative Ability of Quackgrass Rhizome Segments

Objective

To investigate whether an application of Ethrel before or after amitrol-T or dalapon application would enhance the effectiveness of the herbicides on quackgrass thus retarding the regenerative potential of the rhizomes.

Materials and Methods

Two identical experiments were set up. One for the Ethrel plus amitrol-T treatments and the second for the Ethrel plus dalapon

treatments. In each experiment, Ethrel at 0, 3, or 6 lb/A was applied to well-developed quackgrass plants two weeks before, one week before, two hours before, or one week after the application of amitrol-T (3 lb a.i./A) or dalapon (7.5 lb a.e./A). All amitrol-T and dalapon treatments were applied at one time. The time of Ethrel applications was varied to obtain the desired time intervals between Ethrel and herbicide applications.

Six weeks after the application of the herbicides, the rhizome system of each plant was cut into two-inch segments and the pieces replanted one inch deep in fresh soil. The dry weight of regrowth shoots was determined three months after replanting the rhizome pieces.

Results and Discussion

The application of amitrol-T (3 lb a.i./A) alone completely inhibited regrowth from the rhizome systems of 30% of the treated plants (Table 15). However, the rhizome segments of 60% of the plants treated with amitrol-T plus Ethrel (3 lb/A) failed to form any regrowth. Plants receiving amitrol-T plus six lb Ethrel/A had 44% regrowth failure. As it was noted in Experiment 14, the treatment combinations involving amitrol-T plus Ethrel were more effective in completely inhibiting regrowth of the treated plants than the treatments with amitrol-T alone. But in the present experiment,

Table 15. The effects of Ethrel and Amitrol-T applied to quackgrass plants on the regrowth dry weight produced by the replanted rhizome pieces of the treated plants.

Ethrel rate lb/A	Time of Ethrel application in relation to the time of Amitrol-T (3 lb a. i. /A) application	Regrowth dry weight (10^{-4} g) three months after replanting the segmented rhizomes of the treated plants												
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Avg.
Zero	Two weeks before Amitrol-T	44	33	40	189	185	541	61	0	259	77	336	16	148
	One week " "	245	74	217	25	180	49	0	0	0	105	102	99	91
	Two hours " "	0	51	0	225	218	47	0	324	0	231	110	127	111
	One week after "	446	0	0	69	400	86	262	122	0	0	0	0	115
Mean														116
3	Two weeks before Amitrol-T	333	62	0	0	0	0	0	0	0	62	0	0	38
	One week " "	266	0	0	63	103	0	0	203	0	0	83	182	75
	Two hours " "	318	0	55	539	168	0	0	0	0	182	66	62	116
	One week after "	0	0	454	106	0	0	0	153	0	0	0	290	84
Mean														78
6	Two weeks before Amitrol-T	76	0	0	0	178	126	0	0	217	0	120	85	67
	One week " "	0	0	303	109	0	0	102	100	90	0	0	0	59
	Two hours " "	0	0	23	0	61	36	164	75	168	0	0	82	51
	One week after "	130	55	300	18	0	0	409	249	26	0	491	54	144
Mean														80

ANOV - Dry weight of Regrowth

Source	df	MS	F
Block	11	15,092.2	0.99 NS
Ethrel rate	2	22,461.5	1.47 NS
Time of Ethrel appl.	3	10,194.5	0.67 NS
Ethrel x time	6	15,263.2	1.85*
Error	121		

*Significant at the 10% level

LSD (0.10) for Ethrel x time: 83×10^{-4} g

Means for Time of Ethrel Application:

Two weeks before Amitrol-T	84×10^{-4} g
One week " "	75×10^{-4} g
Two hours " "	92×10^{-4} g
One week after "	114×10^{-4} g

increasing the amount of applied Ethrel from three lb/A to six lb/A did not result in more plants failing to produce regrowth whereas in Experiment 14 it did.

For reducing the amount of regrowth dry weight produced by the replanted rhizome segments, treating quackgrass plants with Ethrel before amitrol-T application was somewhat more effective than applying Ethrel one week after amitrol-T.

When compared with amitrol-T, dalapon was much less effective in reducing the amount of regrowth dry weight produced by the rhizome segments of the treated plants (Tables 15 and 16).

Similar to the results obtained in Experiment 14, the rhizomes from the plants treated with dalapon and Ethrel, especially at the highest rate, produced more regrowth dry weight than plants treated with dalapon alone (Table 16).

Whether Ethrel was applied before or after dalapon, it did not increase the effectiveness of dalapon in reducing the regrowth dry weight of the rhizome segments.

Table 16. The effects of Ethrel and dalapon applied to quackgrass plants on the regrowth dry weight produced by the replanted rhizome pices of the treated plants.

Ethrel rate lb/A	Time of Ethrel application in relation to the time of dalapon (7.5 lb a.e./A application)	Regrowth dry weight (10^{-2} g) three months after replanting the segmented rhizomes of the treated plants												
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Avg.
Zero	Two weeks before dalapon	23	13	13	13	9	14	11	10	20	14	8	8	13
	One week " "	38	12	8	11	13	6	9	15	13	14	9	7	13
	Two hours " "	18	11	16	23	9	25	9	15	15	9	12	10	14
	One week after "	30	9	20	21	9	18	11	14	9	7	29	13	16
Mean														14
3	Two weeks before dalapon	3	11	16	11	12	14	6	13	7	17	32	8	12
	One week " "	18	13	27	12	12	15	25	16	22	26	37	29	21
	Two hours " "	11	8	11	12	18	29	10	15	6	16	14	15	14
	One week after "	12	16	21	9	11	6	10	14	2	15	24	14	13
Mean														15
6	Two weeks before dalapon	17	15	17	16	9	15	33	16	5	25	14	29	18
	One week " "	25	22	14	19	22	9	13	8	18	25	28	8	18
	Two hours " "	21	11	25	21	24	23	16	21	18	23	18	19	20
	One week after "	12	11	15	12	18	19	11	18	13	11	38	15	16
Mean														18

ANOV - Dry Weight of Regrowth

Source	df	MS	F
Block	11	91.10	2.16**
Ethrel rate	2	185.36	4.39**
Time of dalapon appl.	3	55.65	1.32 NS
Ethrel x time	6	96.23	2.28**
Error	121	42.25	

**Significant at the 5% level

LSD (0.05) for Ethrel rate: 2.6×10^{-2} g

LSD (0.05) for Ethrel x time: 5.2×10^{-2} g

Means for Time of Ethrel Application:

Two weeks before Amitrol-T	14×10^{-2} g
One week " "	17×10^{-2} g
Two hours " "	16×10^{-2} g
One week after "	15×10^{-2} g

SUMMARY AND CONCLUSIONS

Non-Chemical Factors Influencing the Sprouting Ability of Quackgrass Rhizome Buds

Temperature

The foliage regrowth rate of quackgrass plants kept for 100 days at a high air temperature (70°F day and 60°F night) was moderately higher than that of similar plants growing at a low air temperature (45°F day and 35°F night).

The percent sprouting of the single-node rhizome buds excised from the plants at the high air temperature gradually but steadily decreased during the 100-day period. Concurrently, the percent sprouting of the rhizome buds of the plants at the low air temperature increased moderately.

Soil Moisture

The percent sprouting of the single-node rhizome buds of quackgrass plants subjected to a severe water stress (20 ml water per plant twice a week) for 21 days decreased drastically. The single-node rhizome buds of quackgrass plants receiving 40 ml or more water per plant twice a week did not lose their ability to sprout.

