

GROWTH, COMPETITIVENESS AND CONTROL OF QUACKGRASS (*Elytrigia repens* (L.) Nevski)  
IN FLAX (*Linum usitatissimum* (L.)).

A thesis

Submitted to the Faculty of

Graduate Studies

University of Manitoba

By

David Chikoye

In Partial Fulfilment of the

Requirement for the Degree

of

Master of Science

Department of Plant Science

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(*Elytrigia repens*(L.)Nevski) IN FLAX

(*Linum usitatissimum*(L.)

BY

DAVID CHIKOYE

A thesis submitted to the Faculty of Graduate Studies of  
the University of Manitoba in partial fulfillment of the requirements  
of the degree of

MASTER OF SCIENCE

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## ABSTRACT

Chikoye David, M.Sc., University of Manitoba, 1990. Growth, Competitiveness and Control of Quackgrass (*Elytrigia repens* (L.) Nevski) in flax (*Linum usitatissimum* (L.)). Major Professor: Dr. I.N. Morrison. Department of Plant Science.

The growth, competitiveness and control of quackgrass with sethoxydim was investigated in field experiments at Portage la Prairie in 1988 and 1989. A stratified random sampling design was used to study quackgrass interference in three commercial flax fields. Each site was systematically sampled at 30, 70 and 100 days after planting (DAP). In both years quackgrass shoots increased from 62 shoots m<sup>-2</sup> 30 DAP to 138 shoots m<sup>-2</sup> at the end of the growing season. Rhizome biomass increased from 5.6 to 46.7 g m<sup>-2</sup> during the growing season. Most of the quackgrass rhizome biomass was accumulated during the flax ripening period. Quackgrass competition caused substantial yield losses in flax. These losses were described by the rectangular hyperbola  $y = 2.07x/(1+2.07x/130)$ , where  $y$  = flax seed yield loss (%) and  $x$  = quackgrass density (shoots m<sup>-2</sup>) 30 DAP.

The effect of 0.81 kg a.i. ha<sup>-1</sup> sethoxydim plus 2% (v/v) Assist on quackgrass shoot and rhizome growth, and regrowth the following spring was investigated under competitive and non-competitive situations. The plots were systematically sampled at 3- to 4- week intervals throughout the growing season. Sethoxydim suppressed the growth of quackgrass for eight weeks, and regrowth was less in plots sown to flax than in uncropped plots. In the absence of flax competition, sethoxydim reduced quackgrass shoot density at the end of the growing season by 67% in 1988 and 93% in 1989 compared to untreated plots. In plots seeded to flax, sethoxydim reduced quackgrass shoot density by 94% in 1988 and 97% in 1989. Reductions in shoot densities were associated with corresponding reductions in rhizome buds and biomass.

The suppression of quackgrass regrowth coincided with a 70 to 80% reduction in photosynthetic photon flux density penetrating the crop canopy to ground level. Although sethoxydim effectively reduced rhizome buds, proportionately more of the treated buds sprouted to form shoots the following spring. In treated plots about 60% of the rhizome buds sprouted into new shoots the following spring compared to 28% in the untreated plots.

The efficacy of 0.5 and 0.81 kg a.i. ha<sup>-1</sup> sethoxydim plus 2% (v/v) Assist and 2 kg ha<sup>-1</sup> analytical grade ammonium sulphate on quackgrass clones, collected from seven locations in Manitoba, was evaluated using a factorial design. The clones were allowed to grow to the ten leaf stage and then clipped to ground level. Sethoxydim was applied to quackgrass in the 3- to 4-leaf stage following regrowth. There was differential response to sethoxydim among quackgrass selections. Of the four parameters evaluated, only shoot biomass could be related to reductions in quackgrass shoot and rhizome growth due to sethoxydim. Quackgrass selections high in shoot biomass tended to be more difficult to control. Sethoxydim at 0.5 kg ha<sup>-1</sup> resulted in similar control of quackgrass as 0.81 kg ha<sup>-1</sup> in 1988. In 1989 the higher dosage resulted in about 15% better quackgrass control. Generally, addition of ammonium sulphate and Assist together to sethoxydim resulted in 5% better quackgrass control than addition of Assist alone.

## 1. INTRODUCTION

Quackgrass (*Elytrigia repens* (L.) Nevski) is native to Europe but is widely distributed in the temperate areas of the world (Holm et al. 1977). The weed is thought to have been introduced to Eastern Canada during colonization, and spread westwards as a result of sowing infested bromegrass and transportation of infested hay and straw. Presently, quackgrass thrives in most of the agricultural regions of Canada (Werner and Rioux 1977).

In Manitoba, quackgrass is found in all agricultural regions of the province, but the frequency of occurrence varies among regions. In a 1986 weed survey, quackgrass was found in the northwest region in 22.2% of the fields surveyed, whereas in the central region 8.1% of the fields surveyed were infested; infestation levels were 0.2 to 31.6 shoots m<sup>2</sup> and 0.2 to 66.8 shoots m<sup>2</sup>, respectively (Thomas and Wise 1988).

Quackgrass can cause substantial yield losses in cereals (Anonymous 1989b; Wilcox and Morrison 1988; O'Donovan and Newman 1990). Yield losses are expected to be more severe in less competitive crops such as flax. Quackgrass may also reduce forage quality (Leroux 1987) and serve as alternate host plants for several pests of grain crops (Werner and Rioux 1977).

Quackgrass is very difficult to control because it mainly propagates by a vigorous underground rhizome system (Holm et al. 1977). The weed also spreads by seed (Holm et al. 1977) which remain viable in the soil for up to 10 years (Toole and Brown 1946). Quackgrass is highly variable in form and environmental adaptability due to its self sterility and a low frequency of inbreeding (Williams 1973b). In addition, there may be variation in biochemical and physiological systems in the plant which may influence quackgrass response to herbicide control measures.

Both selective and non-selective herbicides are registered for quackgrass control in

Canada. Even though glyphosate gives good control of quackgrass for more than one growing season, it is non-selective and limited to non-crop situations. Selective post emergence graminicides control quackgrass selectively in broadleaved crops but only give seasonal control (Anderson 1985).

Despite the seriousness of the quackgrass problem in flax, there is no published information on the response of this crop to quackgrass interference, nor has there been a detailed investigation on the efficacy of specific graminicides now recommended for quackgrass control in flax. Studies were initiated in 1988 and repeated in 1989 to investigate:

1. the effect of quackgrass interference on flax growth and seed yield.
2. the relationship between quackgrass shoot densities 30 days after planting and flax yield losses.
3. the effect of sethoxydim on growth and competitiveness of quackgrass in flax over the growing season and,
4. the efficacy of sethoxydim on quackgrass selections collected from seven locations in Manitoba.

**This thesis was written in manuscript style following the format of Weed Science**

## 2. REVIEW OF LITERATURE

### 2.1. QUACKGRASS

#### 2.1.1. Nomenclature

Quackgrass is distributed throughout the world and is known by numerous common names including couchgrass, scutchgrass, twitchgrass, quitchgrass, quickgrass, and chiendent (Holm et al. 1977). The wide variability within quackgrass and its generic relatives has caused confusion in its scientific naming. It was originally named *Triticum repens* (L.) by Linneaus in 1753. In 1812, Beauvois removed quackgrass from the wheat genus and renamed it *Agropyron repens* (L.) Beauv. Subsequently, in 1933 Nevski classified quackgrass as *Elytrigia repens* (L.) Nevski. Gould renamed the species *Elymus repens* (L.) Gould in 1947 (Melderis et al. 1980; Alex 1987). Reclassification was mostly based on differences in spikes and spikelets. Although quackgrass most commonly appears as *Agropyron* in the scientific literature, *Elytrigia* and *Elymus* are becoming increasingly popular. In North America, *Elytrigia repens* (L.) Nevski has been accepted as the valid name (Anonymous 1989a).

#### 2.1.2. Distribution

Quackgrass is native to Europe but is widely distributed in the temperate areas of the world (Holm et al. 1977). Quackgrass is the most serious perennial weed of the northern temperate zone (Holm et al. 1977). Quackgrass is generally absent in the tropics because low temperatures are required to initiate vegetative growth (Palmer and Sagar 1963). In North America, the weed thrives in the northern half of the United States and most of the agricultural areas of Canada (Holm et al. 1977; Werner and Rioux 1977).

Quackgrass is thought to have been introduced to Eastern Canada during colonization, and spread westwards as a result of sowing infested bromegrass and by transportation of infested hay and straw (Werner and Rioux 1977). In Manitoba, quackgrass is found in all the agricultural regions of the province (Thomas and Wise 1988). However, considerable variability in the distribution is noted throughout the province. In the 1986 weed survey, quackgrass was found in the northwest region in 22.2% of the fields surveyed whereas in the central region 8.1% of the fields surveyed were infested (Table 1).

### 2.1.3. Habitat

Quackgrass is commonly designated as a "cool-season" grass. It is common in areas of moderate rainfall and is rare in areas of low rainfall (Werner and Rioux 1977). It is a plant of open areas, mainly occurring where the native vegetation is disturbed. It is common in agricultural fields, road margins, waste places and abandoned fields (Palmer and Sagar 1963; Frankton and Mulligan 1987). Quackgrass can grow on a wide range of soils, from dry sand to wet alluvium, but grows best on well drained, medium- to fine-textured soils. It will grow on soils with a pH range of 4.5 to 8.0, but does best at a pH of 6.5 to 8.0 (Werner and Rioux 1977). Also, quackgrass will grow on soils containing a relatively high concentration of soluble salts (70-95 mg/100 g soil) (Tesu et al. 1970).

## 2.2. QUACKGRASS BIOLOGY AND ECOLOGY

### 2.2.1. Morphology

Quackgrass is a long lived perennial which spreads by both seed and by an extensively branching underground rhizome system (Frankton and Mulligan 1987; Holm et al. 1977). The

Table 1. Summary of quackgrass distribution in Manitoba regions.

Region	Frequency (%)	Field uniformity (%)	Field density (no. m <sup>2</sup> )	Density range
Northwest	22.2	33.4	7.6	0.2 - 31.6
Southwest	19.2	21.3	8.9	0.2 - 99.6
Central	8.1	32.1	15.8	0.4 - 66.8
Eastern	11.8	16.7	3.1	0.6 - 5.8
Interlake	15.1	15.0	3.1	0.2 - 19.2

Source: Thomas and Wise, 1988

Frequency - the number of fields in which quackgrass occurred expressed as a percentage of the total number of fields surveyed.

Field uniformity (occurrence) - the number of quadrats in which quackgrass occurred expressed as a percentage of total number of quadrats for the occurrence fields only.

Field density (occurrence) - the number of quackgrass shoots found in a square quadrat averaged over the number of fields in which quackgrass occurred.

Density range (number m<sup>2</sup>) - the lowest and the highest field density recorded for quackgrass.

rhizomes are hard, long and slender, about 2-4 mm in diameter, white or yellowish in colour, with very sharp pointed tips (Frankton and Mulligan 1987). Rhizomes often extend laterally to 150 cm, 15-20 cm in depth (Holm et al. 1977). They have nodes from which adventitious roots may be produced, and the internodes are partially covered by light coloured scale leaves (Palmer and Sagar 1963). The rhizomes branch at the nodes, with some branches turning upwards to emerge as new shoots and others continuing to grow and branch horizontally, expanding the patch in all directions (Holm et al. 1977). Stems are prostrate to erect, ranging from 30 to 120 cm in height. The stem is smooth and hairless but the leaf sheaths may either be smooth or finely to densely hairy, especially the lower-most sheath on the shoot. Stem nodes, usually 4-5 in number, are distinct and often purplish in colour (Holm et al. 1977). The leaf blades are usually flat, 5-10 mm wide and 6-30 cm long, finely pointed towards the tip, glabrous but very slightly roughed on the under surface. The upper surface of the leaf blade has a few scattered hairs (Sampson 1987) and its ribs are not prominent. The ligule is membranous, less than 1 mm long, and flat across the top. There are two distinct, spreading auricles which more or less clasp the stem like little hooks. The stems either do not flower during the whole growing season, or flower producing a slender, unbranched inflorescence called a spike. The spike is erect, 4-30 cm long, symmetrical, with one spikelet per node on alternate sides of the rachis. Spikelets are oblong to wedge-shaped, very rigid, 10-20 mm in length, with outer glumes and 3-8 florets, each consisting of the hard, chaffy lemma and palea, and the grain (caryopsis). Glumes and lemmas may be awned or awnless (Palmer and Sagar 1963; Holm et al. 1977; Werner and Rioux 1977).

### 2.2.2. Growth and development

An understanding of quackgrass growth and physiology is useful in determining the

relative competitiveness of this weed at different growth stages and its potential susceptibility to chemical and cultural control methods. Several workers have reviewed the physiology of quackgrass growth and development (Holm et al. 1977; Werner and Rioux 1977; Marshall 1987) and the reader is referred to these papers for a comprehensive review of the subject.

The growth and reproductive potential of quackgrass from rhizome fragments and from seed has been reported (Wilcox and Morrison 1987). The authors found that seedlings were initially less robust than the plants propagated from rhizomes, however, fourteen weeks after planting the seedlings and rhizome-propagated plants were indistinguishable. These results confirmed an earlier study when quackgrass was grown in absence of crop competition (Williams 1973a). Under wheat competition plants from rhizome fragments were more vigorous than the seedlings (Williams 1973a). Plants propagated from rhizomes are more vigorous because they have more food reserves compared to seeds (Thurston and Williams 1968). Furthermore, seeds, being dry, need to imbibe moisture to initiate the germination process whereas rhizome fragments are already imbibed, and therefore establish faster than the seedlings (Thurston and Williams 1968).

When soil temperatures consistently exceed 0 C in spring, quackgrass can produce new roots and primary aerial shoots. Quackgrass plants exhibit no innate dormancy at any time of the year (Hakansson 1982). Rhizome buds present at the nodes regenerate a new root and shoot system when the rhizomes are fragmented. In undisturbed rhizome systems, the majority of buds never break dormancy due to apical dominance from actively growing terminal buds (Werner and Rioux 1977; Hakansson 1982). Fragmentation seems to remove the inhibitory effects of apical dominance.

Tillers and new rhizomes develop when there is a minimum amount of dry matter left in the rhizome following initial root and shoot development. Tillers and new rhizomes are usually

formed when quackgrass is in the 3-4 leaf stage for plants propagated from rhizomes and in the 4-6 leaf stage for seedlings (Werner and Rioux 1977). The rhizomes grow horizontally throughout late spring and summer.

The extent of underground growth is quite considerable. One plant is capable of generating up to 154 m of new rhizomes per season, confined to an area of 3 m<sup>2</sup>. Rhizome fragments weighing 1 g produced new rhizome biomass of up to 80 g in one season (Raleigh 1962 as cited by Marshall 1987). In Manitoba, Wilcox and Morrison (1987) reported that a single plant produced 69 g of shoot biomass, rhizome length of 75 m and 1593 buds in one season.

The influence of various physical and environmental factors on quackgrass growth and development has been reviewed by Marshall (1987). Apical dominance in the rhizomes can be controlled by changing the nitrogen level (McIntyre 1965). At low nitrogen levels (2-5 ppm) the growth of lateral buds was strongly inhibited by the rhizome apex. At relatively high nitrogen levels (210 ppm) the rhizome apex failed to suppress the growth of lateral buds. However, when the rhizome was detached from the mother, shoot apical dominance was rapidly restored even when grown under a high nitrogen status. Apical dominance was released when the rhizome apex was removed immediately, but was not if the rhizome was detached from the mother shoot and the apex removed after one week. Lateral buds from isolated rhizome showed significant growth when supplied with 2 % sucrose. McIntyre (1969) suggested that the increased apical dominance is due to competition for limited carbohydrate between the apex and the lateral buds which is rapidly depleted if the shoot system is absent.

Plant hormones also affect apical dominance of rhizomes. Kinetin (6-furfurylaminopurine) at 50-500 ppm applied to lateral buds reduced the influence of apical dominance on lateral buds (McIntyre 1971). Leakey and Chancellor (1975) observed that 1-naphthylacetic acid (NAA) and 6-benzylaminopurine (BAP), both at 500 ppm, applied to the distal end of decapitated rhizomes

attached to the parent shoots inhibited the growth of lateral buds. However, NAA and BAP applied to the apical ends of detached multi-nodal rhizome fragments did not maintain apical dominance unless the same growth regulators were applied simultaneously to the basal end of rhizome fragments. Endogenous hormones may be important in controlling the activity of lateral buds.

Temperature affects the development of rhizome buds (McIntyre 1970). An increase in temperature from 15 to 25 C caused a 25% increase in the number of rhizome buds developing as shoots. There was a corresponding decrease in the number of buds developing into rhizomes. The response was greatest at the rhizome apex while buds at the rhizome base increased (5%) in dormancy with a temperature increase.

Reductions in light intensity have the same effect on bud activity as increases in temperature (McIntyre 1970). As the level of illumination was reduced from 3200 to 500 foot-candles, there was a marked increase in shoot production (10-60%) whereas rhizome production was entirely suppressed. At high light intensity (3200 foot-candles) about 10% of the rhizome buds developed into shoots. In multi-nodal fragments, increased light intensity inhibited apical dominance (Leakey and Chancellor 1975). Stukerud (1984) reported a 25 cm increase in stem height of quackgrass shoots in response to a 50% reduction in illumination.

High humidity around the rhizomes also promoted bud and root growth at the nodes (McIntyre 1976). At low humidities, the new rhizomes were unbranched and hairless. The promotion of bud and root growth by high humidity may have been a direct response to increased hydration of the tissues resulting from a reduction in the loss of water by evaporation. This is supported by the evidence that cell division and extension, cell wall synthesis, and protein synthesis are all extremely responsive to changes in water potential (McIntyre 1976).

### 2.2.3. Reproduction

Quackgrass is a perennial weed species that reproduces by both seed and clonal growth by means of rhizomes (Holm et al. 1977). The rhizome buds are the primary means of propagation and survival (Palmer and Sagar 1963; Werner and Rioux 1977). The ability of quackgrass to reproduce by seed is a significant factor contributing to its spread and survival within a range of habitats. Although seeds do not contribute substantially to the spread of quackgrass within a field, they introduce genetic variability in new habitats and also represent a means of long distance dispersal to new habitats (Swanton 1987).

Quackgrass is self sterile, requiring cross pollination from a genetically distinct population to produce seed (Palmer and Sagar 1963). Quackgrass flowers in late June to July in Canada (Frankton and Mulligan 1971) with seeds ripening in early August to early September and dropping from the mother plant by late September (Werner and Rioux 1977). The number of seeds produced range from 15 to 400 seeds per plant, with 25-40 being most common (Werner and Rioux 1977). Seed production is influenced by crop competition (Williams and Attwood 1971; Sampson and Watson 1987), density of spikes per unit area (Williams and Attwood 1971), compatibility and proximity of neighbouring genotypes, and environmental factors (Swanton 1987).

Quackgrass seeds possess no special morphological adaptation for dispersal. They fall off the parent plant passively (Werner and Rioux 1977). Seeds may be spread by machinery and during crop seed distribution.

Newly formed quackgrass seed do not require an after ripening period and readily germinate (Holm et al. 1977). High germination percentages occur when temperatures fluctuate between 20-30 C (Holm et al. 1977). Buried seeds remain viable for up to 10 years (Toole and Brown 1946). Seeds can retain their viability after passing through the digestive systems of cows, sheep and horses, but not hogs (Muenscher 1952). Germination is promoted and inhibited by

gibberellic acid at  $10^{-2}$  M and abscissic acid at  $10^{-4}$  M, respectively (Holm and Miller 1972).

#### 2.2.4. Clonal variation

In Canada, Bowden (1965) described two forms of quackgrass (*forma repens* and *aristatum*). However, Alex et al. (1980) stated that quackgrass is one species in which no forms or varieties exist despite the observed differences in morphology and physiology. The numerous types or variants reported have no taxonomic significance. Because the species is of hybrid origin, the high polymorphism is due to the high heterozygosity of the species. Such differences do not provide a basis for taxonomic distinction (Prokudin *in* Sampson 1987).

Quackgrass is a highly variable species in form and environmental adaptability due to its self sterility and very low frequency of inbreeding. The high degree of heterozygosity present within the species has resulted in the description of a large number of varieties, forms and clones (Williams 1973b; Sampson 1987).

Several authors have reported significant variation amongst quackgrass clones for morphological and physiological factors (Williams 1973b; Westra and Wyse 1981). The amount of variation reflects the heterozygosity present within quackgrass.

Williams (1973b) reported variation in several quackgrass clones in England. Westra and Wyse (1981) reported variation in ten quackgrass clones collected in Minnesota. In southern Ontario, Sioen and Dekker (1984) reported variations in 19 quackgrass selections. In Quebec, Tardif and Leroux (1987) reported morphological variability among several quackgrass clones collected from different sites.

Quackgrass varies from erect to very prostrate (Sioen and Dekker 1984) with significant variation in height (59-74 cm) (Westra and Wyse 1981). The colour of the leaf varies from blue to yellowish green. The leaf surface and rachis of the inflorescence varied from glabrous to

densely hairy among the Minnesota collections. Shoot production varied from 7 to 235 shoots per plant and shoot biomass ranged from 48 to 362 g per plant (Westra and Wyse 1981), the differences being attributed to differences in tiller number and plant height.

Variation in rhizome growth included rhizome biomass (29-89 g per plant) (Williams 1973b), bud number (246-1211 buds per plant) (Westra and Wyse 1981), length of largest rhizome (114-135 cm), rhizome thickness and ratios of shoot to rhizome biomass (0.47-1.73) (Westra and Wyse 1981).

Clones have also been classified on basis of spikelet morphology. Wide variation has been observed in awn length, varying from no awns to florets with prominent awns as long as 6 mm (Sioen and Dekker 1984). Westra and Wise (1981) reported variation in the number of spikes produced (4 to 62 spikes per plant), the number of spikelets per spike (12.5-26.4), number of florets per spikelet (5.3-8.3) and floret length (7.5-9.5 mm).

Physiological variation is wide-spread in quackgrass. The season at which plants commence growth and the time at which spikes emerge varies considerably (Williams 1973b), as does robustness or vigour of clones (Pooswang et al. 1972). Results from a study conducted in England showed that some clones stored carbohydrate in the rhizomes more than others and there also seemed to be seasonal variation in biomass production and allocation (Pooswang et al. 1972).

### 2.3. QUACKGRASS INTERFERENCE

Interference is defined as the adverse effects that neighbouring plants exert on each others growth (Putnam 1985). Interference can occur as a result of competition, allelopathy or changes in the physical and biological environment that interferes with the growth of neighbouring

plants (Putnam 1985). However, literature on quackgrass competition does not clearly differentiate the relative roles of competition and allelopathy in the total interference.

### 2.3.1. Allelopathy

Allelopathy is defined as the production of chemicals by the living or decaying tissue or microorganisms associated with the living plant, which interfere with growth of the neighbouring plants (Putnam 1985). Allelopathic influences of weeds upon crops have been manifested as reductions in crop germination and stands (Weston and Putnam 1985), root and shoot growth (Gabor and Veatch 1981; Weston and Putnam 1986), yield, nodulation and nitrogen fixation (Touchette 1989; Weston and Putnam 1985). However, most of the effects of allelopathy have only been demonstrated in laboratory studies.

In growth chamber studies Toai and Linscott (1979) observed that decaying quackgrass rhizomes and leaves reduced alfalfa growth (*Medicago sativa* L.) by 21 and 27.3 %, respectively. These results confirm earlier studies by Ohman and Kommendal (1964). However, these studies could not demonstrate that living quackgrass plants released phytotoxic root or rhizome exudates in the soil (Ohman and Kommendal 1964). Under field conditions, the deleterious effects of quackgrass may be due to dead quackgrass residuals.

### 2.3.2. Competition.

Competition is defined as "a physical process which arises from the reaction of one plant upon the physical factors about it and the effect of the modified factors upon its competitors" (Zimdahl 1980). The definition goes further to identify water content, nutrients, light, and heat as the main limiting factors. Competitive plants must be more successful in resource capture than non-competitive plants and competitiveness is determined by such factors as plant size, time of

competition (Harper 1977), plant vigour and hardiness (Zimdahl 1980).

### 2.3.3. Competition Studies Involving Quackgrass

Several studies have determined the influence of quackgrass on the yield of field crops. In Minnesota, Young et al. (1982) observed that quackgrass at densities of up to 160 shoots  $m^{-2}$  did not cause significant yield losses in soybean. Mean densities of 520 and 910 shoots  $m^{-2}$  caused yield losses of 19 and 55%, respectively. Densities of 680 shoots  $m^{-2}$  caused yield losses of 11% in a wet year and 33% in a dry year. The yield reductions were ascribed to significant reductions in the number of branches, pods and seeds per plant as well as reduced net assimilation rates, leaf weights and new leaf area production of soybean.

Similarly, Young et al. (1984) reported corn yield reductions of 12 to 16% from quackgrass densities of 65 to 390 shoots  $m^{-2}$ . Quackgrass densities between 55 and 900 shoots  $m^{-2}$  reduced corn yield by 13%. Moisture was the main limiting factor. High quackgrass shoot densities significantly reduced corn height, ear length, kernels per row, rows per ear and seed weight. The authors concluded that the minimum density of quackgrass required to cause substantial yield loss in corn and soybean is not static. In years when moisture was abundant, denser stands of quackgrass were required to cause substantial yield losses than in dry years when moderate densities caused substantial losses.

The statistical methods used in analyzing the above mentioned competition studies were inappropriate in that multiple comparisons (Duncan's Multiple Range Test) were used to analyze structured data (Cousens 1988). The significant soybean yield loss observed at a quackgrass density of 520 shoots  $m^{-2}$  (Young et al. 1982) suggest the existence of a critical density below which no yield loss is observed which is not the case. Cousens suggested the use of regression techniques to establish response curves which are predictive. The equations from the fitted data

can be used to calculate economic thresholds or yield loss per unit weed density.

Zimdahl (1980) reported that the relationship between crop yield and weed density was sigmoidal in nature. The model assumes some minimum weed density which does not cause crop yield reduction. Cousens et al. (1984) does not support the use of a sigmoidal model to describe density related crop losses. He argues that lack of yield loss demonstrated by this model, due to inherent variability at low weed densities, does not mean that yield losses do not occur. He suggests the use of a hyperbolic model in estimating yield losses due to weeds. The model assumes that at low weed densities intraspecific competition is absent due to very large mean distances between the weeds. The addition of each weed at low densities is therefore expected to have additive effects on crop yield. The hyperbolic model further assumes that as the weed density increases, there will be corresponding decreases in their mean distances resulting in increased intraspecific competition. The competitive effect of the weed will therefore decrease as some function of weed density.

The rectangular hyperbola (Cousens et al. 1984) takes the form:

$$y_i = Id/(1+Id/A)$$

where  $y_i$  = percent yield loss,  $d$  = weed density,  $I$  = percent yield loss per weed plant per unit area as weed density approaches zero,  $A$  = percent yield loss as weed density approaches infinity. Parameters  $A$  and  $I$  are agronomic terms which are affected by such factors as crop density, relative time of crop and weed emergence, and soil type. The quotient of  $I/A$  is a measure of weed intraspecific competition which increases as weed density increases.

Wilcox and Morrison (1988) used the rectangular hyperbolic model to describe yield losses in spring wheat due to quackgrass infestation. Yield reductions of 25% were obtained with quackgrass densities close to 200 shoots  $m^{-2}$  at crop harvest. However, Rioux (1982) defined the relationship between quackgrass shoot density and barley yields using linear regression

methods and concluded that 10 quackgrass shoot  $m^{-2}$  would reduce the yield of barley by 1.6%.

Crop yield loss models that relate to weed density at crop harvest are of little help to growers. Growers require yield loss models which relate yield losses occurring at crop harvest to weed density early in the growing season. Wilcox and Morrison (1988) developed a model that related quackgrass densities in spring to quackgrass densities occurring at crop harvest. This model combined with the yield loss model could be used in predicting yield losses early in the growing season. O'Donovan and Newman (1990) reported that canola (*Brassica campestris*) yield loss was related to quackgrass densities by the following rectangular hyperbola:

$$yL = 0.41d/[1+(0.41d/141)], R^2 = 0.66$$

where  $yL$  is the percentage canola yield loss and  $d$  is the density of quackgrass in late May or early June. From the model, it can be calculated that canola yield would be reduced by approximately 32% from a quackgrass infestation of about 100 shoots  $m^{-2}$  early in the season. Yield loss predictive models enable growers to make informed management decisions prior to undertaking control measures.

## 2.4. CULTURAL AND CHEMICAL CONTROL OF QUACKGRASS

### 2.4.1. Cultural Control

Merivani and Wyse (1984) observed that over a four-year period tillage decreased quackgrass density by 53% compared to non-tilled plots whereas conventional tillage reduced quackgrass density by 83% compared to non-tilled plots. In reduced tillage plots quackgrass tended to occur in patches rather than over the whole field. Tillage is used to physically break the rhizome, thereby releasing dormant buds from apical dominance (McIntyre 1970). In wet years, repeated cultivations can be used to deplete the food reserves in the rhizomes. In dry

years, rhizomes brought to surface can be desiccated by the sun or frost. However, tillage may deeply bury or spread the rhizomes around the field. For all cases tillage should be started before quackgrass starts to produce new rhizomes.

Competition between weeds and crops is an important factor in weed control. Crop competition influences the growth of quackgrass (Cussans 1968; Williams 1973a; Permin 1985). Williams (1973a) reported the effect of cereals and field beans on quackgrass seedlings. There was little quackgrass seedling growth in cereals whereas more growth occurred in field beans. Rhizome growth was also less under cereal competition. Similarly, Cussans (1968) observed reduced quackgrass growth under rapeseed and cereal competition but not field beans. It appears that early shoot development by cereals could have shaded the quackgrass seedlings and suppressed their growth.

Selection of a sequence of crops that are more competitive and are produced using different agronomic practices may reduce quackgrass in the long term. In Sweden, Landstrom (cited by Kirkland 1987) showed that six year rotations involving only cereals did not reduce quackgrass stands. However, inclusion of potatoes, turnips and fallow in the rotation significantly reduced quackgrass densities. Additional soil disturbances associated with the growth of these crops could have resulted in considerable rhizome desiccation (Kirkland 1987).

Although crop competition significantly reduces the amount of quackgrass rhizomes produced during the growing season, rhizomes continue to grow as the crop matures and after the crop has been harvested (Permin 1985; Cussans 1968). Consequently, crop competition as a means of controlling quackgrass must be integrated with other control measures including the use of herbicides.

#### 2.4.2. Chemical control

Both non-selective and selective herbicides are registered for quackgrass control in Canada. The most commonly used non-selective herbicide is glyphosate, and selective herbicides are sethoxydim and fluazifop-butyl. Other selective herbicides including quizalofop-ethyl, clethodim, haloxyfop-methyl, propanil, etc, are still under experimental use and may be registered for quackgrass control in the near future.

**Glyphosate** (N-(phosphonomethyl)glycine) is a broad spectrum, non-selective, non-residual, postemergence herbicide (Anonymous 1989c). Absorption is through the foliage and the chemical translocates throughout the whole plant. The mode of action of glyphosate is inhibition of aromatic amino acid biosynthesis in plants (Cole 1985).

Good control of quackgrass has been achieved using glyphosate. Quackgrass was controlled at 0.72 and 1.44 kg a.i. ha<sup>-1</sup> (Harvey et al. 1981; Sheppard et al. 1982). O'Keeffe (1981) controlled quackgrass with pre-harvest applied glyphosate at 0.36 to 4.32 kg a.i. ha<sup>-1</sup>. Quackgrass has been controlled by glyphosate at 0.5 to 2.0 kg a.i. ha<sup>-1</sup> (Blair et al. 1982) and at 2.8 kg ha<sup>-1</sup> (Valgardson and Corns 1974). However, the non-selective properties of glyphosate limit its use to just prior to crop emergence or just before or/and after harvest.

**Selective postemergent graminicides** are a relatively new group of herbicides, some of which are now registered for quackgrass control in broad leaved crops. These chemicals include fluazifop-butyl and sethoxydim, both of which provide seasonal control of quackgrass (Anderson 1987). While graminicides provide good initial control of perennial grasses, late season shoot regrowth from rhizomes often occurs. For example, while Hodupp et al. (1984) showed that fluazifop effectively controlled quackgrass in soybean and ornamentals for 13 weeks after application, shoot regrowth from the rhizomes was observed later in the season.

Using <sup>14</sup>C labelled herbicides, Harker and Dekker (1988) reported the distribution of these

compounds in quackgrass rhizomes under controlled conditions. They observed that more of the sethoxydim was located in the distal buds rather than in the crown buds. Because the rhizome buds closest to the mother shoot were dormant and sethoxydim is mainly translocated to the actively growing terminal buds, they did not receive lethal doses of the chemical. Although the number of growing buds was reduced after herbicide application, the remaining buds resumed growth in fall or spring.

Sethoxydim (2[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexe-1-one) and fluazifop (2-(4-[[5-trifluoromethyl]-2-pyridinyl]oxy]phenoxy) propanoic acid), are systemic post emergence herbicides (Anonymous 1989c). Their mode of action is the inhibition of Acetyl-CoA carboxylase, which catalyses an early step in lipid biosynthesis (Anonymous 1989c). They also disrupt cell membrane integrity of susceptible plants (Burton et al. 1987). Dicotyledonous plants are resistant to these chemicals because the acetyl-coA carboxylase enzyme is insensitive to the chemicals.

These chemicals are registered for control of annual and perennial grasses in western Canada (Anonymous 1987b). Graminicides provide quackgrass control for 6 to 8 weeks which allows the crop time to grow and get well established in a weed free environment. Sethoxydim at 0.81 kg a.i. ha<sup>-1</sup> plus 2% (v/v) Assist ( 17% polyol fatty acid esters and polyoxyethylene derivatives and 83% phytobland paraffinic oil), applied to quackgrass in the 1-3 leaf stage provided season-long control of quackgrass in several crops including canola and flax. A rate of 0.5 kg a.i. ha<sup>-1</sup> plus Assist plus analytical grade ammonium sulphate resulted in similar control as the higher rate (Stewart 1987). Sethoxydim at 1 kg a.i. ha<sup>-1</sup> controlled quackgrass for one growing season in soybean (Dekker 1985). At 0.75 kg ha<sup>-1</sup>, sethoxydim gave good quackgrass control in soybean in the year of application (Doll 1985). Effective quackgrass control with fluazifop was achieved at 0.5 kg a.i. ha<sup>-1</sup> (Thiessen 1987), 1 kg a.i. ha<sup>-1</sup> (Dekker 1985) and at

0.75 kg a.i. ha<sup>-1</sup> in several crops including soybean, canola and flax (Anderdon and Sutton 1985). Fluazifop controlled quackgrass in peas for one season and was much more effective (60%) than sethoxydim at comparable rates (Ammisepp and Hallgren 1985).

Two half-rate split applications of fluazifop and sethoxydim resulted in 1.6 times better quackgrass control than corresponding single full rate (Hicks and Jordan 1984). The first application was when quackgrass was at the 3- to 5-leaf stage and the second application was 3-4 weeks after the first application (Thiessen 1987). Increased control from split applications may be due to a greater amount of herbicide translocating into the rhizome of perennial weeds. A single full rate may elicit toxic effects in the plant system which may adversely affect translocation of the herbicide (Hicks and Jordan 1984). The second application may also control the regrowth initiated after removal of apical dominance by the first application.

**Clonal response to herbicides.** Haddad and Sagar (1968) reported that four clones of quackgrass displayed different dose responses to shoot and root application of dalapon and amino-triazole. Rhizome production was inhibited at 0.01 ppm of dalapon for the most susceptible clone while the most tolerant clone required 100 ppm. The most susceptible clone required 0.01 ppm of amino-triazole to inhibit rhizome production while the most tolerant required 10 ppm.

Differential quackgrass response to sethoxydim has been reported in Eastern Canada (Sampson 1987). Percent mortality in quackgrass ranged from 24 to 92%. Although the plants differed in colour, leaf area, tiller number, degree of pubescence, rhizome biomass, size and growth habit, herbicide response could only be correlated with the rhizome bud number. Clones with higher bud number tended to be more tolerant. The author concluded that in plants which had a higher number of buds, there may be some buds which do not receive a lethal dose of the chemical.

Alcantara et al. (1989) also reported a differential response of quackgrass clones to

sethoxydim and haloxyfop. Shoot regrowth varied from 0 to 50% for sethoxydim and 3.5 to 62% for haloxyfop. Differences in herbicide response were associated with number of crown buds. Clones with the greatest number of crown buds were the most difficult to control.

It is not possible to achieve complete control of quackgrass with only one control method. Integration of all control methods is required to achieve satisfactory long term quackgrass control. Chemical control methods should be supplemented by tillage, rotation and growing of competitive crops so that quackgrass is continuously pressured throughout the growing season.