Supplemental Light

The percent sprouting of the single-node rhizome buds of quackgrass plants growing in a greenhouse without supplemental light was much lower than that of similar plants receiving supplemental light (700 foot-candles) in addition to natural light.

Effects of Ethrel on Growth, Morphology, and Regeneration Capacity of Quackgrass Plants

Foliage Present at the Time of Spraying

Spraying quackgrass plants with Ethrel produced slight to moderate chlorosis of the leaves, caused partial dehydration of the foliage and suppressed or inhibited elongation of existing shoots. The higher the rates of Ethrel applied, the more severe were the symptoms.

Growth Initiation of the Vegetative Buds

Ethrel applied to the intact well-developed quackgrass plants was very effective in removing the inactivity of the underground vegetative buds and inducing them to grow. Some of these growing buds remained underground and developed into rhizome branches of varying lengths. Others emerged and formed long, rhizome-like aerial shoots having minute scaly leaves and short internodes. These

aerial shoots were morphologically distinct and were called "ethrel shoots" to distinguish them from normal shoots.

Shoot Formation and Foliage Growth

After emergence, the "ethrel shoots" continued growing longitudinally for two to four weeks without forming any normal leaves. The influence of Ethrel on these shoots diminished gradually and normal leaves eventually developed on the upper part of the shoots. The lower part of the shoots always remained devoid of normal leaves.

Comparing the total number of shoots produced by the Ethrel treated plants with that formed by the untreated plants will provide an indication of the effectiveness of Ethrel in promoting shoot formation. Generally, low rates of Ethrel (1/2 to 1.5 lb/A) were not very effective in increasing the total number of shoots formed on each plant. Ethrel rates in the ranges of two to four lb/A and four to six lb/A approximately doubled and tripled the total number of shoots per plant, respectively.

In some experiments, the effects of Ethrel in promoting formation of aerial shoots were studied over a several week period. In these experiments, as the time interval between Ethrel application and sampling dates increased the ability of lower Ethrel rates to induce formation of additional aerial shoots diminished faster than that of the higher rates.

Soil-applied nutrients, especially nitrogen, are known to increase the number of shoots formed per plant. When Ethrel was applied to quackgrass plants growing at three soil nutrient levels, it was noted that both Ethrel and high soil nutrient level significantly increased the number of shoots formed on each plant. But the interaction between Ethrel and soil nutrient was insignificant. This indicates that the influence of Ethrel and soil nutrient in promoting shoot formation is simply additive rather than being synergistic.

Application of Ethrel to 30 day old foliage regrowth (18-26 inches tall) of well-developed quackgrass plants was more effective in increasing the number of shoots formed per plant than similar treatments applied to younger (ten days old; 8-14 inches tall) or older (50 days old; 24-32 inches tall) foliage regrowth.

At an equal total rate, a split application of Ethrel to young regrowth was more effective in increasing the number of shoots formed per plant than when the older regrowth was treated. It appeared that as the foliage became older and produced more foliar surface to intercept a greater portion of sprayed chemical, the split application of Ethrel lost its advantage over the single application.

Compared with the untreated plants, the foliage fresh weight of quackgrass plants usually decreased during the first three to four weeks after Ethrel application. This reduction was mainly due to a partial chlorosis and dehydration of the old treated leaves and a lack

of any appreciable growth of the newly formed shoots. Later, however, the new shoots grew at a relatively fast rate. This resulted in an almost doubling of the foliage fresh weight of the treated plants within six to eight weeks after Ethrel application. The changes in the foliage dry weight due to Ethrel followed the same pattern as those noted for the foliage fresh weight.

Higher rates of Ethrel (4 to 6 lb/A) usually caused more reduction in the fresh and the dry weight of foliage than did the lower rates (1 to 2 lb/A). Also, the older plants were less subject to a reduction in foliage weight than the younger ones.

Rhizome Formation and Development

It was not possible to visually separate the rhizome growing buds or branches initiated under the influence of Ethrel from those formed without Ethrel. Therefore, the total number of rhizome buds growing and remaining underground were counted in several experiments and collectively called rhizome growing points.

Ethrel, especially at higher rates, applied to intact quackgrass plants appreciably increased the number of rhizome growing points. In time-course studies, it was evident that as the time interval between Ethrel application and harvest date increased, the difference between the number of rhizome growing points from the Ethrel-treated plants and the untreated plants narrowed. As the time passed,

more of the rhizome growing points produced by the Ethrel-treated plants developed into aerial shoots rather than remaining underground. On the other hand, more of the growing rhizome buds of untreated plants did not emerge above ground and developed into rhizome branches. This fact accounted for the narrowing of the difference between the number of rhizome growing buds of the treated and the untreated plants.

The number of rhizome growing points per plant increased as the level of soil-applied nutrient or the rate of Ethrel application increased. However, the interaction between the two factors was not significant.

The increase in the number of rhizome growing points was the same whether Ethrel was applied as a single or as a split application to quackgrass plants.

Ethrel application to the 30-day old regrowth of quackgrass was more effective in increasing the number of rhizome growing points than its application to younger or older regrowth.

Application of Ethrel (4 to 6 lb/A) to mature plants slightly reduced the fresh weight of the rhizomes produced over a six-week period. The dry weight of the same rhizomes was reduced by about 35% from the third to the sixth week after Ethrel application. Consequently, Ethrel retarded the accumulation of dry matter in the rhizomes of the treated plants and caused the formation of more

succulent rhizomes. Lower rates of Ethrel (1 to 2.5 lb/A) did not cause any appreciable reduction in the rhizome dry weight.

Ethrel applied to young quackgrass plants just starting to form rhizomes did not inhibit rhizome production.

A direct application of Ethrel to the excised quackgrass rhizome buds did not increase or decrease their ability to sprout. The same was true when the intact plants were sprayed with Ethrel and later their rhizomes segmented and tested for sprouting. However, a high soil nutrient level increased the percent sprouting of the single-node rhizome buds.

Root Growth

The root fresh weight of quackgrass plants was decreased drastically from the first to the third week after Ethrel application (6 lb/A). No further reduction was noted. Root dry weight did not reduce over a six-week period. Reduction in fresh weight, therefore, was due to dehydration of the roots.

Compared with the untreated plants, however, root growth of Ethrel-treated plants completely ceased during the six weeks after treatment.

Effects of Ethrel on Growth, Morphology, and Regenerative Capacity of Field Bindweed Plants

Foliage Present at the Time of Spraying

Field bindweed was much more sensitive to Ethrel than quackgrass. This sensitivity was noted even at a low rate of 1/4 lb/A.

Within three to four days after Ethrel application, the leaves started to turn yellow and soon they became thoroughly chlorotic and started to shed. Plants were completely defoliated in 10-15 days. Depending on the rate of Ethrel applied, all or most of the existing stems also died off.

Defoliation and death of stems were slight for the low Ethrel rates (1/4 to 1/2 lb/A) and they progressively became more severe at higher Ethrel rates (1 to 5 lb/A).

Growth Initiation of Vegetative Buds and Their Development

Since Ethrel killed most of the existing shoots, many secondary shoots, originating from the rootstocks of the plants, emerged as aerial shoots. These shoots, having been developed under Ethrel influence, had very minute leaves and short internodes--an effect very similar to that observed on the Ethrel-treated quackgrass plants.

The number of the secondary shoots from Ethrel (1 lb/A) treated plants was three times that produced by the untreated plants.