### 3. QUACKGRASS (*Elytrigia repens* (L.) Nevski) INTERFERENCE IN FLAX (*Linum usitatissimum* L.)

*Abstract.* Field experiments were conducted in 1988 and 1989 to determine the influence of quackgrass interference on flax growth and seed yield in Manitoba. A stratified random sampling design was used to monitor quackgrass dynamics in three commercial flax fields. Each site was systematically sampled at 30, 70 and 100 days after planting (DAP). In both years, quackgrass densities increased from 62 shoots m<sup>-2</sup> 30 DAP to 138 shoots m<sup>-2</sup> 100 DAP. Rhizome biomass increased from 5.6 g m<sup>-2</sup> 30 DAP to 46.9 g m<sup>-2</sup> 100 DAP. Most of the quackgrass rhizome biomass was accumulated late in the season as the crop matured. The major flax variates affected by quackgrass interference were flax straw biomass and bolls. Results indicate that quackgrass competition causes substantial yield losses in flax. These losses were described by the rectangular hyperbolic equation  $y = 2.07x/(1+2.07x/130)$ , where  $y$  = flax seed yield loss (%) and  $x$  = quackgrass density 30 days after planting (shoots m<sup>-2</sup>). Based upon the derived yield loss equation, a quackgrass density of 62 shoots m<sup>-2</sup>, the average density recorded 30 DAP, would result in a 65% reduction in flax seed yield at crop harvest.

## INTRODUCTION

Quackgrass is the most troublesome perennial grass weed in Canadian field crops. In Manitoba, Thomas and Wise (1988) ranked quackgrass as the 12<sup>th</sup> most abundant weed of field crops in the 1986 weed survey. Quackgrass occurred in 15.0% of the fields surveyed at mean densities of 8.4 shoots m<sup>-2</sup> after herbicide application. In flax fields surveyed, 25% were infested with quackgrass at densities ranging from 0.2 to 99 shoots m<sup>-2</sup>.

While there have been only two detailed studies on crop losses due to quackgrass in

Western Canada (Wilcox and Morrison 1988; O'Donovan and Newman 1990), wide ranging yield losses due to quackgrass infestations have been reported. A Manitoba agriculture fact sheet indicated that quackgrass densities of up to 167 shoots m<sup>2</sup> reduced barley yields by between 14 and 75%, while densities of 42 shoots m<sup>2</sup> reduced yields of canola by 22% and wheat by 60% (Anonymous 1989b).

O'Donovan and Newman (1990) reported that the relationship between canola yield loss and quackgrass shoot density in spring was described by the following hyperbolic equation:

$$YL = 0.41d/[1+0.41d/141], R^2 = 0.66,$$

where YL = canola yield loss and d = quackgrass density (shoots m<sup>2</sup>). The equation predicts a canola yield loss of 32% due to a spring quackgrass density of 100 shoots m<sup>2</sup>. Wilcox and Morrison (1988) reported a 25% reduction in spring wheat yield due to quackgrass infestation of close to 200 shoots m<sup>2</sup> at crop harvest.

Manitoba is the major flax growing province in Canada, producing more than 50% of total production in the country (Anonymous 1987c). Despite the seriousness of the quackgrass problem in flax, there is no published information on the response of this crop to quackgrass competition. Since flax is a poor competitor (Marshall et al. 1989), more severe yield losses are expected than those recorded in wheat, barley and rapeseed, which are relatively more competitive (Anonymous 1989b; Wilcox and Morrison 1988; O'Donovan and Newman 1990). Growers need information on the influence of quackgrass on the flax yield so that they can make rational management decisions early in the growing season before any control measures are effected. As such, a study was conducted to determine the influence of quackgrass interference on flax growth and seed yield.

## MATERIAL AND METHODS

In southwest Manitoba, three commercial flax fields infested with quackgrass were surveyed using a dynamic stratified random sampling design (Figure 1). This design was used because of large variation between sampling units (Snedecor and Cochran 1980). Sampling units within a plot were grouped into strata and were then selected randomly from each stratum. The grouping was in such a way that variability between sampling units within a stratum was smaller than that between strata. When each stratum is sampled over time the sampling is referred to as dynamic stratified random sampling. The patchy growth nature of quackgrass warranted the use of such a design.

In 1988, one field was surveyed near Portage la Prairie (Trimble) while in 1989 two fields were surveyed at the University of Manitoba field station (UM) and at the Integrated Crop and Pest Management Services field station (ICMS), Portage la Prairie. At the UM site, Norlin flax was planted while at the other two sites the fields were seeded to McGregor flax.

Immediately after planting, an area with varying quackgrass densities was selected and a 1 m<sup>2</sup> permanent grid system was superimposed over an area of 324 m<sup>2</sup> using twine (Figure 1). The selected area was divided into 9 strata of 36 m<sup>2</sup> each. Each strata had 18 possible sampling plots of which six were sampled at each sampling date. Each plot was only sampled once.

Weed control was achieved by a combination of conventional commercial farm practices appropriate for the whole field and by hand-weeding. Broadleaved weeds were controlled by application of bromoxynil (3,5-dibromo-4-hydroxybenzotrile) (0.28 kg a.i. ha<sup>-1</sup>) and MCPA ester (4-chloro-2-methylphenoxy) acetic acid) (0.28 kg a.i. ha<sup>-1</sup>). At the UM site annual grass weeds were controlled by application of diclofop-methyl (2-[4-(2,4-dichlorophenoxy) phenoxy] propanoate) (0.73 kg a.i. ha<sup>-1</sup>). In other sites annual grasses and late emerging weeds were hand-weeded.

At each sampling date, 30, 70 and 100 days after planting (DAP), a 1/4 m<sup>2</sup> quadrat

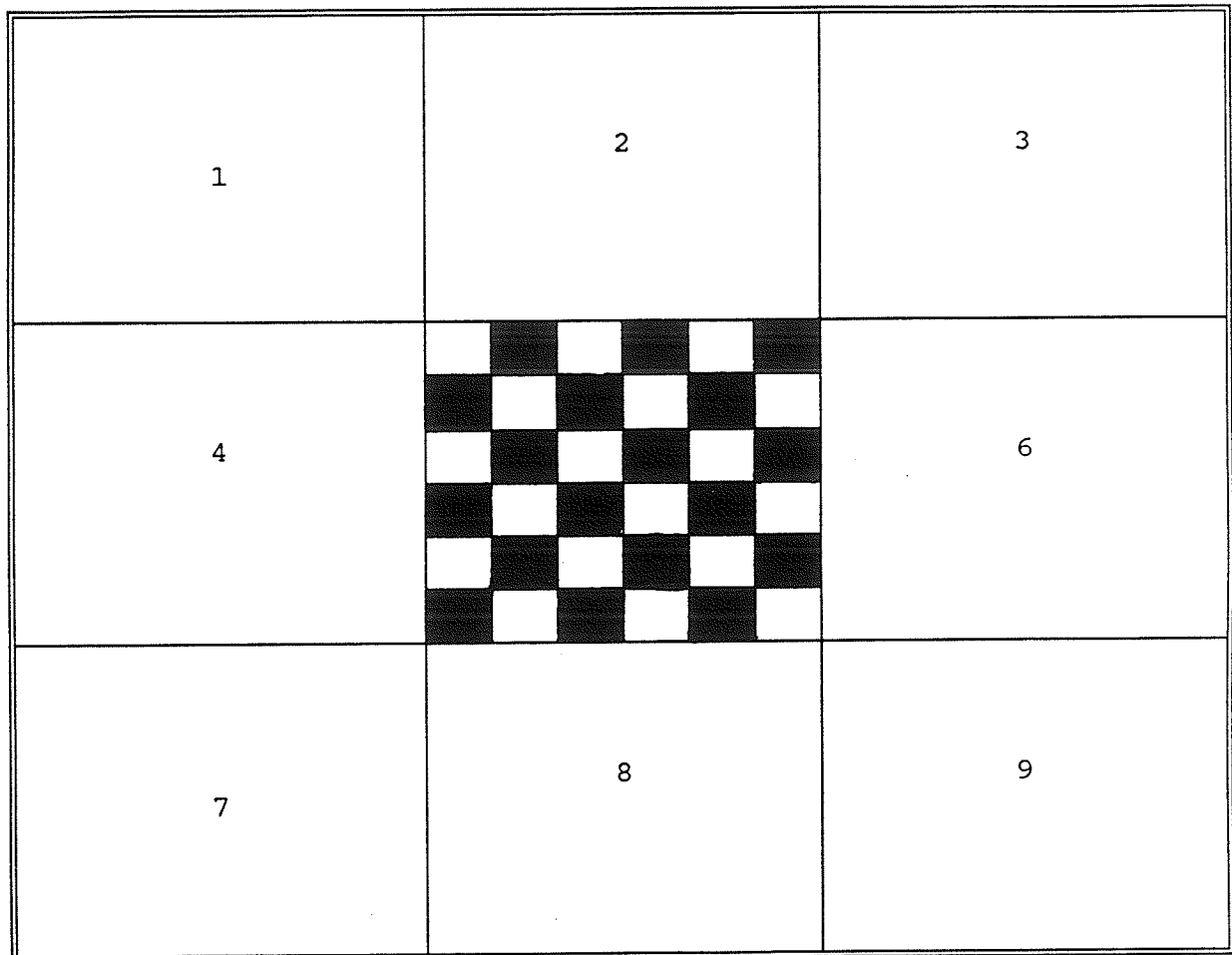


Figure 1. Experimental plan illustrating the stratified random sampling design. The centre strata illustrates the checkerboard pattern of sampling in which only diagonal grid squares are randomly sampled at each harvest.

was placed in the centre of its allocated 1 m<sup>2</sup> grid square and all quackgrass shoots and flax were clipped at ground level. Rhizomes were recovered from the soil to a depth of at least 15 cm. A checker board pattern was used during which only diagonal grids were sampled at each date (Figure 1). The vegetative plant material was separated by species and various variates were determined. For quackgrass, rhizome length, node number, rhizome biomass, shoot number, height and biomass were determined. Stem density (branches m<sup>-2</sup>) and biomass of flax were determined. At crop maturity boll number and seed yield were also determined. Biomass was determined by oven-drying the plant materials at 80 C for at least 24 hours.

Results from all sites were converted to a 1 m<sup>2</sup> basis and results from each strata were pooled and averaged to facilitate comparison between each strata. Linear and non-linear regression procedures were used to relate quackgrass variates to flax variates at each harvest date.

**Yield loss determination.** Results from the three commercial flax fields and two untreated research plots (see Chapter 4) were pooled to generate the yield loss equation using derivative free non-linear procedures (proc nonlin, method dud, SAS V5) (Frued and Little 1986). A rectangular hyperbolic model was used to describe the relationship between flax seed yield and quackgrass shoot density at crop harvest (Cousens et al. 1984). Relative flax yield was determined by fitting data from individual sites to a rectangular hyperbola and extrapolating the "Y" intercept to a 100% yield and adjusting the flax yields from that site accordingly. To relate spring quackgrass shoot densities (30 DAP) to flax yield losses occurring at crop harvest, quackgrass shoot densities at crop harvest were divided by the average quackgrass shoot increase over the growing season calculated from the five sites. The resulting dataset was also fitted to a rectangular hyperbolic model (Cousens et al. 1984).

**Meteorological data.** In both years temperature and precipitation were recorded for the months

of May, June, July, August and September and plotted in a seasonal subseries graph (Cleveland and Terpenning 1982). A horizontal line portrays the mean of the season. The individual monthly values are portrayed by the ends of the vertical bars. The 30 year temperature and precipitation means were also plotted (Figure 2).

## RESULTS AND DISCUSSION

All sites differed from one another in several respects (e.g., cultivars and quackgrass stand) although in most cases the influence of quackgrass on flax followed a similar general trend. The ICMS site had significantly higher flax density (571 plants  $m^{-2}$ ) compared to the UM and Trimble sites (310 and 344 plants  $m^{-2}$ , respectively) 30 DAP. However, at the UM and Trimble sites flax had 1.3 times as many branches as that at the ICMS (data not shown). Most branching occurred in the growth period between germination and 30-70 DAP.

Flax density was not significantly affected by quackgrass competition at any of the sampling harvesting dates (Figure 3). Young et al. (1982) reported that soybean density was not affected by increasing densities of quackgrass either.

The average quackgrass density 30 DAP was 62 shoots  $m^{-2}$  (Table 2). Quackgrass shoots increased more than two-fold during the growing season. Most of the shoot increase was observed in growth period 30-70 DAP. Quackgrass shoot biomass increased eight-fold over the season. Length, node number and biomass of quackgrass rhizomes increased 5- to 12-fold during the growing season (Table 2). During the last interval these quackgrass variates more than tripled at all but the Trimble site. Dry weather during crop ripening in 1988 could have checked quackgrass growth at that site (Figure 2). Quackgrass mostly headed during the 30-70 DAP interval and further increases in head number was not substantial during the later part of the season.

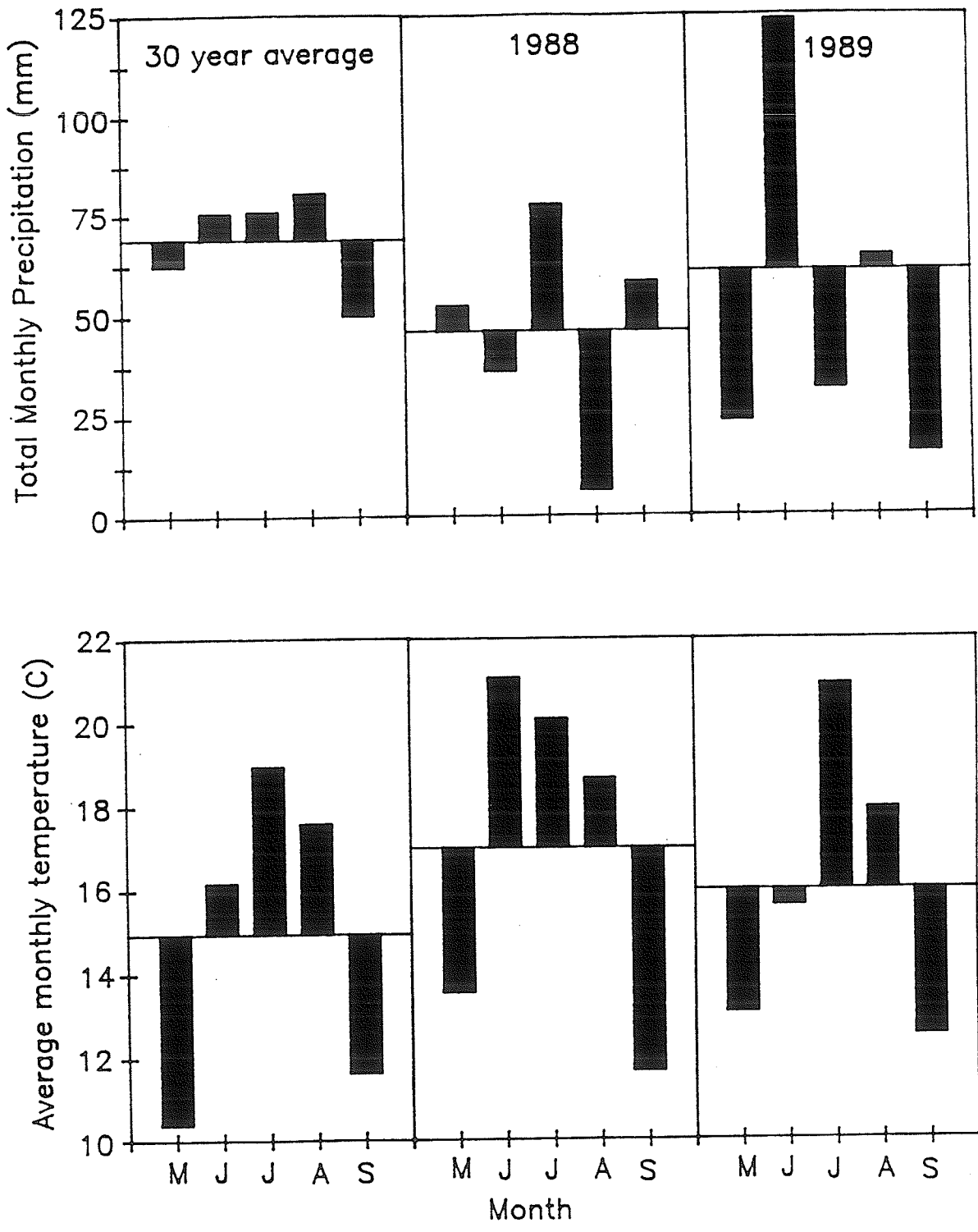


Figure 2. Total monthly precipitation and mean monthly temperatures for Portage la Prairie during 1952-82, 1988 and 1989.

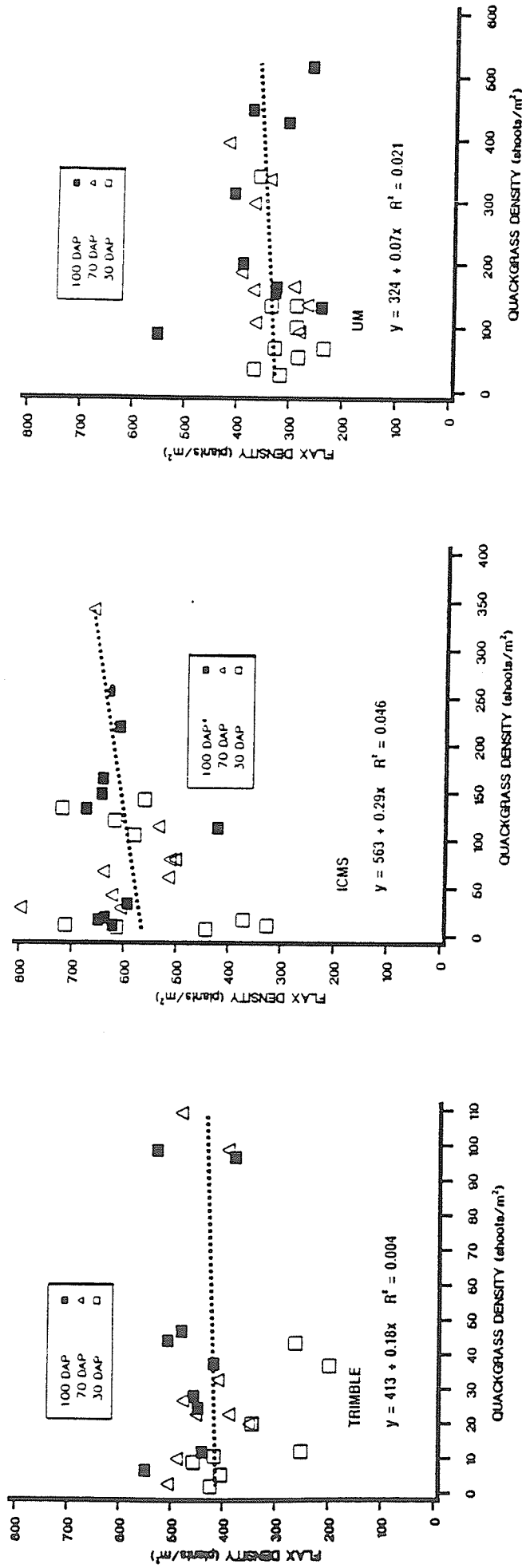


Figure 3. Effect of quackgrass density (shoots m<sup>-2</sup>) on flax density (plants m<sup>-2</sup>).

Table 2. Mean quackgrass variates over the growing season (standard errors in the parentheses)

DAP	rhizome			shoots			heads		
	length cm m <sup>-2</sup>	nodes no. m <sup>-2</sup>	biomass g m <sup>-2</sup>	number no. m <sup>-2</sup>	biomass g m <sup>-2</sup>	number no. m <sup>-2</sup>	biomass g m <sup>-2</sup>	number no. m <sup>-2</sup>	biomass g m <sup>-2</sup>
UM site									
30	1012 (437)	424 (189)	10.7 (4.2)	105.8 (31.8)	9.2 (3.8)	0	0	0	0
70	2131 (475)	840 (187)	25.4 (6.1)	207 (35.6)	83.9 (16.4)	42.3 (11.1)	5.6 (1.6)	42.3 (11.1)	5.6 (1.6)
100	5405 (986)	2418 (402)	76.8 (14.0)	274.3 (52.5)	177.4 (34.5)	45.0 (11.5)	7.9 (2.2)	45.0 (11.5)	7.9 (2.2)
ICMS site									
30	403 (145)	130 (44.3)	3.8 (1.5)	61.2 (20.3)	18.2 (6.4)	0	0	0	0
70	1394 (285)	455 (86.0)	18.9 (3.2)	93.4 (32.3)	68.9 (22.4)	12.2 (4.2)	2.3 (0.8)	12.2 (4.2)	2.3 (0.8)
100	3509 (655)	1502 (273)	49.9 (11.7)	97.7 (25.7)	86.1 (27.5)	11.2 (4.7)	1.5 (0.7)	11.2 (4.7)	1.5 (0.7)
Trimble site									
30	247 (66.5)	94 (28.1)	1.8 (0.5)	17.8 (4.7)	1.7 (0.4)	0	0	0	0
70	652 (222)	250 (87.0)	20.3 (8.6)	38.4 (12.8)	17.4 (5.7)	1.0 (0.4)	0.1 (0.09)	1.0 (0.4)	0.1 (0.09)
100	616 (205)	258 (81.0)	13.7 (4.4)	44.5 (11.1)	19.6 (5.9)	1.0 (.2)	0.2 (0.08)	1.0 (.2)	0.2 (0.08)

DAP - days after planting

Flax biomass increased 20-30 times during the 30-70 DAP growing interval and increased further, during the last interval by 1.22 times (Figure 4; Table 3). The period when there was no substantial increase in flax biomass coincided with the period when quackgrass accumulated most of its rhizome biomass. For example at the UM site, this was during crop maturity when crop competition is relatively less due to senescence. Similar results were reported by Cussans (1968) and Permin (1985) who observed rapid quackgrass growth during wheat, barley and rapeseed maturity.

The influence of increasing quackgrass density on flax biomass at each harvest date was best described by linear regression equations (Figure 4; Table 3). Quackgrass competition had little effect on flax growth during the first 30 DAP. Although flax biomass increased up to 30-fold during the 30-70 DAP interval, the competitive effect quackgrass was observed during this period. During the final stages of crop growth, the effect of quackgrass on flax biomass was similar to that observed for the 30-70 growth interval.

Increasing quackgrass densities had significant effects on flax seed yield (Figure 5; Table 4). Linear regression equations provided the best fit for the individual sites. However, at the ICMS and Trimble sites where quackgrass infestation levels were low the relationship between quackgrass density and seed yield was poor as shown by the very low  $R^2$ . The reduction in seed yield may be ascribed to the significant reduction in flax biomass (Figure 4), boll number and boll biomass (Figure 6). As previously indicated flax plant density (Figure 3) and a thousand kernel weight were not significantly affected by increasing quackgrass density (data not shown).

**A generalized model of quackgrass interference in flax.** To describe the relationship between flax seed yield loss and quackgrass shoot density relative flax yield was calculated for five individual sites; three from the survey sites described in this Chapter and two from experiments reported in Chapter 4. The resulting data were fitted to a rectangular hyperbolic model

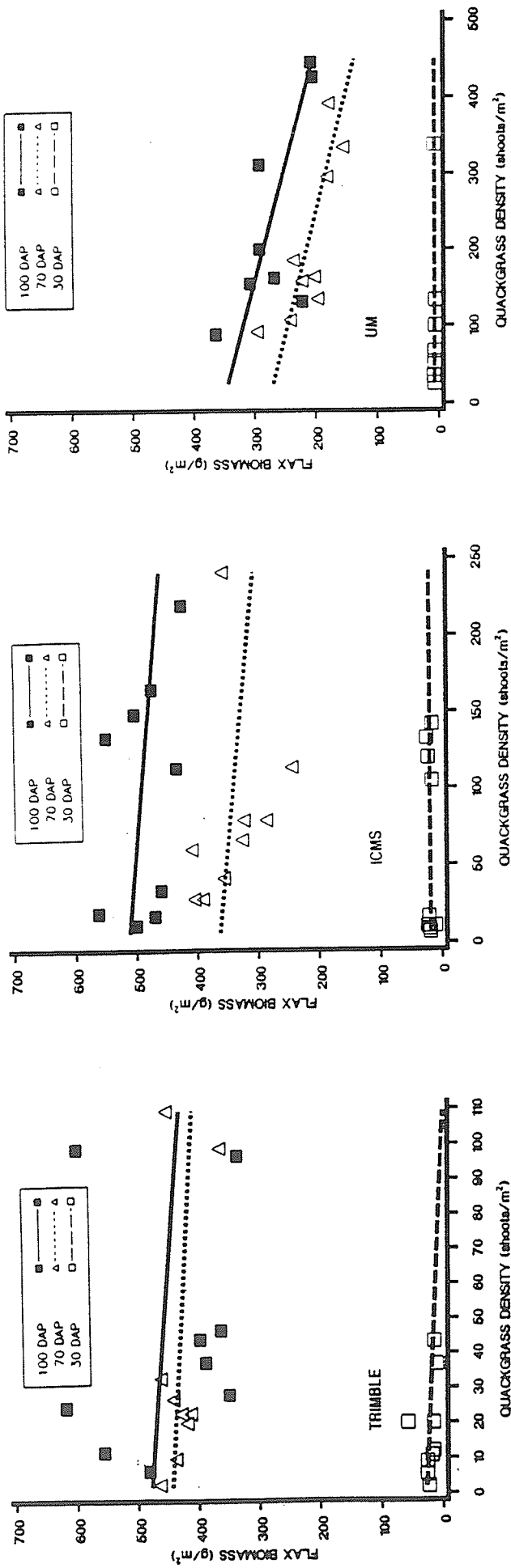


Figure 4. Effect of quackgrass density (shoots m<sup>-2</sup>) on flax biomass (g m<sup>-2</sup>)

Table 3. Parameter estimates for the relationship between flax biomass in grams  $m^{-2}$  (y) and quackgrass density (shoot  $m^{-2}$ ) (x) following the model  $Y = a + bx^*$  (standard errors in parentheses)

Harvest date	a	b	R <sup>2</sup>
<u>TRIMBLE</u>			
30	26.88 (8.13)	-0.24 (0.37)	0.058
70	444.3 (14.81)	-0.29 (0.28)	0.135
100	478.8 (68.79)	-0.41 (1.26)	0.014
<u>ICMS</u>			
30	18.9 (2.39)	0.0035 (0.63)	0.002
70	364.0 (31.55)	-0.240 (0.31)	0.090
100	513.0 (26.56)	-0.220 (0.22)	0.120
<u>UM</u>			
30	6.58 (0.51)	0	0.001
70	277.16 (21.43)	-0.311 (0.09)	0.614
100	352.10 (30.02)	-0.33 (0.06)	0.623

\*a is the intercept, b is the linear regression coefficient

and R<sup>2</sup> the coefficient of determination

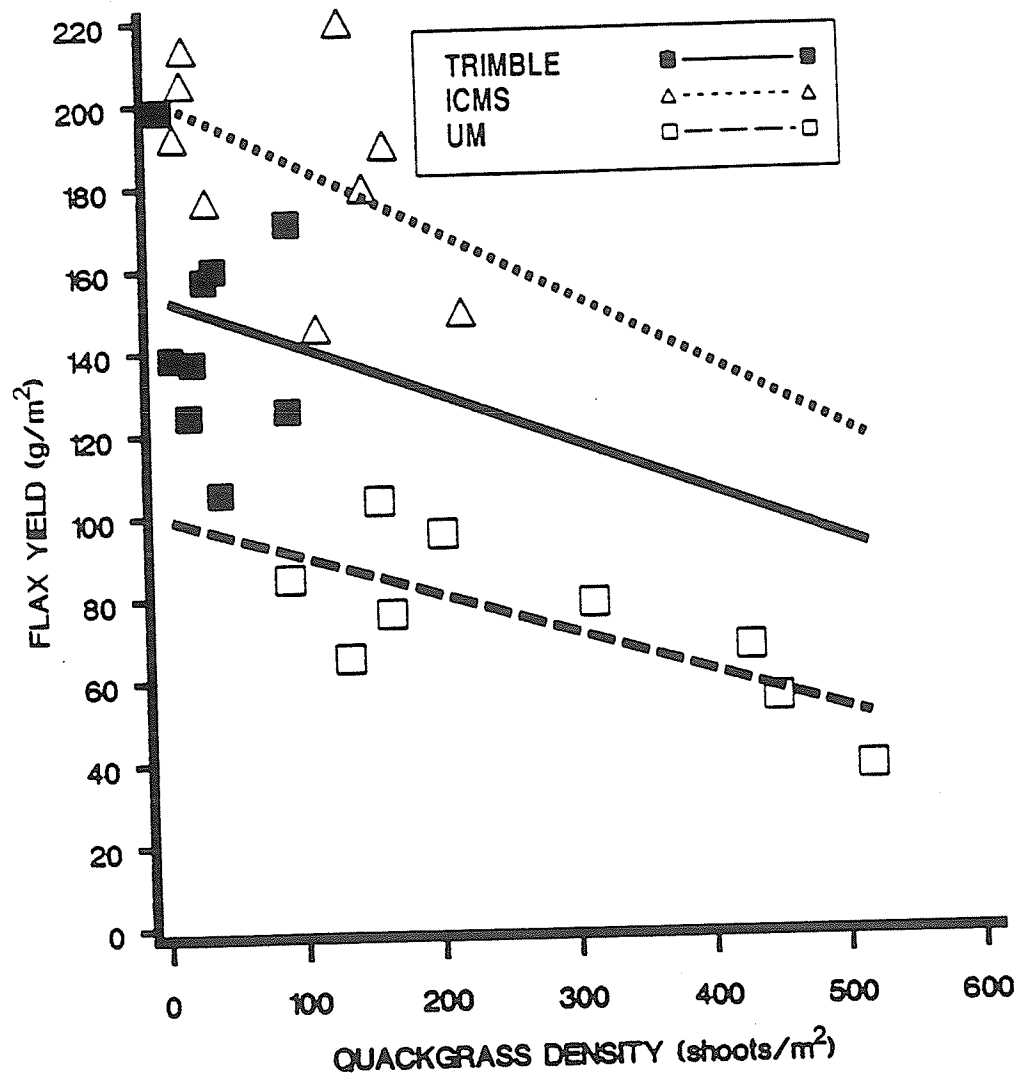


Figure 5. Relationship between quackgrass density (shoots m<sup>-2</sup>) and flax seed yield (g m<sup>-2</sup>)

Table 4. Parameter estimates for the relationship between flax seed yield in grams  $m^{-2}$  (y) and quackgrass density (shoot  $m^{-2}$ ) (x) following the model  $y = a + bx$  (standard errors in parentheses)

Site	a	b	R <sup>2</sup>
UM	99.80 (10.11)	-0.095 (0.032)	0.550
ICMS	201.56 (13.72)	-0.161 (0.112)	0.230
TRIMBLE	153.32 (17.28)	-0.119 (0.317)	0.019

\*a is the intercept, b is the linear regression coefficient and R<sup>2</sup> the coefficient of determination

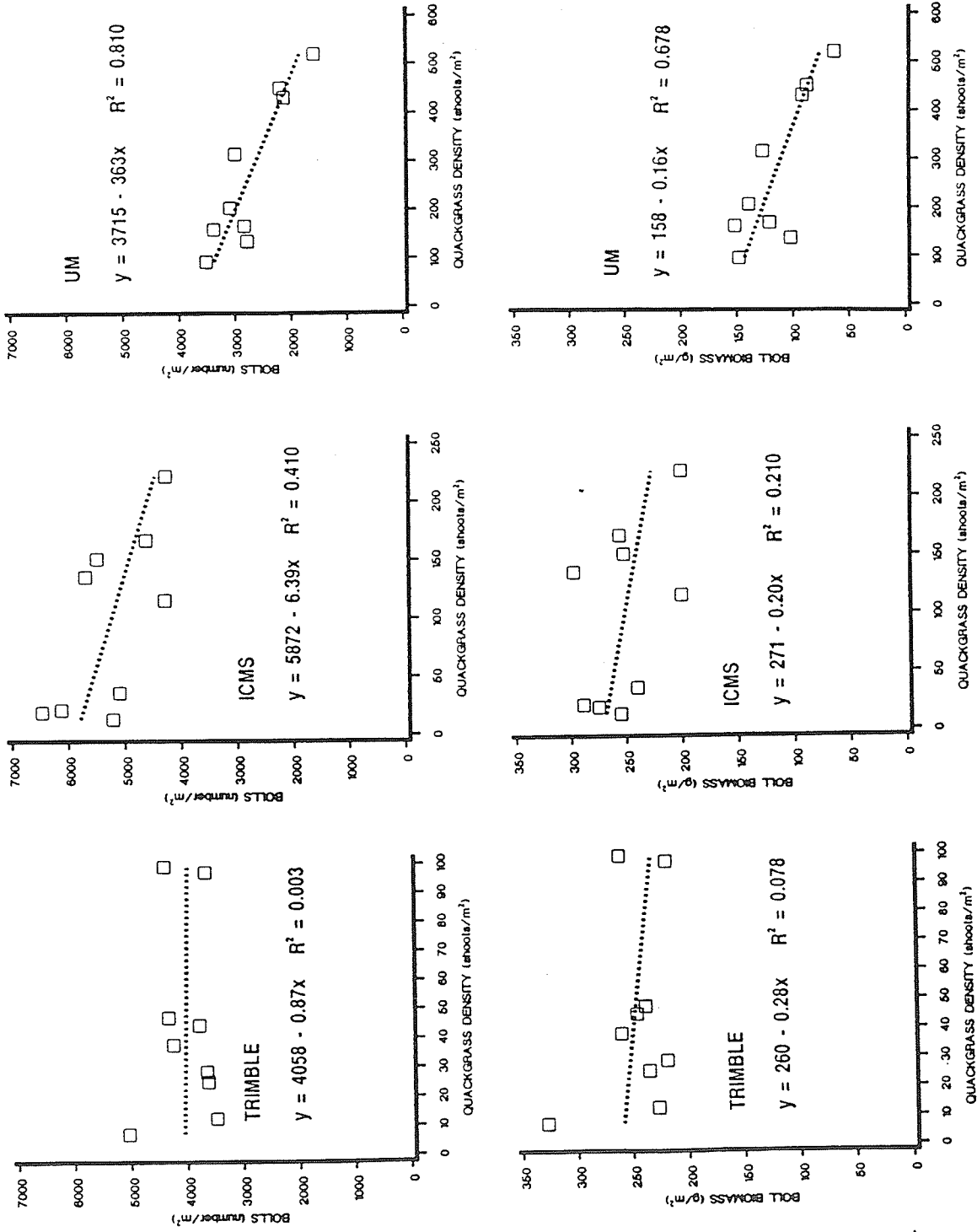


Figure 6. Effect of quackgrass density (shoots m<sup>-2</sup>) on flax bolls (number m<sup>-2</sup>) and biomass (g m<sup>-2</sup>)

(Figure 7). The data were also fitted to a quadratic regression model. In both cases an  $R^2$  of 0.42 was obtained indicating that both models equally fitted the data. However, the quadratic regression model predicted a yield loss of 4.5% when there was no quackgrass and was less biologically relevant. Consequently, only the rectangular hyperbolic model is included in further discussion.

During the 30-100 DAP growing interval it was calculated that, on average, quackgrass shoot densities at the five sites increased 10.9-fold (data not shown). Combined with quackgrass shoot densities 100 DAP, this factor was used to calculate quackgrass shoot densities 30 DAP. The resulting dataset was used to develop a hyperbolic model describing the relationship between flax yield loss and quackgrass shoot density 30 DAP (Figure 8). For example, using this equation it can be predicted that the average quackgrass density of 62 shoots  $m^{-2}$  30 days after planting would result in a 65% flax yield loss at harvest.

From the generalized models comparing flax yield losses to canola (O'Donovan and Newman 1990) and wheat (Wilcox and Morrison 1988), it is clear that canola and wheat are less affected by quackgrass interference (Figure 9). At quackgrass densities of 100 shoot  $m^{-2}$  canola and wheat would be reduced by 30% and 36%, respectively. Flax yield losses at these quackgrass densities would be about 80% indicating that wheat and canola are more competitive than flax. In large part, the greater competitiveness of canola and wheat is related to denser canopy structures compared to flax.

The hyperbolic model used to describe flax yield losses in this study differs from the linear model used to describe yield losses in barley (Rioux 1982). Quackgrass shoot densities reported in the barley study were low (300 shoots  $m^{-2}$ ) and could be within the linear range of the hyperbolic model at low weed densities (Cousens et al. 1984). In this study quackgrass densities of up to 1500 shoots  $m^{-2}$  were observed. It can be reasoned that the hyperbolic model

best describes yield losses when weed densities are high while at low weed densities other models such as linear regression may provide better yield loss description.

Coupled with weed survey data, the generalized model developed in this thesis could be useful in predicting crop losses due to weeds in southern Manitoba and, in the absence of more definitive data, for western Canada recognizing that cultural practices and regional differences in growing conditions occur across the prairies.

To improve such yield loss models the importance of various factors that affect the competitiveness of quackgrass should be addressed. O'Donovan et al. (1985) demonstrated that the relative time of emergence of wild oats can influence its competitive effects on crop yield. This is one factor that could be studied to improve the yield loss model. Similarly, in spring wheat, Morrison et al. (1990) reported that relative quackgrass (quackgrass culm number / quackgrass culm number plus wheat culm number) was a better indicator of wheat yield losses than quackgrass shoot counts alone. While the present study did not show that flax affected the competitiveness of quackgrass, additional research is required to confirm this observation. An understanding of the relative roles of soil fertility, different moisture regimes, cultural and tillage practices, etc., on the competitiveness of quackgrass would also be beneficial in improving the yield loss model.