Higher rates of Ethrel (5 lb/A) applied to plants reduced the number of secondary shoots. It seems, then, that Ethrel stimulated the rootstocks to initiate many shoot buds which emerged above ground.

Six weeks after Ethrel application, the rootstocks were visually examined, segmented into two-inch pieces and replanted for regrowth measurement. Observation revealed that numerous shoot buds along the rootstocks of Ethrel-treated (1 lb/A) plants had commenced growth and many of them had already formed minute shoots underground. Such development was not observed on the rootstocks of the untreated plants.

The number of regrowth shoots from the segmented rootstocks of the Ethrel-treated plants was three times more than that produced by the untreated plants. Also, the regrowth dry weight obtained from treated plants was approximately five times that produced by the untreated plants. There was no visual morphological difference between the regrowth shoots of the treated and the untreated plants.

The effect of Ethrel on shoot and root growth of young field bindweed plants was temporary and similar to mechanical defoliation or mowing. Depending on the extent of defoliation and death of the stems, the root growth was reduced or stopped over a period of time. In this period (approximately four weeks) the resources of the plants were mainly used for foliage production. Later, both roots and shoots proceeded to grow.

Effects of Ethrel on Growth and Regenerative Capacity of Quackgrass When Used as a Pretreatment to Application of Amitrol-T and Dalapon

Amitrol-T

Amitrol-T (1/2 lb a.i./A) applied to quackgrass plants three weeks after Ethrel application (1.25 to 2.50 lb/A) stopped further initiation of "ethrel shoots". Also, the growth of "ethrel shoots" already formed was stopped. Since amitrol-T inhibits photosynthesis, it is evident that the initiation and development of "ethrel shoots" greatly depends on a continuously available supply of photosynthates.

The effects of Ethrel and amitrol-T treatments applied singly and in combination on regenerative capacity of the replanted rhizome segments were not conclusive. In one experiment Ethrel application (2.5 lb/A) slightly reduced the dry weight of the regrowth shoots from the replanted rhizome segments. In a second experiment, however, the dry weight was increased due to Ethrel application (3 lb/A). Similarly, the regrowth dry weight increased due to 1/2 lb/A amitrol-T application and it decreased when 3 lb/A amitrol-T was applied.

For reducing the average regrowth dry weight, pre-treating quackgrass plants with Ethrel did not significantly increase the effectiveness of amitrol-T applied subsequently. But Ethrel in combination with amitrol-T completely inhibited regrowth from the rhizome segments of 60% to 80% of the plants; whereas regrowth failure

percentages for amitrol-T alone were 30% to 50%.

Application of Ethrel one or two weeks ahead of amitrol-T application was moderately more effective in reducing regrowth dry weight than when Ethrel was applied two hours before or one week after amitrol-T.

Dalapon

Dalapon was much less effective than amitrol-T in reducing regenerative potential of the replanted rhizome segments.

In two experiments, it was noted that the rhizomes from the plants treated with Ethrel and dalapon produced more regrowth dry weight than the plants treated with dalapon alone. The cause of this antagonistic effect between Ethrel and dalapon could not be determined with the present data.

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APPENDIX

Appendix Table 1. The influence of two temperature levels on foliage regrowth, number of rhizome buds and percent sprouting of the single-node rhizome segments of quackgrass plants over a 100 day period after initial removal of the old shoots.

		Days after removal of the old shoots														
		10			20			30			40			50		
Temperature levels	Rep	Regrowth dry weight g	No. of buds	% sprouting	Regrowth dry weight g	No. of buds	% sprouting	Regrowth dry weight g	No. of buds	% sprouting	Regrowth dry weight g	No. of buds	% sprouting	Regrowth dry weight g	No. of buds	% sprouting
High Temperature	I	0.02	71	35	0.23	72	79	0.50	83	84	1.30	89	20	0.90	103	44
70°F - Day	II	0.03	119	67	0.17	62	56	0.63	65	17	1.62	42	81	1.70	107	31
60°F - Night	III	0.02	94	77	0.28	47	66	0.38	98	65	1.18	102	71	1.10	97	6
	IV	0.05	53	68	0.32	78	70	0.63	45	69	1.22	110	59	1.60	80	19
	V	0.04	78	78	0.35	46	61	0.70	82	51	1.02	102	26	1.50	114	61
	Avg.	0.03	83	65	0.27	61	66	0.57	75	57	1.27	89	51	1.40	100	32
Low Temperature	I	0.02	104	63	0.21	122	42	0.47	82	83	1.13	93	88	1.40	98	78
45°F - Day	II	0.04	60	78	0.29	71	52	0.31	120	61	0.76	95	70	0.80	105	48
35°F - Night	III	0.04	50	78	0.23	42	81	0.30	83	84	0.69	56	95	0.50	90	70
	IV	0.05	57	84	0.23	113	49	0.60	71	75	0.53	97	84	1.10	116	78
	V	0.04	63	14	0.29	32	62	0.71	81	80	0.97	60	87	0.90	76	9
	Avg.	0.04	67	63	0.25	76	57	0.48	87	77	0.82	80	85	0.90	97	57
		Days after removal of the old shoots														
		60			70			80			90			100		
High Temperature	I	2.00	78	20	2.20	112	12	1.30	102	13	1.20	138	57	2.10	167	48
70°F - Day	II	1.40	44	16	1.10	46	13	1.80	115	33	1.70	134	8	1.30	114	12
60°F - Night	III	1.40	105	44	1.10	99	9	1.70	98	10	1.80	89	9	1.90	76	7
	IV	2.00	109	8	2.90	64	75	2.30	112	4	2.00	125	4	0.90	61	5
	V	1.10	121	21	2.20	117	76	1.90	123	28	2.30	94	79	1.90	147	22
	Avg.	1.60	91	22	1.90	88	37	1.80	110	18	1.80	116	31	1.60	113	19
Low Temperature	I	0.80	90	92	1.50	24	100	1.90	100	89	1.50	109	94	2.90	91	80
45°F - Day	II	1.40	109	47	0.80	92	80	1.30	89	27	1.10	71	55	1.10	146	79
35°F - Night	III	1.20	78	92	1.80	85	91	1.00	55	76	0.80	97	75	1.60	106	81
	IV	1.80	96	79	1.70	73	85	1.50	100	90	2.30	79	76	1.30	91	86
	V	2.60	77	51	1.00	121	89	2.00	83	83	2.00	92	79	1.80	97	59
	Avg.	1.60	90	72	1.40	79	89	1.50	85	73	1.50	90	76	1.70	106	77

Analyses of Variance for Appendix Table 1

ANOV-Regrowth Dry Weight

Source	df	MS	F
Temperature	1	0.937	5.47**
Days	9	4.068	23.75***
Temp x Days	9	0.127	0.73 NS
Error	80	0.171	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Number of Buds

Source	df	MS	F
Temperature	1	1,169.64	1.89 NS
Days	9	1,687.77	2.73***
Temp x Days	9	471.91	0.76 NS
Error	80	618.10	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Arcsin $\sqrt{\%}$ Sprouting

Source	df	MS	F
Temperature	1	11,630.54	61.39***
Days	9	379.83	2.00**
Temp x Days	9	625.62	3.30***
Error	80	189.46	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

Appendix Table 2. The effects of Ethrel on shoot and rhizome growth of quackgrass plants treated when foliage regrowth was 10, 30 or 50 days old.