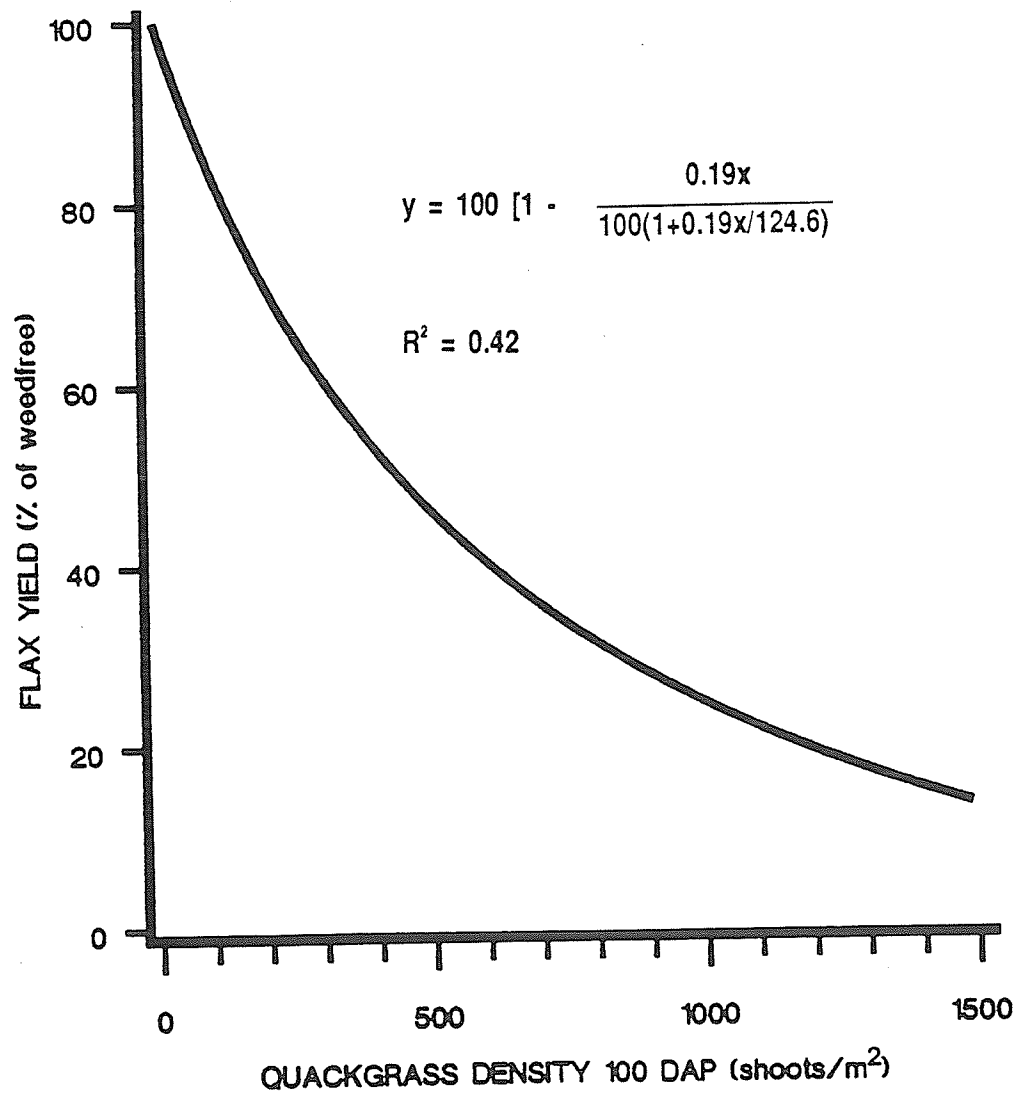


Figure 7. Relationship between quackgrass density 100 DAP (shoots m<sup>-2</sup>) and flax yield (g m<sup>-2</sup>)

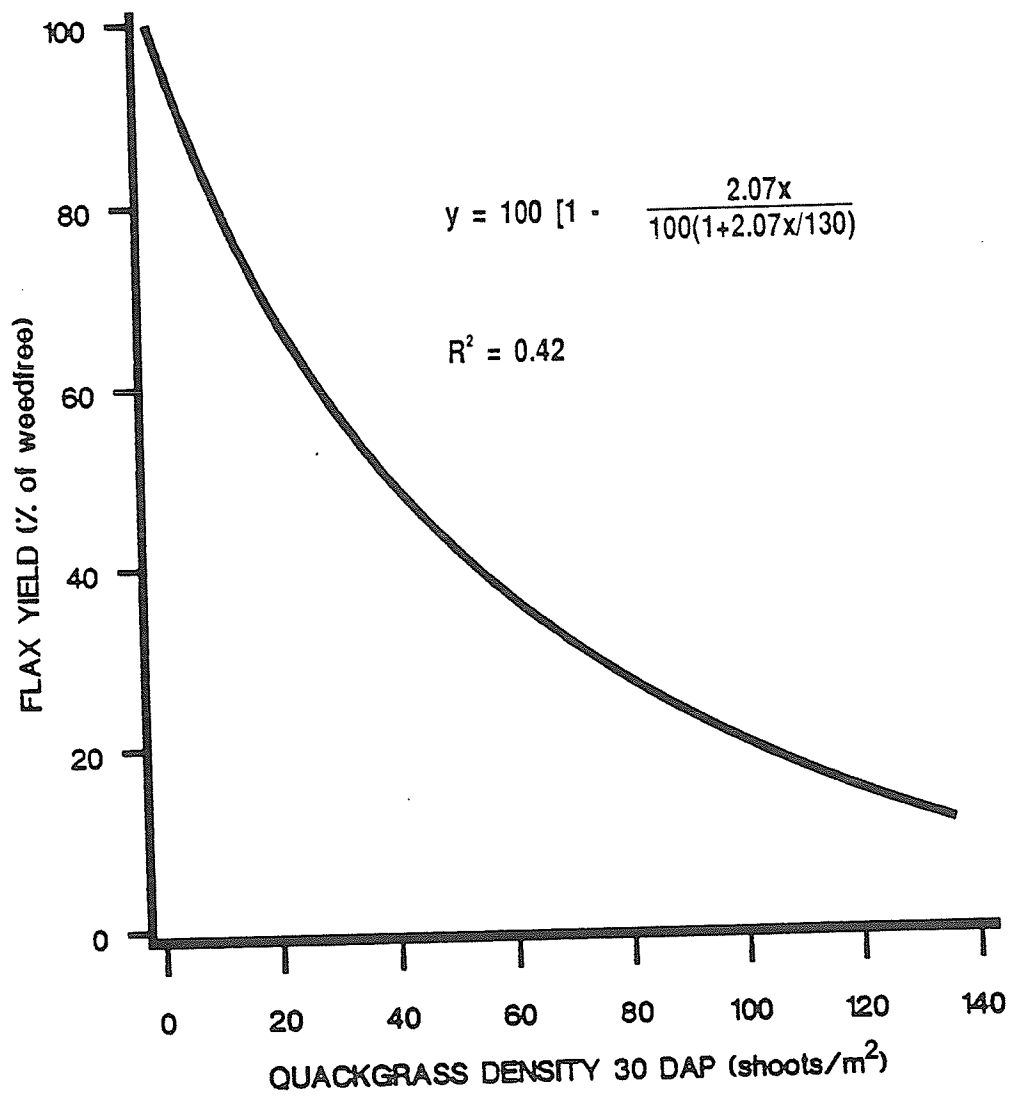


Figure 8. Relationship between quackgrass density 30 DAP (shoots m<sup>2</sup>) and flax yield (g m<sup>2</sup>)

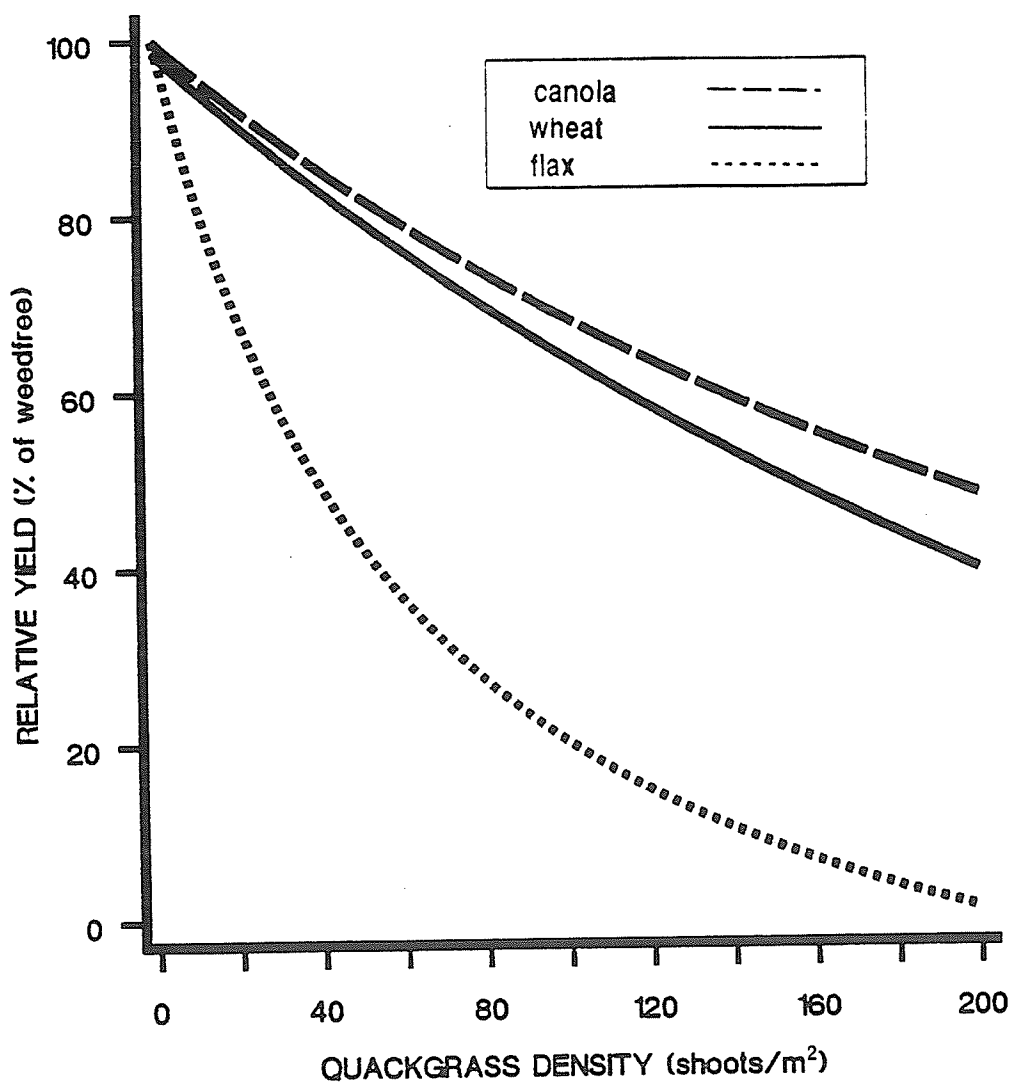


Figure 9. Generalized model comparing the relationship between quackgrass shoot density and yield losses in flax, canola and wheat. Adopted from O'Donovan and Newman (1990) and Wilcox and Morrison (1988).

#### 4. THE EFFECT OF SETHOXYDIM ON GROWTH AND COMPETITIVENESS OF QUACKGRASS (*Elytrigia repens* (L.) Nevski) IN FLAX (*Linum usitatissimum* L. 'Norlin')<sup>1</sup>.

*Abstract.* The effect of 0.81 kg ha<sup>-1</sup> sethoxydim plus 2% (v/v) Assist (17% polyol fatty acid esters and polyoxyethylene derivatives and 83% phytobland paraffinic oil) on quackgrass shoot density, rhizome node number and biomass, and regrowth the following spring was investigated under competitive and non-competitive situations at Portage la Prairie, Manitoba in 1988 and 1989. Quackgrass was sampled at three- to four-week intervals throughout the growing season. Sethoxydim suppressed the growth of quackgrass for eight weeks, and regrowth was less in plots sown to flax than in uncropped plots. In the absence of flax competition, sethoxydim reduced quackgrass shoot density at the end of the growing season by 67% in 1988 and 93% in 1989 compared to untreated plots. In plots seeded to flax, sethoxydim reduced quackgrass shoot density at crop harvest by 94% in 1988 and 97% in 1989. Reductions in shoot densities were associated with corresponding reductions in rhizome nodes and biomass. Although sethoxydim effectively reduced rhizome buds, proportionately more of the treated buds sprouted the following spring. In treated plots, approximately 60% of the buds sprouted compared to 28% in the untreated plots. The results indicate that flax competition contributes to the effective suppression of quackgrass by sethoxydim.

#### INTRODUCTION

Quackgrass can cause substantial yield losses in crops. As discussed in Chapter 3, the

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<sup>1</sup>Data presented in this Chapter was awarded first place in the poster competition at the 1989 Expert Committee on Weeds (Western section) meeting in Banff, Alberta, 28-30 November.

losses can be quite severe in a relatively non-competitive crops like flax compared to more competitive crops such as canola and wheat. The severity of yield losses reported in Chapter 3 underscores the necessity of controlling quackgrass in flax.

Effective control of quackgrass may be attained by utilizing an integrated program of cultural control methods such as tillage (Merivani and Wyse 1984), summerfallow and crop competition (Permin 1985). However, the vigour and persistence of quackgrass rhizomes generally requires the use of herbicides which kill the rhizomes in addition to killing the shoots. Although certain herbicides translocate to quackgrass rhizomes, the majority of the rhizome buds are dormant (Johnson and Buchhertz 1964) and as a result are hard to kill.

Glyphosate is extensively used for quackgrass control in western Canada. Valgardson and Corns (1973) applied glyphosate at  $2.8 \text{ kg ha}^{-1}$  to control quackgrass prior to planting winter rye and oats. Treated plots seeded to rye and oats had significantly lower quackgrass densities compared to uncropped plots. Quackgrass control was equally good whether glyphosate was applied in the fall or spring, and crop competition contributed to the control of quackgrass.

Although glyphosate controls quackgrass for more than one growing season (Dekker 1985), the non-selective properties of the chemical limit its use to prior to crop emergence and to when the crop has matured or been harvested. The high cost of glyphosate coupled with some application risks, (e.g., drift from aerial applications) also limits the use of the chemical.

Selective graminicides are a new group of herbicides for quackgrass control in broad-leaved crops. They have certain advantages over glyphosate in that they offer the possibility of a rescue treatment to control quackgrass selectively in the crop. These compounds also have an economic advantage in that they can be used in emerged crops to control both quackgrass and emerged annual grasses (Anderson 1987). Generally the pyridinyloxyphenoxypropionates (e.g., fluazifop-butyl, haloxyfop-methyl) provide better better quackgrass control than the

cyclohexanediones (e.g., sethoxydim, cloproxydim, cycloxydim) (Ammisssepp and Hallgren 1985).

Friesen (1989) applied clethodim, quizalofop and propaquizafop at various rates to control quackgrass in non-cultivated land. He observed variable quackgrass control depending on the rate used. Harker (1989) observed similar results with sethoxydim, clethodim and quizalofop, with higher rates reducing quackgrass densities to a greater extent. Split applications of the higher dosages resulted in control equal to or better than a single application. Despite the fact that selective graminicides offer good initial quackgrass control, late season shoot regrowth often occurs (Hodupp et al. 1984), resulting in these chemicals generally being effective for only one growing season.

Although selective graminicides are widely used in western Canada, there has been no detailed investigation into the efficacy of specific graminicides currently recommended for quackgrass control in flax. This study was conducted in 1988 and 1989 to determine the effect of sethoxydim on quackgrass shoot density, rhizome node number and biomass, and regrowth the following spring in a competitive and non-competitive situation.

## MATERIALS AND METHODS

**General field operations.** In 1988 and 1989, field experiments were conducted at the University of Manitoba field station, Portage la Prairie, on a Neuhorst clay loam soil composed of 25% sand, 44% silt and 31% clay with an organic matter content of 8.5% and pH of 7.3.

The experiments were conducted in a field artificially infested with quackgrass. Quackgrass seed obtained from D. Derksen, Agriculture Canada, Indian Head, was seeded 3 cm deep in rows 15 cm apart. Quackgrass was allowed to establish for one year in the absence of a crop prior to initiation of the experiment. The area was cultivated twice on May 8 in 1988 and May 9 in 1989. Flax (cv. Norlin) was sown at 40 kg ha<sup>-1</sup> on May 16 in both years. The seed

was placed 3 cm deep in rows 15 cm apart. Prior to seeding, ammonium phosphate fertilizer (23-24-00) was broadcast at 217 kg ha<sup>-1</sup> over the experimental area. Prior to crop emergence a permanent grid system was superimposed over the experimental plots using twine, with each quadrat measuring 0.5 by 0.5 m.

The experiment design was a randomized complete block with seven replications in 1988 and six replications in 1989. There were four treatments consisting of quackgrass alone and quackgrass growing in competition with flax, with the quackgrass in each situation either treated or not treated with sethoxydim. Plot size was 12 m x 14 m. On May 23 (both years), flax was removed from the crop-free treatments by handweeding. Sethoxydim at 0.81 kg a.i. ha<sup>-1</sup>, with 2% (v/v) Assist (17% polyol fatty acid esters and polyoxyethylene derivatives and 83% phytobland paraffinic oil), was applied when the quackgrass was at the 3- to 4-leaf stage on June 1, and 4- to 6-leaf stage on June 21 in 1988 and 1989, respectively. The herbicide was applied using a bicycle sprayer delivering a spray volume of 123 L ha<sup>-1</sup> at 310 kPa. The herbicide was applied in the evenings when it was cool. Maximum and minimum air temperatures on the day of treatment were 30.6 and 18.0 C (1988), and 24.4 and 17.3 C (1989). Maximum and minimum air temperatures one day after treatment were 30.2 and 16.2 C (1988), and 25.7 and 13.5 C (1989)

Control of other weeds was achieved using a combination of herbicides selected to minimise injury either to the quackgrass or the crop. In both years, diclofop-methyl (2-[4-(2,4-dichlorophenoxy)phenoxy] propanoate) (0.71 kg a.i. ha<sup>-1</sup>) was applied twice early in the growing season to control annual grass weeds. In both years broad-leaved weeds were removed by spraying with a tank mixture of bromoxynil (3,4-dibromo-4-hydroxybenzotrile) (0.28 kg a.i. ha<sup>-1</sup>), MCPA ester (4-chloro-2-methylphenoxy)acetic acid) (0.28 kg a.i. ha<sup>-1</sup>), plus thifensulfuron (methyl-3-[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]-2-

thiophenecarboxylate) ( $0.008 \text{ kg a.i. ha}^{-1}$ ) and 2% Agral 90 (90% nonylphenol ethoxylate). In 1989, the same herbicide combination was used minus the Agral 90. Late emerging weeds were removed by handweeding.

Systematic destructive sampling of five to ten quadrats per plot began about two and five weeks after seeding the crop in 1988 and 1989, respectively, and continued at three- to four-week intervals throughout the growing season, up to 20 September. The plots were again sampled in the second week of May 1989 (trial established in 1988) and in the first week of May 1990 (trial established in 1989) when the quackgrass regrowth was in the 3 to 4 leaf stage.

To facilitate sampling a checker board pattern was mapped out in which only diagonal grids were sampled (Figure 1, Chapter 3). At each sampling date, a  $0.09 \text{ m}^2$  quadrat was laid in the centre of its allocated grid square and all the quackgrass and flax clipped at ground level. Quackgrass rhizomes were recovered from each quadrat to a depth of at least 15 cm. Quackgrass shoot density, shoot height, rhizome length and node number as well as flax density and biomass were determined for each quadrat. The quackgrass shoots were separated into leaves, stems and heads. In the spring harvest, quackgrass shoot numbers from each quadrat were expressed as a percent of the total number of rhizome buds to determine the percentage of sprouted buds. Biomass was determined after drying the samples at  $80 \text{ C}$  for at least 24 hours in an oven.

At crop maturity, August 20, 1988 and September 20, 1989, the flax plants in each quadrat were cut at ground level and divided into straw and bolls. Final seed yield and straw biomass as well as a thousand kernel weight were determined.

**Meteorological data.** At each harvest date (1988) and weekly (1989), incoming photosynthetic

photon flux density (PPFD) was measured using a 1m long line quantum sensor<sup>2</sup> during the period of 1200 - 1300 hours. These readings were taken at three locations per plot, with the sensor placed lengthwise between the crop rows at ground level. Readings were also taken above the crop canopy and were used in determining the fraction of incoming PPFD penetrating the crop canopy to ground level.

## RESULTS AND DISCUSSION

In 1988, the average quackgrass density was 37 shoots m<sup>2</sup> where there was no crop while in plots seeded to flax the average density was 36 shoots m<sup>2</sup> 30 DAP. In 1989, the average shoot densities of quackgrass 30 DAP were slightly higher than in 1988 with 58 shoots m<sup>2</sup> where there was no crop, and 49 shoots m<sup>2</sup> in plots seeded to flax. At crop maturity, the 1988 site had an average quackgrass density of 560 shoots m<sup>2</sup> where there was no crop, while under flax competition the average density was 470 shoots m<sup>2</sup>. Quackgrass density at harvest in 1989 was much lower than in 1988 (Table 5). In pure quackgrass stands, the average density was 281 shoots m<sup>2</sup> while under flax competition the average density was only 91 shoots m<sup>2</sup>.

Sethoxydim suppressed the growth of quackgrass for eight weeks, and regrowth was less in plots sown to flax than where there was no crop (Table 5). In the absence of flax competition, sethoxydim reduced quackgrass shoot densities at crop maturity by 67% in 1988 and 93% in 1989. Flax competition plus sethoxydim reduced quackgrass shoot densities by 94% in 1988 and 97% in 1989 compared to untreated plots. Flax competition alone reduced quackgrass shoot density by 16% and 68% in 1988 and 1989, respectively.

Reductions in shoot densities were associated with corresponding reductions in

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<sup>2</sup> Line Quantum Sensor, Model LI-191SB, LiCor Inc., Lincoln, NE.

Table 5. Effect of sethoxydim on quackgrass shoot density, rhizome buds and biomass at the end of the growing season (standard errors in parentheses).

Treatment	Shoots m <sup>2</sup>		Rhizome biomass g m <sup>2</sup>		Nodes m <sup>2</sup>	
	1988	1989	1988	1989	1988	1989
<u>No flax</u>						
No Sethoxydim	566 (78)	281 (111)	207 (29.9)	147.8 (59.7)	5444 (742.5)	2180 (931.3)
Sethoxydim	186(50)	19 (10.6)	28.6 (5.5)	6.8 (4.0)	982 (195.7)	97.4 (81.7)
% reduction	67	93	86	95	82	95
<u>Flax</u>						
No sethoxydim	467 (85)	91 (30.2)	161 (27.3)	40.5 (15)	4059 (638.2)	586.9 (204.2)
Sethoxydim	30 (6.3)	3 (2.1)	4.5 (1.8)	4.2 (2.9)	161 (61.2)	13 (11.7)
% reduction	94	97	84	90	96	98
<u>No sethoxydim</u>						
No flax	566 (78)	281 (111)	207 (29.9)	147 (59.7)	5444 (742.5)	2180 (931.3)
Flax	467 (85)	91 (30.2)	161 (27.3)	40.5 (15)	4059 (638.2)	97.4 (81.7)
% reduction	16	68	22	78	25	73

quackgrass rhizome biomass and nodes (Table 5). Generally, the percentage reduction in rhizome biomass and node number were slightly greater than those for shoot densities.

In both years there were significantly fewer quackgrass heads in the treated plots (less than 1 head  $m^{-2}$ ) compared to the untreated plots. In untreated plots, however, quackgrass head number in plots seeded to flax was similar to in uncropped plots. There were 35 and 41 (1988), and 1.5 and 5.7 (1989) quackgrass heads  $m^{-2}$  in cropped and uncropped plots, respectively.

Where no sethoxydim was applied the average quackgrass rhizome length was 125 m (1988) and 113 m (1989) per  $m^2$  in uncropped plots. Under flax competition the average rhizome was 93 m (1988) and 23 m (1989) per  $m^2$ . Rhizome length may determine the extension of a quackgrass patch in a given season.

The large differences in the effectiveness of crop competition alone between the two years is ascribed to differences in quackgrass and crop stand, and environmental conditions between the two years. In 1988, quackgrass shoot densities were high and the crop was poor, while in 1989 the opposite was true. The two growing seasons were quite distinct in terms of their meteorological characteristics (Figure 2, Chapter 3). The 1988 growing season was characterised by very warm and dry weather which reduced crop emergence relative to quackgrass emergence. The 1989 growing conditions were characterised by a relatively wet weather which resulted in good flax emergence and establishment. Flax emergence, two weeks after seeding, was 274 and 429 plants  $m^{-2}$  in 1988 and 1989, respectively.

Over the growing season quackgrass shoot and rhizome growth was suppressed more by sethoxydim than by flax competition (Figures 10, 11; Tables 6, 7). Where sethoxydim was applied, mid-season crop competition effectively suppressed quackgrass regrowth. The suppression of quackgrass regrowth by flax competition coincided with a 70 to 80% reduction in photosynthetic photon flux density penetrating the crop canopy the ground level (Figure 12).

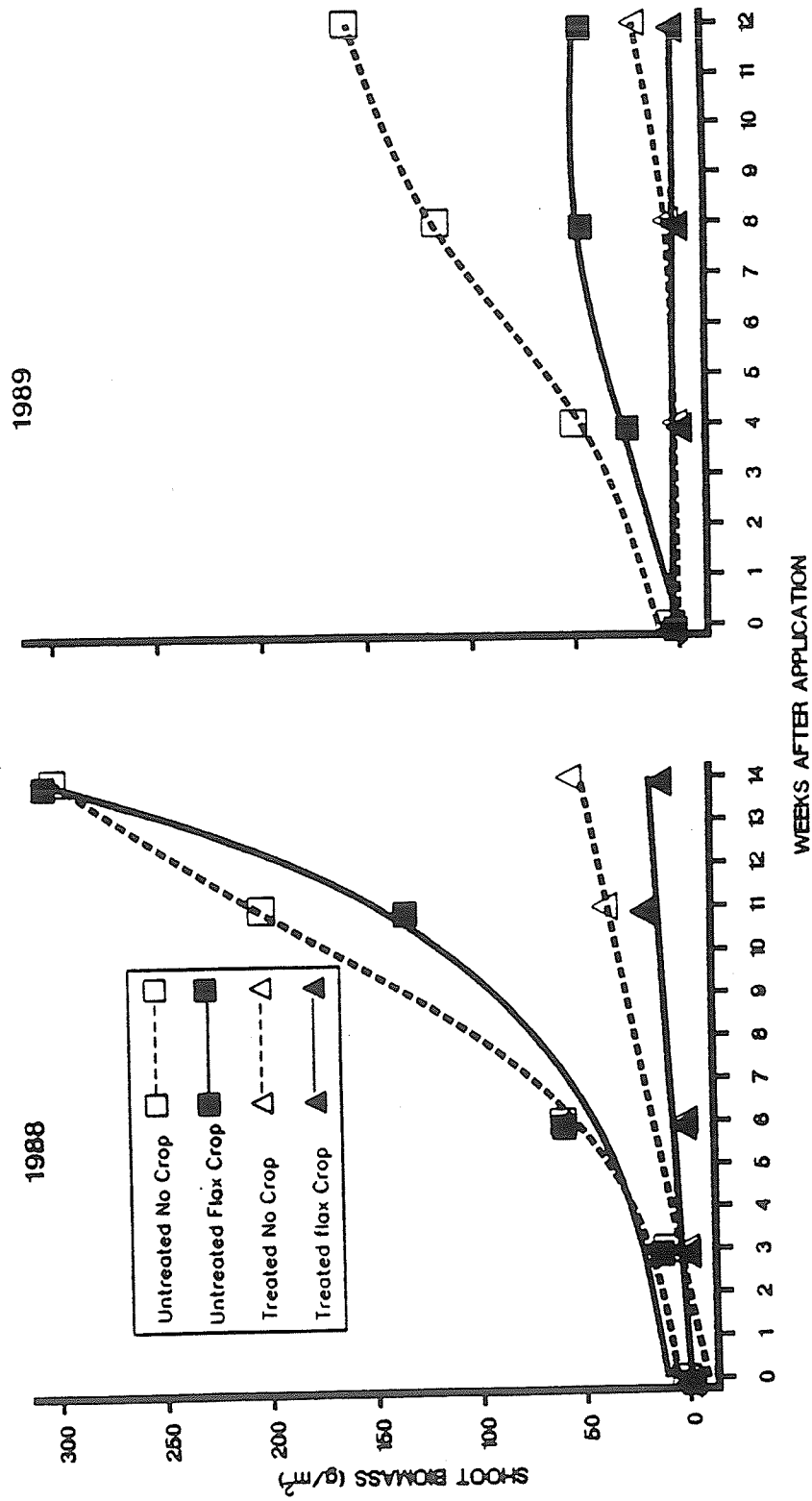


Figure 10. Quackgrass shoot biomass during 1988 and 1989 growing season

Table 6. Logistic and linear equation parameter estimates (standard errors in parentheses) for quackgrass shoot biomass over the growing season following models  $y = a/(1+be^{-cx})$  and  $y = a + bx$ , respectively

Treatment*	a	b	c	R <sup>2</sup>
<u>1988</u>				
1.	382 (138)	62.8 (75.6)	0.40 (0.20)	0.73
2.	377 (123.1)	65.7 (73.1)	0.39 (0.16)	0.74
3.	-0.67 (2.73)	1.15 (0.33)		0.29
4.	-8.96 (6.7)	4.1 (0.79)		0.44
<u>1989</u>				
1.	48.1 (10.67)	21269 (3.5 x 10 <sup>8</sup> )	2.5 (2491)	0.23
2.	169 (63.20)	15.5 (29.30)	0.45 (0.40)	0.30
3.	2.9 (1.17)	-0.17 (0.16)		0.05
4.	1.4 (1.98)	3.65 (5.15)	0.33 (1.30)	0.36

$y$  = shoot biomass,  $x$  = weeks after application,  $R^2$  is the coefficient of determination

Logistic function:  $a$ ,  $b$  and  $c$  are non-linear parameters,  $a$  = upper asymptote,  $a/(1+b)$  = the  $y$  intercept,  $ac/4$  is the slope at the inflection point and  $e$  is the natural logarithm

Linear equation:  $a$  is the  $y$  intercept and  $b$  is the linear regression coefficient

\* 1. Untreated Flax Crop

2. Untreated No Crop

3. Sethoxydim Treated Flax Crop

4. Sethoxydim Treated No crop

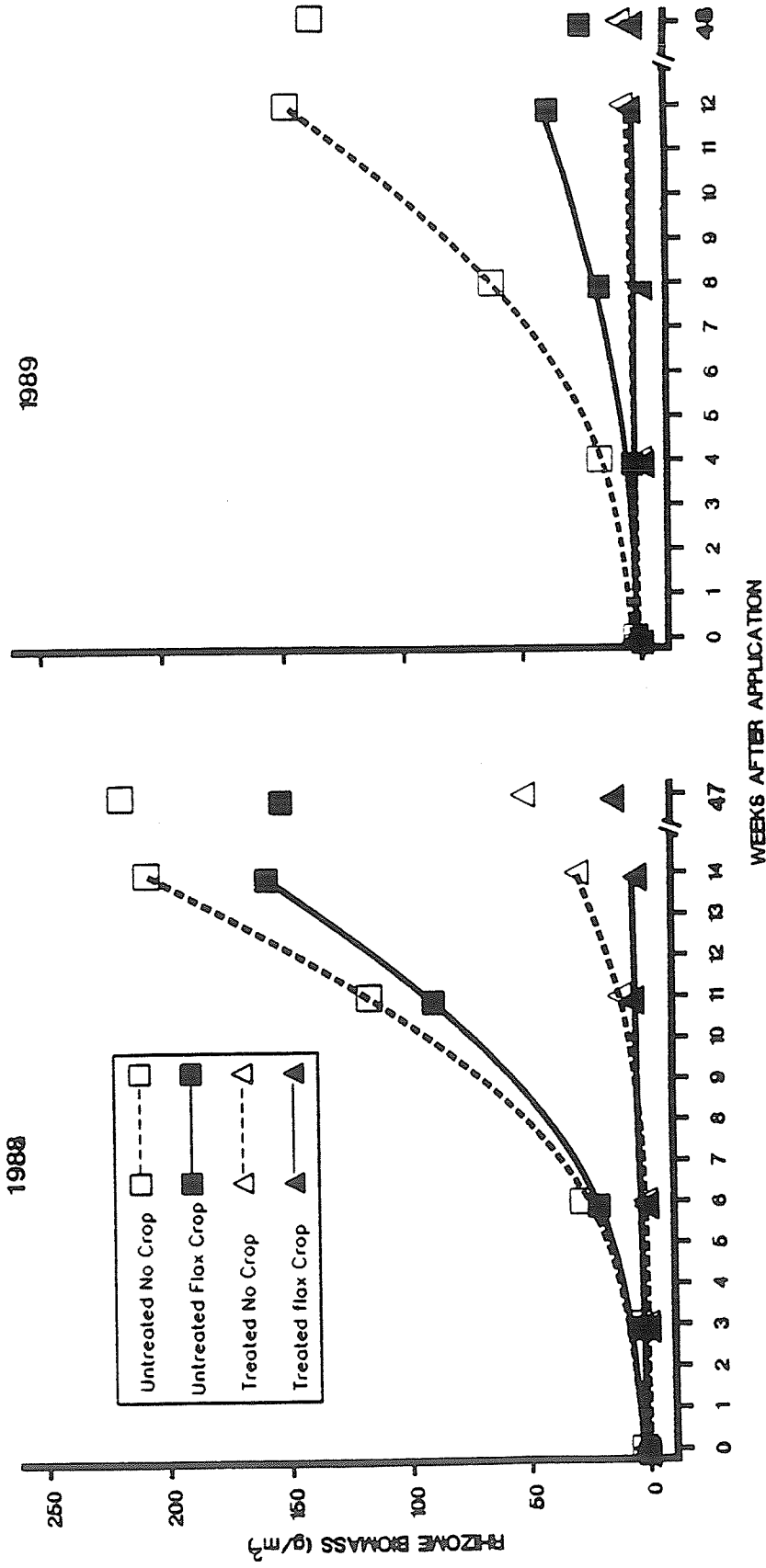


Figure 11. Quackgrass rhizome biomass during 1988 and 1989 growing season.

Table 7. Logistic and linear equation parameter estimates (standard errors in parentheses) for quackgrass rhizome biomass over the growing season following models  $y = a/(1+be^{-cx})$  and  $y = a + bx$ , respectively

Treatment	a	b	c	R <sup>2</sup>
<u>1988</u>				
1.	258 (159)	99.6 (99.6)	0.36 (0.16)	0.77
2.	324 (164.9)	120 (120.1)	0.38 (0.15)	0.82
3.	0.74 (0.91)	0.32 (0.11)		0.21
4.	44 (67.1)	1566 (9129)	0.57 (0.71)	0.71
<u>1989</u>				
1.	61 (107.2)	40 (73.9)	0.36 (0.51)	0.37
2.	230 (487.2)	63 (161.8)	0.39 (0.65)	0.36
3.	2.06 (1.53)	0.013 (0.20)		0.002
4.	0.77 (1.85)	0.32 (0.25)		0.07

$y$  = rhizome biomass,  $x$  = weeks after application,  $R^2$  is the coefficient of determination

Logistic function:  $a$ ,  $b$  and  $c$  are non-linear parameters,  $a$  = upper asymptote,  $a/(1+b)$  = the  $y$  intercept,  $ac/4$  is the slope at the inflection point and  $e$  is the natural logarithm

Linear equation:  $a$  is the  $y$  intercept and  $b$  is the linear regression coefficient

\* 1. Untreated Flax Crop

2. Untreated No Crop

3. Sethoxydim Treated Flax Crop

4. Sethoxydim Treated No crop

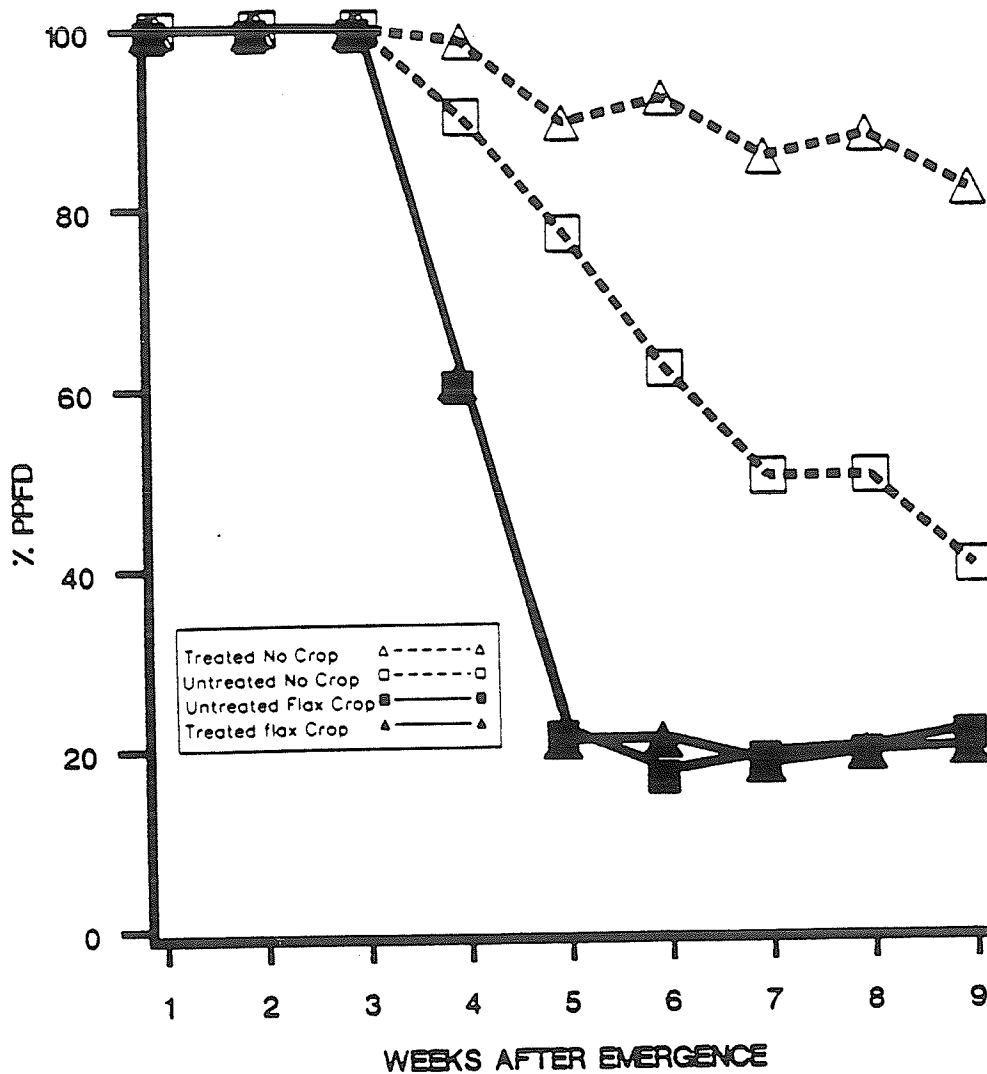


Figure 12. Percent photosynthetic photon flux density (PPFD) 400 to 700 nm wavelength light penetrating the crop to the ground. Mean values for each treatment are plotted for both years.