Regrowth age at treatment days	Single or split application	Ethrel rate lb/A	Rep	No. of shoots when Ethrel applied	Six weeks after Ethrel application: Total No. of shoots	No. of shoots due to Ethrel	No. of rhizome growing points	Foliage dry weight g	Rhizome dry weight g
10	Single	zero	I	3	4	0	16	2.0	2.7
			II	5	6	0	10	2.0	1.4
			III	4	4	0	9	2.0	1.0
			IV	4	8	0	5	2.4	3.2
			V	5	5	0	19	2.0	1.9
			VI	4	5	0	9	1.9	1.6
			Avg.	4.2	5.3	0	11.3	2.0	2.0
	Single	0.65	I	4	4	0	11	1.7	1.3
			II	4	7	4	2	2.3	2.0
			III	6	5	0	7	1.7	2.0
			IV	6	6	0	3	1.8	1.5
			V	6	6	1	6	2.3	1.4
			VI	4	7	2	7	2.0	1.8
			Avg.	5.0	5.8	1.2	6.0	2.0	1.7
	Single	1.30	I	4	4	1	10	1.6	1.6
			II	4	3	0	9	1.8	1.7
			III	6	5	1	5	2.0	1.9
			IV	4	4	0	2	1.7	2.3
			V	2	5	1	2	1.6	2.0
			VI	6	8	4	0	1.5	1.4
			Avg.	4.3	4.8	1.2	4.7	1.7	1.8
	Split	1.30	I	4	9	6	2	1.4	1.4
			II	4	10	6	2	1.7	1.7
			III	5	10	8	7	1.8	1.9
			IV	3	8	6	2	2.2	3.0

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Appendix Table 2 Continued.

Regrowth age at treatment days	Single or split application	Ethrel rate lb/A	Rep	No. of shoots when Ethrel applied	Six weeks after Ethrel application: Total No. of shoots	No. of shoots due to Ethrel	No. of rhizome growing points	Foliage dry weight g	Rhizome dry weight g
10	Split	1.30	V	5	8	5	4	1.4	1.4
			VI	3	6	3	3	1.4	1.6
			Avg.	4.0	8.5	5.7	3.3	1.6	1.8
	Split	2.60	I	5	11	8	7	0.9	1.8
			II	5	12	10	7	0.8	1.4
			III	2	7	5	3	0.8	1.6
			IV	5	11	9	4	0.6	1.7
			V	4	13	11	5	0.8	1.0
			VI	2	15	13	7	1.0	1.6
			Avg.	3.8	11.5	9.3	5.5	0.8	1.5
30	Single	zero	I	7	7	0	6	2.4	2.4
			II	5	6	0	9	3.0	2.0
			III	3	6	0	9	1.6	3.4
			IV	5	6	0	16	2.7	2.2
			V	5	5	0	2	2.6	1.1
			VI	4	4	0	6	2.1	3.6
			Avg.	4.8	5.7	0	8.0	2.4	2.4
	Single	0.65	I	3	4	1	39	1.5	4.0
			II	5	9	4	8	1.1	1.7
			III	4	12	8	14	1.3	2.1
			IV	4	9	5	47	1.2	3.5
			V	4	9	5	18	1.4	2.5
			VI	7	10	3	25	1.4	2.6
			Avg.	4.5	8.8	4.3	25.0	1.3	2.7

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Appendix Table 2 Continued.

Regrowth age at treatment days	Single or split application	Ethrel rate lb/A	Rep	No. of shoots when Ethrel applied	Six weeks after Ethrel application: Total No. of shoots	No. of shoots due to Ethrel	No. of rhizome growing points	Foliage dry weight g	Rhizome dry weight g
30	Single	1.30	I	8	10	2	29	1.1	2.5
			II	7	12	9	18	0.9	2.4
			III	7	9	4	30	1.8	2.5
			IV	5	11	4	13	1.3	1.7
			V	2	5	3	20	1.3	3.5
			VI	5	10	6	13	1.4	2.6
			Avg.	5.7	9.5	4.7	20.0	1.3	2.5
	Split	1.30	I	2	7	5	14	1.4	3.0
			II	5	12	8	36	1.5	3.1
			III	7	14	7	20	1.1	2.6
			IV	4	6	3	18	1.5	2.7
			V	5	10	5	14	0.8	1.4
			VI	7	12	8	6	1.2	2.8
			Avg.	5.0	10.0	6.0	18.0	1.2	2.6
	Split	2.60	I	5	17	12	35	0.9	2.1
			II	5	12	8	11	0.8	0.8
			III	6	14	11	11	1.3	1.3
			IV	5	12	7	30	1.3	2.1
			V	3	6	3	26	0.6	2.1
			VI	4	6	3	16	1.3	2.1
			Avg.	4.7	11.0	6.0	22.0	1.0	1.8
60	Single	zero	I	5	5	0	21	2.7	4.6
			II	4	5	0	5	3.0	1.9
			III	3	4	0	7	1.9	2.5
			IV	4	5	0	5	2.8	3.2
			V	5	5	0	6	2.8	2.3

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Appendix Table 2 Continued.

Regrowth age at treatment days	Single or split application	Ethrel rate lb/A	Rep	No. of shoots when Ethrel applied	Six weeks after Ethrel application: Total No. of shoots	No. of shoots due to Ethrel	No. or rhizome growing points	Foliage dry weight g	Rhizome dry weight g
60	Single	zero	VI	8	8	0	10	3.1	3.4
			Avg.	4.8	5.3	0	9.0	2.7	3 0
	Single	0.65	I	7	7	0	20	2.5	3.5
			II	8	11	3	10	2.4	3.9
			III	7	9	2	11	2.5	3.3
			IV	3	3	0	10	1.9	2.0
			V	5	5	0	5	0.8	1.3
			VI	4	8	4	15	3.5	4.6
			Avg.	5.7	7.2	1.5	11.8	2.3	3.1
	Single	1.30	I	6	9	3	11	2.3	2.8
			II	5	11	6	7	2.1	1.5
			III	5	6	1	6	1.8	3.1
			IV	6	7	1	10	1.9	1.8
			V	3	6	3	11	2.0	3.0
			VI	4	6	2	15	1.9	2.4
			Avg.	4.8	7.5	2.7	10	2.0	2.4
	Split	1.30	I	7	8	1	26	1.7	4.1
			II	6	12	7	11	3.1	4.1
			III	6	10	4	10	2.5	3.0
			IV	7	7	1	4	1.4	1.6
			V	7	9	2	15	2.1	4.4
			VI	5	7	2	15	2.7	4.6
			Avg.	6.3	8.8	2.8	13.5	2.2	3.6

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Appendix Table 2 Continued.

Regrowth age at treatment days	Single or split application	Ethrel rate lb/A	Rep	No. of shoots when Ethrel applied	Six weeks after Ethrel application: Total No. of shoots	No. of shoots due to Ethrel	No. of rhizome growing points	Foliage dry weight g	Rhizome dry weight g
60	Split	2.60	I	6	14	8	8	2.7	2.1
			II	5	8	3	20	1.6	3.8
			III	6	7	1	12	2.4	2.5
			IV	4	5	1	24	3.0	3.4
			V	4	4	0	15	2.4	4.0
			VI	3	5	3	9	1.8	1.9
			Avg.	4.7	7.2	2.7	14.7	2.3	3.0

Analyses of Variance for Appendix Table 2

ANOV-Total Number of Shoots

Source	df	MS	F
Reg. age	2	34.84	5.77***
Ethrel rate	4	56.51	9.36***
Age x rate	8	12.84	2.13*
Error	75	6.04	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Number of Rhizome Growing Tips

Source	df	MS	F
Reg. age	2	1169.23	23.67***
Ethrel rate	4	70.07	1.32 NS
Age x rate	8	135.58	2.74**
Error	75	49.40	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Foliage Dry Weight

Source	df	MS	F
Reg. age	2	6.04	36.52***
Ethrel rate	4	2.44	14.79***
Age x rate	8	0.56	3.40***
Error	75	0.16	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Rhizome Dry Weight

Source	df	MS	F
Reg. Age.	2	11.91	19.93***
Ethrel rate	4	1.01	1.69 NS
Age x rate	8	0.58	0.97 NS
Error	75	0.60	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

Appendix Table 3. The effects of three Ethrel rates on the number and growth of shoots and rhizomes of young quackgrass plants treated at the time of rhizome formation and harvested at three different times (each figure is the total of three plants).