Based on this observation it can be reasonably concluded that the suppression of quackgrass regrowth resulted from flax shading. Similar observations were reported by Cussans (1968) who attributed the reduction in quackgrass regrowth to crop shading. Rapeseed and barley were more competitive followed by wheat. Beans was the least competitive. However, quackgrass showed maximum biomass accumulation during the crop maturity phase.

Quackgrass regrowth observed eight weeks after sethoxydim application confirms results previously reported (Stewart 1987). Harker and Dekker (1988) studied the distribution of sethoxydim within quackgrass rhizomes. They observed non-uniform distribution of sethoxydim with more herbicide recovered in the distal rather than in the basal buds of the rhizomes. Sethoxydim mainly translocated to the actively growing terminal buds by-passing the buds near the mother shoot. As a result, later in the growing season quackgrass shoot regrowth occurred from the basal buds which do not receive lethal dosages of the chemical.

The competitive ability of a crop depends upon its density and how early it covers the ground relative to quackgrass emergence (Permin 1985). Flax is a poor competitor partly because of its very small leaf area index (LAI's = 2-5) especially when compared to other crops like rapeseed (LAI's = 6-9) (Marshall et al. 1989). Under dry growing conditions leaf development of flax is severely restricted with LAI's of about 2 while under moist and warm climate the LAI's are about 5 (Marshall et al. 1989). Poor crop emergence coupled with restricted leaf development under dry conditions of 1988 could explain the reduced effectiveness of flax competition in 1988. In 1989 the warm and wet climate could have led to quick flax establishment. Sethoxydim allows the crop to grow and get well established in a quackgrass-free environment.

In unsprayed plots the average number of rhizome nodes 30 days after planting ranged from 40 to 49 m<sup>-2</sup> in both years. In 1988 there was a 16-fold increase in rhizome nodes at the time of harvest compared to the numbers present in spring. In 1989 there was a 9-fold increase

in nodes (Figure 13, Table 8). Nodes determine potential vegetative growth of quackgrass since the weed mainly propagates from rhizome buds.

Permin (1985) reported the influence of precipitation on rhizome buds in Denmark. When precipitation was 10 to 20 % below the normal of 203 mm, the nodes increased 9-fold. When total precipitation was 70% below normal, the increase was only 3- to 5-fold. Normal precipitation resulted in buds increasing up to 20 times the original number. In 1988 the total seasonal precipitation was 67.2% less than the 30 year average (354 mm), for Portage. In 1989, the total seasonal average was about 9% less than the 30 year average. Poor crop emergence and therefore reduced crop competition in the growing season could explain the high increase in rhizome nodes in 1988 even though precipitation was far below normal. In 1989 good crop emergence and early establishment could have reduced node increase. Early crop shading could also have stimulated shoot growth at the expense of rhizome growth, resulting in reduced nodes (Cussan 1968).

Biomass partitioning into rhizome, stem and sheath, leaves and heads was 35, 32.5, 30.5 and 2%, respectively, for quackgrass plants growing under no crop competition (Table 9). The results are similar to those observed by Wilcox and Morrison (1987). Under crop competition shoot production increased with a corresponding decrease in rhizome biomass production. Partitioning into leaves and heads remained the same. Cussans (1968) observed that under crop competition quackgrass produces more foliage at the expense of rhizome production, with reduced light intensity being the stimulus. More foliage is produced above the crop canopy to increase the surface area trapping sunlight.

Where no sethoxydim was applied quackgrass shoot height was similar for both cropped and uncropped plots. In 1988 quackgrass shoot height in plots seeded to flax was 49 cm while in the uncropped plots it was 47.8 cm. In 1989 quackgrass shoots growing under flax competition

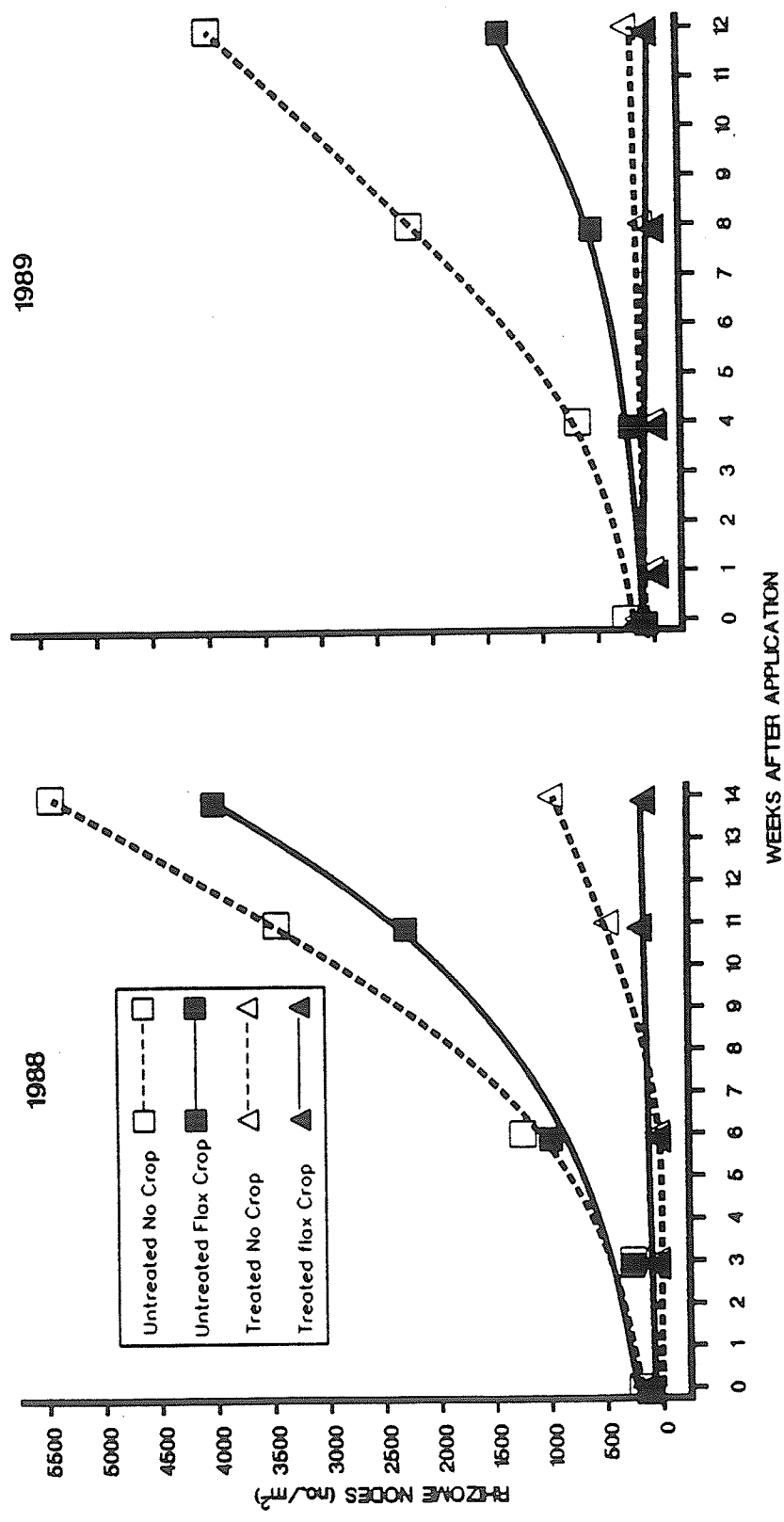


Figure 13. Increase in quackgrass rhizome buds during 1988 and 1989 growing season.

Table 8. Logistic and linear equation parameter estimates (standard errors in parentheses) for quackgrass rhizome node increase over the growing season following models  $y = a/(1+be^{-cx})$  and  $y = a + bx$ , respectively

Treatment	a	b	c	R <sup>2</sup>
<u>1988</u>				
1.	13011 (26944)	55.5 (89.4)	0.23 (0.11)	0.76
2.	8372 (3913)	44.3 (24.7)	0.31 (0.11)	0.81
3.	68.1 (31.5)	7.1 (3.69)		0.10
4.	1063(525)	4652 (72635)	0.75(1.22)	0.62
<u>1989</u>				
1.	163151 (2.2 x 10 <sup>9</sup> )	1632.9 (2.2 x 10 <sup>7</sup> )	0.22 (0.40)	0.39
2.	5272 (5347)	27.8 (54.2)	0.37 (0.44)	0.36
3.	112.99 (41.0)	-8.92 (5.48)		0.027
4.	80.47 (72.3)	6.87 (9.7)		0.022

$y$  = rhizome node number,  $x$  = weeks after application,  $R^2$  is the coefficient of determination

Logistic function:  $a$ ,  $b$  and  $c$  are non-linear parameters,  $a$  = upper asymptote,  $a/(1+b)$  = the  $y$  intercept,  $ac/4$  = the slope at the inflection point and  $e$  is the natural logarithm

Linear equation:  $a$  = the  $y$  intercept and  $b$  is the linear regression coefficient

\* 1. Untreated Flax Crop

2. Untreated No Crop

3. Sethoxydim Treated Flax Crop

4. Sethoxydim Treated No crop

Table 9. Average quackgrass Biomass Partitioning (percentages)

Treatment	Rhizomes	Stems	Leaves	Heads
No Flax Crop	35.0 (3.44)	32.5 (4.28)	30.5 (1.50)	2.0 (0.26)
Flax crop	29.0 (2.58)	39.5 (1.40)	29.5 (1.58)	2.0 (0.22)

\* Averages of five sampling dates and two experiments. Standard errors in parentheses.

were 55 cm tall while in uncropped plots shoots were 39.4 cm tall. The flax crop was about 50 cm in 1988 and 60 cm in 1989. There was a tendency for quackgrass shoots to grow taller under crop competition. Cussans (1968) observed increased quackgrass shoot height when quackgrass was growing under intense competition from rapeseed and barley. In beans, shoots did not grow as tall.

The flax crop in 1989 matured within the average days to maturity (95 days), four weeks earlier than in 1988. The delayed maturity in 1988 could have resulted from injurious effect of the broad-leaved weed herbicides. The addition of Agral 90 to broad-leaved weed herbicides slows down flax growth for one to two weeks (Friesen et al. 1989). In 1989, Agral 90 was not used hence the initial injury to flax was less than in 1988.

The effective suppression of quackgrass by sethoxydim application resulted in flax seed yield of 2.5 and 1.2 times that of the untreated plots, in 1988 and 1989, respectively. The reduction in flax yield was manifested as reductions in flax straw biomass, flax bolls, boll dry weight and 1000 seed weight in the untreated plots (Table 10). Flax density (branches  $m^{-2}$ ) at the end of the growing season was similar in both years.

**Effect of sethoxydim on quackgrass one year after application.** Since rhizome buds are vegetative propagules, their reduction is likely to reduce quackgrass infestation over time. In the absence of crop competition, sethoxydim resulted in an 80 and 93% reduction in the number of rhizome buds  $m^{-2}$  the year after treatment in May 1989 and May 1990, respectively. Flax competition plus sethoxydim resulted in a 90 (1989) and 84% (1990) reduction in buds. In untreated plots, flax competition reduced the buds by 27% in 1989 and 78% in 1990.

Aamissepp and Hallgren (1985) reported the long term effect of sethoxydim on quackgrass. One year after application, the effectiveness of the herbicide was ten percent less than in the spraying year. The results are similar to those of Dekker (1985) who reported more than 50% quackgrass

Table 10. Effect of sethoxydim and quackgrass competition on flax (standard errors in parentheses)

Flax parameter	Year	Treated	Untreated
Straw biomass (g m <sup>-2</sup> )	1988	99.9 (21.1)	47.7* (9.7)
	1989	277.7 (42.7)	233.0* (36.1)
Bolls (no. m <sup>-2</sup> )	1988	4215.6 (447.6)	1667.3* (340.4)
	1989	5492.4 (190.3)	4574.7* (170.5)
Boll dry weight (g m <sup>-2</sup> )	1988	221.1 (23.7)	95.1* (28.1)
	1989	239.6 (11.7)	197.1* (9.1)
Seed yield (g m <sup>-2</sup> )	1988	121.4 (14.6)	47.5* (10.7)
	1989	161.5 (6.8)	136.0 (6.5)
1000 seed weight (g)	1988	5.3 (0.4)	4.5* (0.4)
	1989	4.9 (0.1)	4.7 (0.1)

\* significantly different within row as determined by LSD (p=0.05)

Table 11. Effect of sethoxydim on rhizome bud sprouting the following spring (standard errors in parentheses)

Treatment	1989	1990
<u>Untreated Flax</u>		
Total buds m <sup>2</sup>	5448 (776.9)	1021 (501)
% sprouted	19 (1.1)	46 (78)
<u>Untreated No Flax</u>		
Total buds m <sup>2</sup>	7475 (772.5)	4735 (1087)
% sprouted	21 (1.9)	25 (3.4)
<u>Treated Flax</u>		
Total buds m-2	526 (168.9)	165 (83.1)
% sprouted	55 (8.9)	58 (6.3)
<u>Treated No Flax</u>		
Total buds m-2	1520 (284.1)	326 (178)
% sprouted	59 (8.1)	67 (10.6)

\* Treated with sethoxydim the previous season

shoot control one year after application.

Although sethoxydim effectively reduced the rhizome bud number, proportionately more buds sprouted in the treated plots to form new shoots the following spring (Table 11). In treated plots approximately 60% of the rhizome buds sprouted compared to 28% in the untreated plots. In undisturbed quackgrass stands, about 95% of the rhizome buds are dormant due to apical dominance (Johnson and Buchholtz 1965). Since sethoxydim acts mainly on the terminal buds and removes apical dominance (Harker and Dekker 1988; Stewart 1987), a high proportion of the buds were stimulated to sprout after sethoxydim application.

Although sethoxydim effectively reduced the rhizomes, more buds sprouted the following spring to form new shoots. However, the experiment not managed to represent conventional farming practices. Growers will usually till fields where there are dense quackgrass stands in fall and again in spring before planting. Tillage has significant effects on quackgrass (Merivani and Wyse 1984). In this study the experimental plots were undisturbed from September to spring when quackgrass counts were taken.

Doll (1985) studied the long term effects of fluazifop-butyl, haloxyfop-methyl, sethoxydim and glyphosate on quackgrass in soybean. Quackgrass regrowth assessed after one year of single herbicide application, one ploughing and recropping to alfalfa revealed very low quackgrass regrowth (15-18%). In the current study reinfestation percentages of about 60% were observed. It can be reasoned that herbicide application alone can not give acceptable long term quackgrass control. Tillage and crop competition contribute to the effective suppression of quackgrass. For other studies the author would like to recommend the inclusion of tillage as one of the treatments because this is representative of general farming operations.

## 5. EFFICACY OF SETHOXYDIM ON QUACKGRASS (*Elytrigia repens* (L.) Nevski) SELECTIONS.

*Abstract.* The efficacy of sethoxydim on quackgrass selections collected from seven locations in Manitoba was evaluated at Portage la Prairie in 1988 and 1989. Quackgrass selections were allowed to grow to the ten leaf stage and then clipped to ground level. Sethoxydim at 0.5 kg ha<sup>-1</sup> or at 0.81 kg a.i. ha<sup>-1</sup> plus 2% Assist with or without 2 kg ha<sup>-1</sup> analytical grade ammonium sulphate was applied to quackgrass at the 3- to 4-leaf stage following regrowth. In 1988 the selections showed differential response to sethoxydim for all quackgrass parameters evaluated. In 1989, however, shoot number was the only significant parameter. Although selections significantly differed in rhizome and shoot growth, reduction in quackgrass due to sethoxydim could only be related to shoot biomass. Selections with high shoot biomass tended to be the most difficult to control. Generally, percent control was better in 1989 (76%) than in 1988 (72%). Sethoxydim at 0.5 kg a.i. ha<sup>-1</sup> resulted in similar levels of quackgrass control compared to 0.81 kg a.i. ha<sup>-1</sup> in 1988. In 1989, the higher dosage resulted in 15% better control than the low dosage. For most quackgrass parameters the addition of ammonium sulphate and Assist together to the spray mixture resulted in about 5% better quackgrass control than the addition of Assist oil alone.

### INTRODUCTION

Quackgrass is a highly variable species due to its self sterility and very low frequency of inbreeding. The high degree of heterozygosity within the species has resulted in the description of a large number of varieties and forms of quackgrass (Williams 1973b; Sampson 1987).

The variation within quackgrass populations can have significant effects on the ability to manage this weed species. In addition to marked variation in growth form, there may be

significant variation in biochemical and physiological systems in the populations that may influence response to herbicide control measures.