		Harvested immediately after spraying					Harvested 30 days after spraying					Harvested 60 days after spraying				
Ethrel rate lb/A	Rep	No. of shoots	Total shoots height inch	No. of rhizome growing points	Foliage fresh weight g	Rhizome fresh weight g	No. of shoots	Total shoots height inch	No. of rhizome growing points	Foliage fresh weight g	Rhizome fresh weight g	No. of shoots	Total shoots height inch	No. of rhizome growing points	Foliage fresh weight g	Rhizome fresh weight g
zero	I	9	159	4	8.5	0.4	12	270	8	13.2	4.3	15	277	40	14.3	20.3
	II	9	162	3	8.1	0.8	10	188	11	11.5	7.0	15	256	16	13.8	16.0
	III	12	188	4	8.7	1.2	12	246	9	12.7	5.6	23	393	29	17.0	16.2
	IV	8	133	6	6.8	1.7	8	163	14	9.7	9.5	12	229	39	12.3	23.1
	V	17	244	2	7.8	0.4	18	266	14	10.1	6.5	24	287	26	13.4	21.7
	Avg. 3 plants	11	177	4	8.0	0.9	12	227	11	11.4	6.6	18	288	30	14.2	19.5
2	I	7	119	7	7.6	1.6	21	198	17	12.2	3.9	17	319	28	16.6	14.9
	II	9	134	5	7.0	1.5	20	184	33	9.4	9.1	19	353	15	17.2	13.2
	III	13	190	4	8.1	0.9	26	201	32	9.7	7.6	23	322	23	14.0	15.0
	IV	8	143	5	7.1	1.3	14	133	30	7.5	8.1	20	284	33	13.6	16.0
	V	13	217	2	9.6	0.7	29	259	31	8.3	6.5	21	377	28	17.9	16.0
	Avg. 3 plants	10	161	5	7.9	1.2	22	195	29	9.4	7.0	20	331	25	15.9	15.1
4	I	11	137	3	6.8	1.0	21	205	31	11.7	5.9	30	278	29	12.3	13.1
	II	9	155	4	7.4	1.1	21	181	29	9.3	7.0	18	265	45	12.3	16.4
	III	12	177	5	7.8	1.5	23	213	33	11.4	6.8	36	261	23	11.8	12.5
	IV	7	117	9	7.7	2.4	16	151	38	6.8	7.7	18	293	41	14.0	18.2
	V	13	199	6	9.0	1.0	24	220	36	9.3	7.1	31	264	25	11.1	14.7
	Avg. 3 plants	10	157	5	7.7	1.4	21	194	33	9.7	6.9	27	272	33	12.3	15.0

Analyses of Variance for Appendix Table 3

ANOV-Number of Shoots

Source	df	MS	F
Ethrel rate	2	127.0	6.19***
Harvest time	2	481.8	23.46***
Rate x time	4	65.4	3.18*
Error	36	20.5	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-No. of Rhizome Growing Tips

Source	df	MS	F
Ethrel rate	2	290.5	8.25***
Harvest time	2	2570.3	73.04***
Rate x time	4	230.7	6.55***
Error	36	35.2	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Total Shoot Height

Source	df	MS	F
Ethrel rate	2	2447.8	1.47 NS
Harvest time	2	68949.7	41.31***
Rate x time	4	2231.8	1.34 NS
Error	36	1668.9	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Foliage Fresh Weight

Source	df	MS	F
Ethrel rate	2	7.4	3.36**
Harvest time	2	149.2	67.94***
Rate x time	4	7.3	3.30**
Error	36	2.2	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Rhizome Fresh Weight

Source	df	MS	F
Ethrel rate	2	7.5	2.57*
Harvest time	2	899.9	309.62***
Rate x time	4	13.1	4.52***
Error	36	2.9	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

Appendix Table 4. The effects of Ethrel on the number and the weight of various organs of quackgrass plants treated once and harvested at three different times. (Each figure is the total of three plants).

Time of harvest weeks after Ethrel application	Ethrel rate lb/A	Rep	No. of shoots	No. of rhizome growing points	Weight of leaves (g)		Weight of stems (g)		Weight of roots (g)		Weight of rhizomes (g)		Weight of "Ethrel shoots" (g)	
					FW[1/]	DW[2/]	FW	DW	FW	DW	FW	DW	FW	DW
Zero	Zero	I	10	13	9.1	1.8	12.4	2.3	9.1	1.0	5.6	0.9	None	None
		II	9	13	9.1	1.8	9.6	2.1	12.3	1.2	8.2	1.8	"	"
		III	9	16	10.1	1.9	11.0	2.4	7.7	0.8	6.6	1.3	"	"
		IV	11	12	10.4	2.0	12.8	2.9	9.1	1.1	5.6	1.1	"	"
		V	12	11	10.7	2.0	12.1	2.7	12.6	1.4	5.6	1.0	"	"
		Avg. /3 plants	10	13	9.9	1.9	11.6	2.5	10.2	1.1	6.3	1.2	"	"
	6	I	9	15	11.1	2.2	11.2	2.4	8.7	1.0	6.1	1.2	None	None
		II	11	18	9.6	1.9	10.4	2.1	11.8	1.4	8.1	1.6	"	"
		III	9	16	9.1	1.8	9.7	1.9	7.9	1.3	7.6	1.4	"	"
		IV	9	26	9.2	1.6	10.3	2.0	6.6	1.1	7.1	1.4	"	"
		V	12	8	12.1	2.4	12.8	2.8	13.4	2.0	4.3	0.9	"	"
		Avg. /3 plants	10	17	10.2	2.0	10.9	2.2	9.7	1.3	6.6	1.3	"	"
3	Zero	I	26	83	15.2	4.4	17.1	4.9	11.3	1.6	22.3	5.1	None	None
		II	32	84	18.4	4.3	16.3	4.0	14.0	1.8	21.2	4.2	"	"
		III	21	78	17.0	4.5	14.5	3.8	10.5	1.4	19.1	3.5	"	"
		IV	27	83	17.6	4.3	17.8	5.3	8.0	1.6	23.2	4.2	"	"
		V	34	67	15.8	4.4	15.3	4.3	10.4	2.1	12.9	2.8	"	"
		Avg. /3 plants	28	79	16.8	4.4	16.2	4.5	10.8	1.7	19.8	4.0	"	"
	6	I	37	85	8.7	2.3	14.5	3.4	6.7	1.1	21.4	3.1	5.1	0.7
		II	57	94	9.2	2.4	9.0	2.3	8.5	1.2	25.2	3.9	9.4	1.5
		III	54	131	9.0	2.9	11.2	3.1	9.0	1.7	26.3	4.5	6.1	1.1
		IV	35	102	9.9	2.6	10.6	3.0	5.5	1.1	25.7	4.4	4.6	0.7
		V	68	111	9.8	2.9	10.7	3.3	7.9	1.0	23.1	4.0	8.9	1.6
		Avg. /3 plants	50	105	9.3	2.6	11.2	3.0	7.5	1.4	24.4	3.8	6.8	1.1

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Appendix Table 4 Continued.

Time of harvest weeks after Ethrel application	Ethrel rate lb/A	Rep	No. of shoots	No. of rhizome growing points	Weight of leaves (g)		Weight of stems (g)		Weight of roots (g)		Weight of rhizomes (g)		Weight of "Ethrel shoots" (g)	
					FW[1/]	DW[2/]	FW	DW	FW	DW	FW	DW	FW	DW
6	Zero	I	36	84	21.9	6.0	18.6	5.2	11.3	2.0	38.0	8.0	None	None
		II	39	83	25.0	7.2	18.8	5.4	13.2	2.2	38.0	9.1	"	"
		III	46	89	26.5	7.4	19.1	5.0	12.2	2.8	36.7	8.0	"	"
		IV	37	86	22.8	6.5	21.8	7.2	7.5	2.7	39.6	10.5	"	"
		V	38	107	24.0	7.0	19.3	6.3	17.6	3.9	43.4	9.8	"	"
		Avg. /3 plants	39	90	24.1	6.8	19.5	5.8	12.3	2.7	39.1	9.1	"	"
	6	I	83	110	5.6	2.5	8.5	2.4	7.0	1.7	46.3	7.4	33.7	5.4
		II	113	108	5.9	2.4	6.0	1.8	7.0	1.7	31.9	5.9	44.5	7.6
		III	97	120	5.2	2.8	5.7	1.7	8.1	1.6	32.3	5.4	47.0	7.2
		IV	110	77	7.3	2.8	9.2	2.5	8.2	1.6	35.6	5.9	44.8	7.0
		V	84	79	6.2	2.7	7.6	2.2	6.9	1.8	24.4	3.8	32.7	5.2
		Avg. /3 plants	97	99	6.0	2.6	7.4	2.1	7.5	1.7	34.1	5.7	40.6	6.5

[1/] Fresh weight

[2/] Dry weight

Analyses of Variance for Appendix Table 4

ANOV-Number of Shoots

Source	df	MS	F
Weeks	2	8,468	115.76***
Rate	1	5,360	73.27***
Week x rate	2	2,170	29.67***
Error	24	73.2	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-No. of Rhizome Growing Tips

Source	df	MS	F
Week	2	20,450	138.28***
Rate	1	1,203	8.13***
Week x rate	2	322	2.2
Error	24	148	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Fresh Weight of Leaves

Source	df	MS	F
Week	2	63	46.35***
Rate	1	527	386.70***
Week x rate	2	212	155.46***
Error	24	1.4	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Fresh Weight of Stems

Source	df	MS	F
Week	2	18	8.56***
Rate	1	265	122.17***
Week x rate	2	83	38.40***
Error	24	2.2	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Fresh weight of Roots

Source	df	MS	F
Week	2	2	0.32
Rate	1	63	11.52***
Week x rate	2	13	2.30
Error	24	5.5	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Fresh weight of Rhizomes

Source	df	MS	F
Week	2	2,272	143.93***
Rate	1	1	<1
Week x rate	2	58	3.70***
Error	24	15.8	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

Appendix Table 5. The effects of Ethrel and soil nutrient levels on shoot and rhizome-bud growth and percent sprouting of excised rhizome buds of quackgrass.

Nutrient levels mg added to each plant three weeks before Ethrel application	Ethrel rate lb/A	Rep	No. of shoots at the time of Ethrel application	Five weeks after Ethrel application: Total no. of shoots	.No. of "Ethrel shoots"	No. of rhizome growing points	Foliage Dry weight (g)	Total no. of rhizome buds	% Sprouting of excised rhizome buds
High	0	I	9	16	0	21	3.7	75	77
100 mg N		II	6	15	0	12	3.9	103	32
80 mg P_2O_5		III	6	12	0	11	3.8	61	52
75 mg K_2O		IV	11	13	0	14	4.4	77	70
		V	7	12	0	8	3.9	48	73
		VI	7	10	0	14	3.8	82	88
		Avg.	7.7	13.0	0	13.3	3.9	74	74
	0.5	I	7	16	3	17	3.5	129	55
		II	8	16	3	9	2.8	105	70
		III	9	19	1	11	3.1	85	51
		IV	8	13	2	16	3.6	130	62
		V	10	17	2	13	3.2	98	57
		VI	10	16	1	13	3.2	102	58
		Avg.	8.7	16.2	2.0	13.2	3.2	108	59
	1.0	I	7	7	1	27	3.1	148	61
		II	7	11	3	30	3.0	167	62
		III	6	14	6	11	3.0	103	67
		IV	9	12	2	15	2.4	128	57
		V	8	17	3	19	3.0	59	68
		VI	8	14	4	6	3.1	123	79
		Avg.	7.5	12.5	3.2	18.0	3.0	121	66

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Appendix Table 5 Continued.

Nutrient levels mg added to each plant three weeks before Ethrel application	Ethrel rate lb/A	Rep	No. of shoots at the time of Ethrel application	Five weeks after Ethrel application					
				Total no. of shoots	No. of "Ethrel shoots"	No. of rhizome growing points	Foliage Dry weight (g)	Total no. of rhizome buds	% Sprouting of excised rhizome buds
Medium	0	I	6	6	0	8	3.3	71	30
20 mg N		II	8	10	0	3	3.5	110	21
16 mg P_2O_5		III	6	7	0	5	3.8	106	50
15 mg K_2O		IV	5	7	0	5	3.4	47	34
		V	7	9	0	2	3.1	60	83
		VI	8	9	0	8	3.3	100	11
		Avg.	6.7	8.0	0	5.2	3.4	82	38
	0.5	I	7	8	1	9	2.2	88	10
		II	9	10	1	4	2.5	45	73
		III	6	8	2	15	2.6	80	20
		IV	5	5	0	9	1.8	68	68
		V	6	7	1	17	2.0	90	7
		VI	6	6	0	14	2.3	95	17
		Avg.	6.5	7.3	0.8	11.3	2.2	78	32
	1.0	I	5	9	5	14	2.1	103	13
		II	6	9	3	15	2.7	100	50
		III	7	14	7	16	2.9	69	12
		IV	7	12	5	3	2.6	69	12
		V	6	12	6	16	2.1	57	28
		VI	9	11	3	3	2.1	124	31
		Avg.	6.7	11.2	4.8	11.2	2.4	87	24

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Appendix Table 5 Continued.

Nutrient levels mg added to each plant three weeks before Ethrel application	Ethrel rate lb/A	Rep	No. of shoots at the time of Ethrel application	Five weeks after Ethrel application					
				Total no. of shoots	No. of "Ethrel shoots"	No. of rhizome growing points	Foliage Dry weight (g)	Total no. of rhizome buds	% Sprouting of excised rhizome buds
Low	0	I	5	7	0	13	2.4	120	13
		II	6	7	0	6	2.8	73	7
		III	5	6	0	10	2.5	142	17
		IV	8	9	0	4	3.1	64	28
		V	7	6	0	6	2.3	71	13
		VI	5	5	0	5	2.7	68	24
		Avg.	6.0	6.7	0	7.3	2.6	90	17
	0.5	I	6	6	0	16	2.6	76	50
		II	5	5	0	3	1.4	93	26
		III	6	8	2	3	2.0	119	44
		IV	5	5	0	8	2.1	65	22
		V	8	10	3	11	2.6	102	26
		VI	6	8	2	3	1.4	71	35
		Avg.	6.0	7.0	1.2	7.3	2.0	88	34
	1.0	I	6	9	3	8	2.3	111	22
		II	8	9	0	16	1.3	73	3
		III	6	6	0	18	1.7	94	11
		IV	5	8	3	7	2.4	67	15
		V	4	5	1	11	2.7	84	57
		VI	7	8	1	18	1.3	94	10
		Avg.	6.0	7.5	1.3	13.0	2.0	87	20

Analyses of Variance for Appendix Table 5

ANOV-Total Number of Shoots

Source	df	MS	F
Nutrient level	2	226.2	53.77***
Ethrel rate	2	6.9	1.64 NS
Nut x rate	4	21.5	5.11***
Error	45	4.2	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Total No. of Rhizome Buds

Source	df	MS	F
Nutrient level	2	1694.5	2.74*
Ethrel rate	2	1213.1	1.96 NS
Nut x rate	4	1227.5	1.98 NS
Error	45	618.7	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-No. of Rhizome Growing Tips

Source	df	MS	F
Nutrient level	2	188.9	6.81***
Ethrel rate	2	136.5	4.92**
Nut x rate	4	23.5	0.85 NS
Error	45	27.7	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Arcsine Transformed % Sprouting

Source	df	MS	F
Nutrient level	2	3607.6	29.89***
Ethrel rate	2	104.3	0.86 NS
Nut x rate	4	199.5	1.65 NS
Error	45	120.7	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Foliage Dry Weight

Source	df	MS	F
Nutrient level	2	6.12	44.93***
Ethrel rate	2	4.38	32.14***
Nut x rate	4	0.18	1.31 NS
Error	45	0.14	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

Appendix Table 6. The effect of three Ethrel rates on shoot growth and shoot regeneration from rootstocks of field bindweed plants. (Each figure is the total of four plants.)

Ethrel rate lb/A	Rep	At Ethrel application		Six weeks after Ethrel application			Four weeks after replanting rootstock segments	
		No. of main branch	No. of secondary branch	No. of living main branch	No. of living secondary branch	Living shoots dry weight g	No. of regrowth shoots	Regrowth dry weight 10^{-2}g
Zero	I	14	8	14	9	7.1	18	7
	II	12	0	12	7	6.6	23	13
	III	12	2	12	3	7.0	12	14
	IV	13	2	13	7	7.7	18	9
	V	14	0	14	6	7.2	22	10
	VI	10	1	10	6	6.9	19	11
	Avg. /4 plants	12	2	12	6	7.1	19	11
1	I	14	8	4	10	0.8	68	59
	II	13	3	4	16	1.2	47	44
	III	12	5	3	22	1.5	64	52
	IV	13	1	3	11	1.0	52	57
	V	15	2	9	26	1.1	58	47
	VI	13	0	4	22	0.9	73	59
	Avg. /4 plants	13	3	4	18	1.1	60	53
5	I	14	4	0	11	0.2	44	34
	II	11	1	0	4	0.1	13	6
	III	16	2	0	6	0.1	49	43
	IV	12	1	0	6	0.1	46	47
	V	13	0	0	5	0.0	40	32
	VI	14	2	0	10	0.1	41	37
	Avg. /4 plants	13	2	0	7	0.1	39	33

Analyses of Variance for Appendix Table 6

ANOV-No. of Living Main Branch

Source	df	MS	F
Ethrel rate	2	240.5	97.5***
Error	15	2.5	

***Significant at 1% level

ANOV-No. of Living Secondary Branch

Source	df	MS	F
Ethrel rate	2	276.4	13.5***
Error	15	20.4	

***Significant at 1% level

ANOV-Living Shoots Dry Weight (g)

Source	df	MS	F
Ethrel rate	2	85.7	1290.3***
Error	15	0.07	

***Significant at 1% level

ANOV-No. of Regrowth Shoots

Source	df	MS	F
Ethrel rate	2	2795.0	28.4***
Error	15	98.5	

***Significant at 1% level

ANOV-Regrowth Dry Weight

Source	df	MS	F
Ethrel rate	2	2691.7	31.5***
Error	15	85.5	

***Significant at 1% level

Appendix Table 7. The effects of five Ethrel rates on shoot and root growth of young field bindweed plants.

Ethrel rate lb/A	Rep	At the time of Ethrel application			Four weeks after Ethrel application			Eight weeks after Ethrel application		
		No. of living shoots	Dry weight of living shoots 10^{-2}g	Dry weight roots 10^{-2}g	No. of living shoots	Dry weight of living shoots 10^{-2}g	Dry weight roots 10^{-2}g	No. of living shoots	Dry weight of living shoots 10^{-2}g	Dry weight roots 10^{-2}g
Zero	I	1	10	10	2	29	24	6	31	61
	II	1	6	11	1	7	47	3	63	45
	III	1	6	10	2	15	38	6	44	30
	IV	1	6	12	3	15	60	2	44	56
	V	1	8	25	2	17	27	7	88	61
	VI	1	7	20	2	19	52	6	85	65
	VII	1	8	20	4	15	44	7	53	54
	VIII	1	10	18	3	13	36	5	43	58
	Avg.	1	8	16	2	16	41	5	56	54
1/4	I	1	7	11	2	9	21	6	53	48
	II	1	6	10	3	11	40	4	42	47
	III	1	4	13	3	18	21	2	60	76
	IV	1	12	18	4	9	14	5	28	28
	V	1	12	28	3	6	34	6	48	61
	VI	1	11	17	4	12	28	5	81	80
	VII	1	8	14	2	9	20	5	54	60
	VIII	1	11	20	2	14	34	3	24	29
	Avg.	1	9	16	3	11	26	4	49	54
1/2	I	1	7	13	3	16	28	6	54	48
	II	1	8	7	3	13	35	5	45	52
	III	1	12	11	4	12	19	8	43	53
	IV	1	7	19	3	11	18	7	38	35
	V	1	9	16	2	14	29	3	44	42
	VI	1	9	16	1	4	21	6	62	80

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Appendix Table 7 Continued.

Ethrel rate lb/A	Rep	At the time of Ethrel application			Four weeks after Ethrel application			Eight weeks after Ethrel application		
		No. of living shoots	Dry weight of living shoots 10^{-2}g	Dry weight roots 10^{-2}g	No. of living shoots	Dry weight of living shoots 10^{-2}g	Dry weight roots 10^{-2}g	No. of living shoots	Dry weight of living shoots 10^{-2}g	Dry weight roots 10^{-2}g
1/2	VII	1	20	21	3	15	33	8	45	62
	VIII	1	13	17	3	14	30	5	48	43
	Avg.	1	11	15	3	12	27	6	47	52
1.0	I	1	9	12	2	2	20	8	42	41
	II	1	5	14	3	11	17	3	28	40
	III	1	5	9	3	10	21	3	52	33
	IV	1	8	10	2	9	13	5	46	45
	V	1	12	21	4	15	29	3	55	47
	VI	1	8	9	2	4	20	6	56	38
	VII	1	5	8	3	9	10	5	51	56
	VIII	1	9	28	2	5	12	5	39	41
	Avg.	1	8	14	3	8	18	5	46	43
2.0	I	1	6	12	1	3	9	4	20	18
	II	1	9	9	2	10	10	3	25	17
	III	1	5	19	3	6	9	3	13	13
	IV	1	5	15	1	2	15	7	28	39
	V	1	10	22	1	2	38	6	48	53
	VI	1	9	16	2	5	19	2	38	39
	VII	1	10	24	2	1	10	6	76	67
	VIII	1	6	14	2	2	20	3	30	44
	Avg.	1	8	16	2	4	16	4	35	36

Analyses of Variance for Appendix Table 7

ANOV-No. of Living Shoots

Source	df	MS	F
Ethrel rate	4	2.6	2.13*
Harvest time	2	159.4	132.68***
Rate x time	8	1.4	1.20 NS
Error	105	1.2	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Roots Dry Weight

Source	df	MS	F
Ethrel rate	4	774.0	6.91***
Harvest time	2	10804.3	96.56***
Rate x time	8	251.5	2.25**
Error	105	111.9	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

ANOV-Living Shoots Dry Weight

Source	df	MS	F
Ethrel rate	4	426.4	4.47***
Harvest time	2	18573.3	194.72***
Rate x time	8	121.6	1.27 NS
Error	105	95.4	

***Significant at 1% level
**Significant at 5% level
*Significant at 10% level

Appendix Table 8. The influence of pretreatment with Ethrel and subsequent application of amitrol-T on the growth of shoots and rhizome buds and the regeneration capacity of the segmented rhizomes of quackgrass plants maintained at two levels of vigor.

Plants' vigor	Ethrel rate lb/A	Amitrol-T rate lb a.i./A	Rep	No. of Ethrel shoots at herbicide application time	Seven weeks after Amitrol-T application: No. of Ethrel shoots	Seven weeks after Amitrol-T application: No. of rhizome growing points	Seven weeks after Amitrol-T application: Foliage dry weight g	Regrowth dry weight 8 weeks after replanting rhizomes 10^{-2} g
Normal	Zero	Zero	I	0	0	6	2.3	27
			II	0	0	6	1.9	26
			III	0	0	10	2.4	9
			IV	0	0	8	1.9	13
			Avg.	0	0	7.5	2.1	18.8
		1/2	I	0	0	11	2.2	23
			II	0	0	8	2.2	12
			III	0	0	12	1.5	14
			IV	0	0	14	2.0	21
			Avg.	0	0	11.2	2.0	17.5
	1.25	Zero	I	2	3	13	1.7	12
			II	0	2	25	2.3	8
			III	1	2	18	2.0	13
			IV	1	1	8	1.6	27
			Avg.	1.0	2.0	16.0	1.9	15.0
		1/2	I	2	2	24	1.5	18
			II	3	3	4	0.7	9
			III	1	1	6	0.7	19
			IV	0	0	9	1.0	17
			Avg.	1.5	1.5	13.2	1.0	15.8
	2.5	Zero	I	3	5	19	2.3	11
			II	5	7	15	2.4	18
			III	0	3	15	1.6	11
			IV	4	5	11	2.0	10
			Avg.	3.0	5.0	15.0	2.1	12.5

Cont.

Appendix Table 8 Continued.

Plants' vigor	Ethrel rate lb/A	Amitrol-T rate lb a.i./A	Rep	No. of Ethrel shoots at herbicide application time	Seven weeks after Amitrol-T application			Regrowth dry weight 8 weeks after replanting rhizomes 10^{-2} g
					No. of Ethrel shoots	No. of rhizome growing points	Foliage dry weight g	
	2.5	1/2	I	2	3	13	1.2	24
			II	1	2	10	0.8	18
			III	0	0	16	1.2	10
			IV	4	4	17	1.1	13
			Avg.	1.8	2.2	14.0	1.1	16.0
Low	Zero	Zero	I	0	0	*	3.6	18
			II	0	0	*	2.0	5
			III	0	0	*	2.5	5
			IV	0	0	*	1.8	10
			Avg.	0	0	*	2.5	9.5
		1/2	I	0	0	*	1.5	23
			II	0	0	*	2.1	9
			III	0	0	*	1.4	12
			IV	0	0	*	1.5	7
			Avg.	0	0	*	1.6	12.8
	1.25	Zero	I	1	2	*	1.8	8
			II	0	0	*	1.3	5
			III	1	2	*	2.1	7
			IV	0	1	*	1.9	10
			Avg.	0.5	1.2	*	1.8	7.5
		1/2	I	0	0	*	1.8	13
			II	3	3	*	2.1	13
			III	1	1	*	1.6	16
			IV	1	1	*	1.5	14
			Avg.	1.2	1.2	*	1.8	14.0

Continued

Appendix Table 8 Continued.

Plants' vigor	Ethrel rate lb/A	Amitrol-T rate lb a.i./A	Rep	No. of Ethrel shoots at herbicide application time	Seven weeks after Amitrol-T application			Regrowth dry weight 8 weeks after replanting rhizomes 10^{-2}g
					No. of Ethrel shoots	No. of rhizome growing points	Foliage dry weight g	
	2.5	Zero	I	1	3	*	1.5	10
			II	1	1	*	1.5	9
			III	0	2	*	1.7	7
			IV	1	3	*	1.5	8
			Avg.	0.8	2.2	*	1.6	8.5
		1/2	I	0	0	*	1.0	12
			II	1	1	*	1.2	20
			III	0	0	*	1.3	15
			IV	1	1	*	1.9	10
			Avg.	0.5	0.5	*	1.4	14.2

*Not determined

Analyses of Variance for Appendix Table 8

ANOV-Number of Ethrel Shoots at Amitrol-T Application

Source	df	MS	F
Plants' vigor	1	6.02	5.82**
Ethrel rate	2	9.52	9.20***
Amitrol-T rate	1	0.02	NS
Vigor x Ethrel	2	3.40	3.28**
Vigor x Amitrol-T	1	0.52	NS
Ethrel x Amitrol-T	2	1.90	NS
Vigo x Eth x Amit	2	0.27	NS
Error	36	1.03	

***Significant at 1% level
**Significant at 5% level

ANOV-Numbered Ethrel Shoots at Harvest Time

Source	df	MS	F
Plants' vigor	1	10.08	10.37***
Ethrel rate	2	25.33	26.06***
Amitrol-T rate	1	8.33	8.57***
Vigor x Ethrel	2	5.58	5.74***
Vigor x Amitrol-T	1	0.75	NS
Ethrel x Amitrol-T	2	6.08	6.26***
Vigo x Eth x Amit	2	0.25	NS
Error	36	0.97	

***Significant at 1% level
**Significant at 5% level

ANOV-Foliage Dry Weight

Source	df	MS	F
Plants' vigor	1	0.05	NS
Ethrel rate	2	1.33	9.49***
Amitrol-T rate	1	3.31	23.58***
Vigor x Ethrel	2	0.22	NS
Vigor x Amitrol-T	1	0.33	NS
Ethrel x Amitrol-T	2	0.18	NS
Vigo x Eth x Amit	2	0.80	5.73***
Error	36	0.14	

***Significant at 1% level
**Significant at 5% level

ANOV-Regrowth Dry Weight

Source	df	MS	F
Plants' vigor	1	285.19	9.31***
Ethrel rate	2	14.77	NS
Amitrol-T rate	1	117.19	3.83**
Vigor x Ethrel	2	16.19	NS
Vigor x Amitrol-T	1	50.02	NS
Ethrel x Amitrol-T	2	14.81	NS
Vigo x Eth x Amit	2	3.65	NS
Error	36	30.63	

***Significant at 1% level
**Significant at 5% level