Buchholtz (1958) reported variation among quackgrass selections in response to dalapon. Haddad and Sagar (1968) observed differential response of quackgrass selections to dalapon and amino-triazole applied to the root and shoot. Sampson (1987) observed differences in quackgrass response to glyphosate and sethoxydim. Rhizome bud number was correlated to herbicide dose, with high bud number selections showing more tolerance. Alcantara et al. (1989) reported differential response of quackgrass to sethoxydim and haloxyfop application. The level of control was correlated to number of quackgrass crown buds. Plants high in crown bud number tended to be more difficult to control.

It is important to understand the variation in quackgrass response to herbicides and to determine whether this variation is similar in all environmental conditions. Understanding the mechanism involved in the different responses of quackgrass to herbicides could be used in developing more effective control measures. The objective of this research was to determine the efficacy of sethoxydim on rhizome bud and shoot number, and rhizome and shoot biomass of quackgrass selections collected from seven locations in Manitoba.

## MATERIALS AND METHODS

**General field operations.** In 1988 and 1989, field experiments were conducted at the University of Manitoba field station, Portage la Prairie, on a Neurhorst clay loam composed of 25% sand, 44% silt and 31% clay with an organic matter content of 8.5% and a pH of 7.3. The total experimental area was 432 and 770 m<sup>2</sup>, in 1988 and 1989, respectively.

Quackgrass selections were collected by D. Wilcox from fields in seven ecological zones in Manitoba. The selections were coded as shown in Table 12. Selections differed in certain

Table 12. Selection collection regions and ecological zones

Selection number	Collection region	Ecological zone
1	Altamont	2A
2	Arborg	4
3	Brandon	2
4	Medora	1
9	Roblin	5
12	Winnipeg	3
13	The Pas	6

morphological characteristics as shown in Table 13.

**Plant establishment.** In May of 1988 and 1989, rhizomes of quackgrass selections from greenhouse-grown plants were cut into single-node rhizome fragments. Rhizome fragments from each selection were planted in 5 cm x 5 cm peat pots and placed outside for sprouting. The potting soil consisted of a Portage clay loam. Plants were watered as required. On June 3, 1988 and June 5, 1989, uniform plants of each selection, at the 3- to 4-leaf stage, were selected and transplanted into a quackgrass-free field, in blocks consisting of two rows of paired selections. In 1988, plants were spaced at 75 cm apart within and between rows, and 100 cm apart between blocks. In 1989, plants were spaced 100 cm apart within and between rows, with 200 cm between blocks.

Plants were allowed to grow to the ten leaf stage and then clipped to ground level on July 13 and 14 in 1988 and 1989, respectively. Sethoxydim was applied when quackgrass was at the 3- to 4-leaf stage following regrowth. The herbicide was applied using a bicycle sprayer delivering 123 L ha<sup>-1</sup> at a pressure of 310 KPa.

Treatments consisted of sethoxydim applied at 0.81 kg a.i. ha<sup>-1</sup> plus 2% (v/v) Assist, 0.5 kg a.i. ha<sup>-1</sup> plus 2% (v/v) Assist, and 0.5 kg a.i. ha<sup>-1</sup> plus 2% (v/v) Assist plus 2 kg ha<sup>-1</sup> of analytical grade ammonium sulphate, and the untreated control.

Six weeks after sethoxydim application, quackgrass shoots were clipped at ground level and all rhizomes were recovered from the soil. Quackgrass rhizome length and nodes, shoot number and biomass were determined for each selection. Biomass was determined after the plant materials were oven dried at 80 C for at least 24 hours. In 1988 only rhizome fresh weights were determined as rhizomes were required to maintain the selections for the next season.

The experimental design was a factorial arrangement of a randomized block design

Table 13. Some morphological characteristics of the selections

Selection number	Glaucous	Leaf Surface		Growth habit	Colour	Awns
		Under	Upper			
1	r	rg-sm	sm	prost	light	n
2	n	rg	sm	erect	flat	y
3	n	rg	sm	prost/erect	flat	lets
4	n	cs	rg	prost/erect	dark	y
9	y	cs-rg	sm	prost/erect	flat	lets
12	y	rg	sm	erect	light	lets
13	n	rg	sm	prost	light	lets

Source: Wilcox 1990

Key: cs - coarse; sm - smooth; n - no; y - yes; lets - awnlets;

rg - rough; colour - olive green (light, flat, dark);

prost - prostrate.

with four treatments; 6 and 13 replications in 1988 and 1989, respectively. The differences between the treated and untreated controls were expressed as percentages of the untreated controls to determine percent mortality. Since treatment by selection interaction was non-significant, the data presented are averages of treatments or selections.

## RESULTS AND DISCUSSION

There was a variation in quackgrass parameters between the two years (Figure 14). In 1989, the quackgrass selections produced low nodes, shoots and biomass compared to 1988. The reasons for the differences in the extent of growth are unclear. Since 1989 was a relatively close to normal climate it was expected that the extent of growth would be higher in this year than in 1988.

Quackgrass selections were significantly different in their growth habits. In both years the selections were significantly different in rhizome nodes, shoot number and shoot biomass per plant. However, there were no significant differences in rhizome fresh weights in 1988. In 1989 selection 3 was significantly high in rhizome biomass while the other selections had similar rhizome biomass. The selections which were high in node number tended to have high rhizome biomass.

Selection 3 and 4 (1988), and 3 and 9 (1989) produced the largest number of nodes per plant. Selection 12 and 13 produced the fewest nodes per plant in both years. In both years selection 3, 4 and 9 produced more than twice as many nodes as selection 12 and 13.

Selection 2 (1988) and 3 (both years) produced the highest rhizome biomass while selection 12 produced the least rhizome biomass in both years. Selection 2 and 3 produced 1.7 and 2.2 times as much rhizome biomass as produced by selection 12, respectively. In both years selection 1 and 13 produced 1.6-fold less biomass compared to selection 2 and 3.

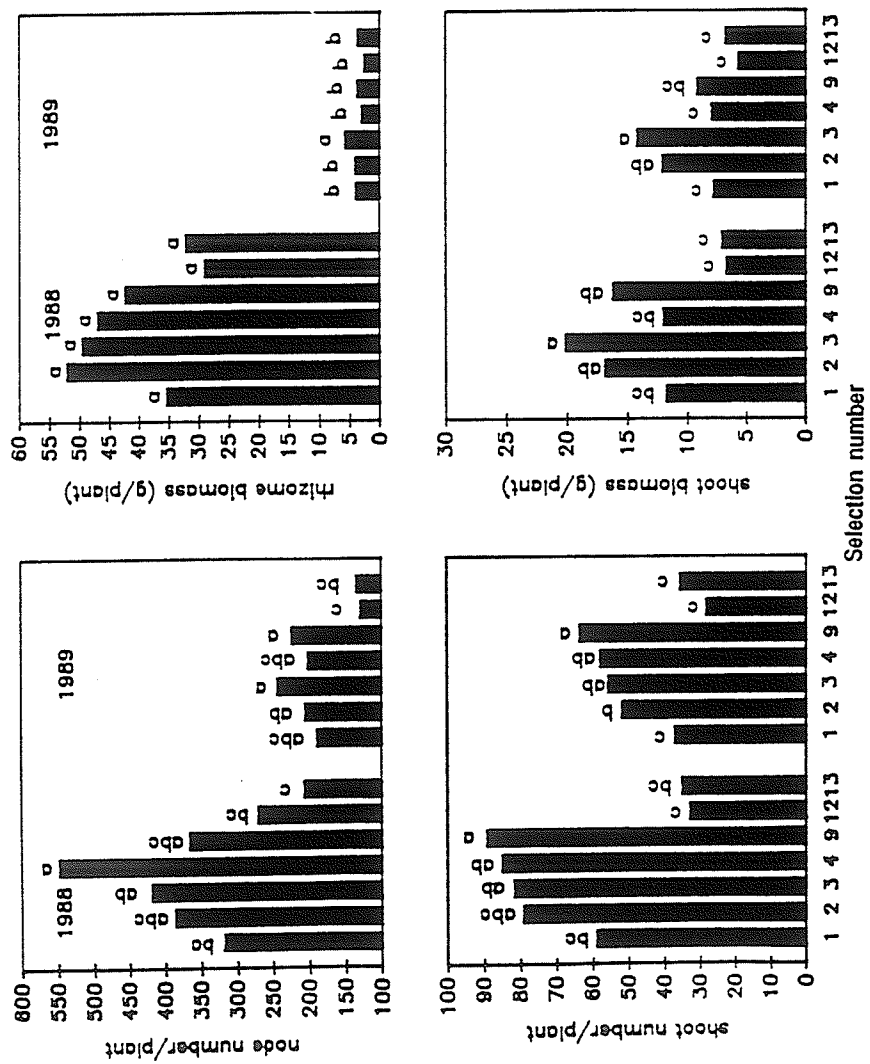


Figure 14. Growth characteristics of quackgrass selections (averages of 6 and 13 replications in 1988 and 1988, respectively). Means followed by same letter(s) are non-significant at  $p=0.05$  in a given year as determined by Duncan's Multiple Range Test. Rhizome fresh weights (1988) and rhizome biomass (1998).

Selection 3, 4, and 9 produced the highest number of shoots per plant, which was 2.5 times the number produced by selection 12 and 13, the least shoot producing selections. Selection 1 produced 1.7 times fewer shoots than the high producing selections (Figure 13).

Selection 2, 3 (both years) and 9 (1988) produced the highest shoot biomass compared to 12 and 13 which produced 2.5 times less biomass. In both years selection 4 and 9 did not flower while selection 13 did not flower in 1989. Williams (1973b) also observed differences in the times at which quackgrass selections flowered.

The current study supports previously reported research that showed variability for several factors among ten quackgrass selections (Westra and Wise 1981). The data showed that rhizome nodes, shoot and bud number, and biomass vary from one selection to another. Generally, selection 2, 3, 4 and 9 were high producers of anyone or all of the four quackgrass parameters studied. Selection 12 and 13 were low producers of the quackgrass parameters. Selection 1 could be classified as intermediate.

There was differential response amongst the quackgrass selections to sethoxydim applied at the 3- to 4-leaf stage after shoot regrowth (Figure 15). Between the two years, however, differences in the pattern of herbicide response were observed. In 1988 all quackgrass parameters responded differently to sethoxydim. In 1989 the quackgrass selections showed similar response to sethoxydim for all quackgrass parameters but shoot biomass. The differences in the response pattern may be due to environmental differences between the two years (Figure 2). Generally, the reduction in all quackgrass parameters was greater in 1989 (76%) than in 1988 (72%).

Reductions in quackgrass parameters observed in this study were lower than previously reported results (Stewart 1987). Alcantara et al. (1989) correlated reduction in quackgrass shoots to the number of crown buds present at the time of herbicide application. Quackgrass at the

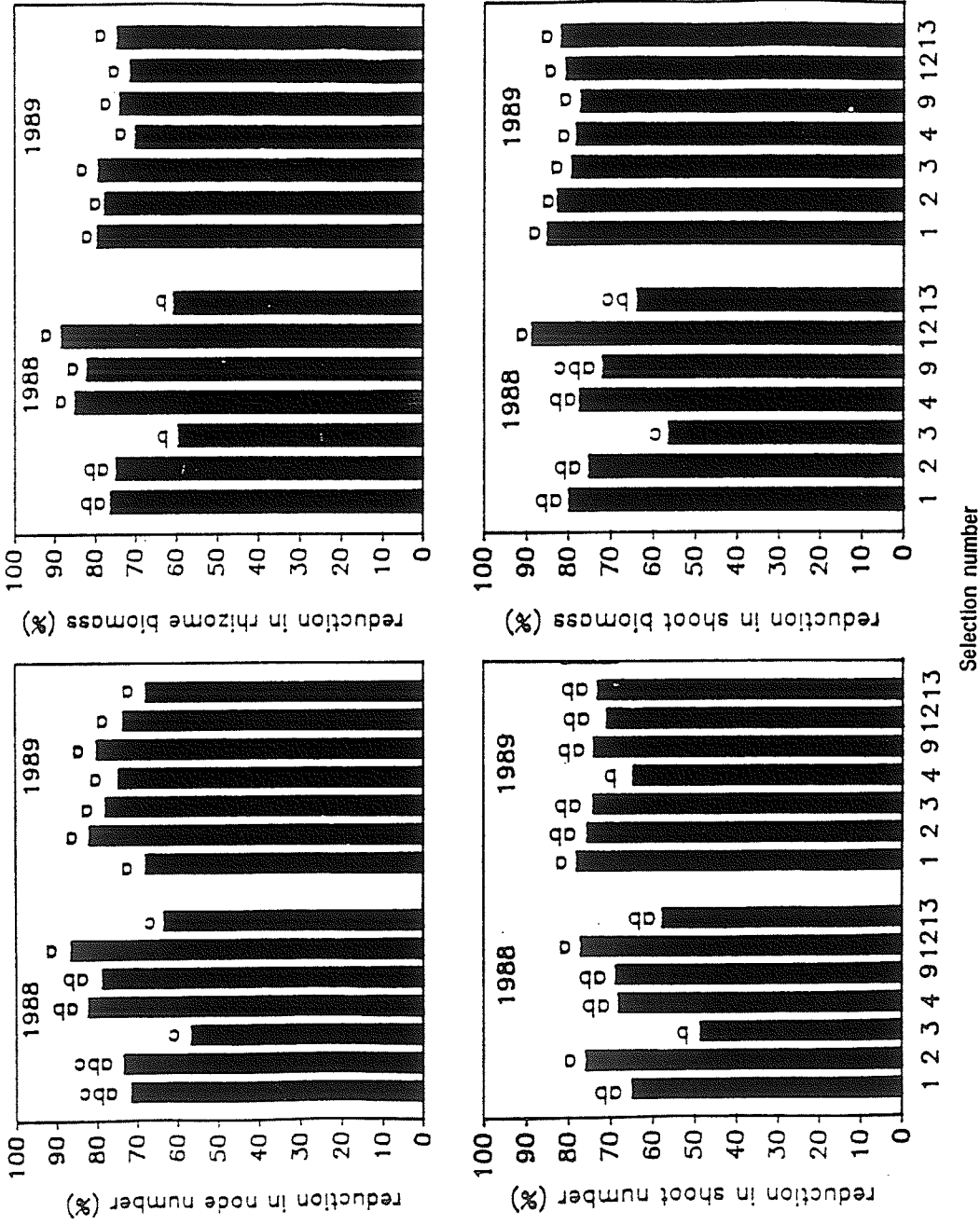


Figure 15. Herbicide response of quackgrass selections (averages of 6 and 13 replications). Means followed by the same letter (s) year are non-significant at  $p=0.05$  as determined by Duncan's Multiple Range Test.

seven to eight leaf stage had enough crown buds to ensure extensive regrowth after herbicide application. Quackgrass was allowed to grow to the ten leaf stage before the herbicide was applied, by which time it could have accumulated the minimum number of crown buds required to resist herbicide application, and which otherwise could have reduced control observed in this study. The variation in shoot reductions may also be due to differences in the efficacy assessment methodologies used.

In 1988 selection 4, 9 and 12 showed the highest reduction in rhizome nodes (about 80%). Rhizome nodes in selection 3 and 13 were reduced by less than 60%. In 1989 the selections showed similar reductions in rhizome nodes. The reductions ranged from 63% for selection 13 and 77% for selection 2. Similarly, rhizome fresh weight reductions were highest in selection 4, 9 and 12 (> 80%) in 1988. Reductions in rhizome biomass were similar in 1989 ranging from 70% (selection 4) to 76% (selection 1).

In 1988 selection 2 (76%) and 12 (78%) had the highest reduction in shoot numbers while selection 3 (50%) had the lowest reduction. In 1989 selection 1 had the highest reduction in shoot number. Selection 4 was reduced the least (55%). With regard to shoot biomass, selection 12 was reduced by 90% in 1988. Selection 1, 2 and 4 also showed high reductions (78-80%) while selection 3 was the least reduced (60%). In 1989 all selections showed similar reductions in shoot biomass (about 80%).

Generally, in 1988, selection 12 was the most susceptible selection to sethoxydim. This selection had 85% reduction in all quackgrass parameters. Selection 3, the most tolerant, was reduced by about 55.5%. The average reduction in quackgrass shoots, nodes and biomass was 73.2, 75.0, 78.3, 75.6 and 61.7% for selection 1, 2, 4, 9 and 13, respectively. In 1989 no one particular selection would be classified as the most tolerant or the most susceptible. All the selections were generally reduced to a higher extent in all quackgrass parameters compared to

1988.

Quackgrass rhizome nodes, shoot number and biomass were correlated to the reduction in the respective quackgrass parameters (Table 14). Shoot biomass was the only parameter that showed a significant correlation coefficient. Selections high in shoot biomass showed a low level of control which may be attributed to the herbicide being diluted to non lethal levels. The other quackgrass parameters showed a weak negative correlation.

Sethoxydim in all combinations resulted in similar quackgrass control in 1988 (Figure 16). However, in 1989, sethoxydim at  $0.81 \text{ kg ha}^{-1}$  plus 2% (v/v) Assist reduced the quackgrass parameters to a greater extent than the other adjuvant combinations. The percent reduction in quackgrass parameters for the low dosage ( $0.5 \text{ kg ha}^{-1}$ ) generally ranged from 63% for shoot numbers to 75% for rhizome nodes, while at the higher dosage ( $0.81 \text{ kg ha}^{-1}$ ) reductions in quackgrass parameters were more than 80%. Quackgrass parameters at the high sethoxydim dosage were reduced by 15% in 1989 than in the previous year. Reductions in quackgrass parameters at the low sethoxydim dosage were similar in both years. The higher dosage of sethoxydim may have resulted in more herbicide per unit gram of biomass because the low plant biomass. The data are in support of previously reported research (Stewart 1987). Sethoxydim applied at  $4.4 \text{ L ha}^{-1}$  and at  $2.7 \text{ L ha}^{-1}$  plus adjuvants resulted in similar quackgrass control. These observations were observed in the 1988 results. In 1989 high dosages of sethoxydim showed significantly higher levels of quackgrass control.

Although statistically non-significant, the addition of ammonium sulphate and Assist together to the spray mixture resulted in a 5% better reduction in all quackgrass parameters but rhizome growth (1989 only) than the addition of Assist only. Nalewaja and Skrzypczack (1986) observed that soybean oil at  $2.3\text{-}4.6 \text{ L ha}^{-1}$  resulted in a 1.8-fold increase in absorption and translocation of sethoxydim at  $0.03$  and  $0.17 \text{ kg a.i. ha}^{-1}$  (1.8-fold) while there was only a 1.2-

Table 14. Relationship between percent control and various quackgrass parameters

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Parameter	Correlation coefficient	Prob>F
Total Biomass	-0.34	0.227
Rhizome biomass	-0.04	0.899
Shoot biomass	-0.57	0.033
Shoot number	-0.31	0.288
Bud number	-0.09	0.758

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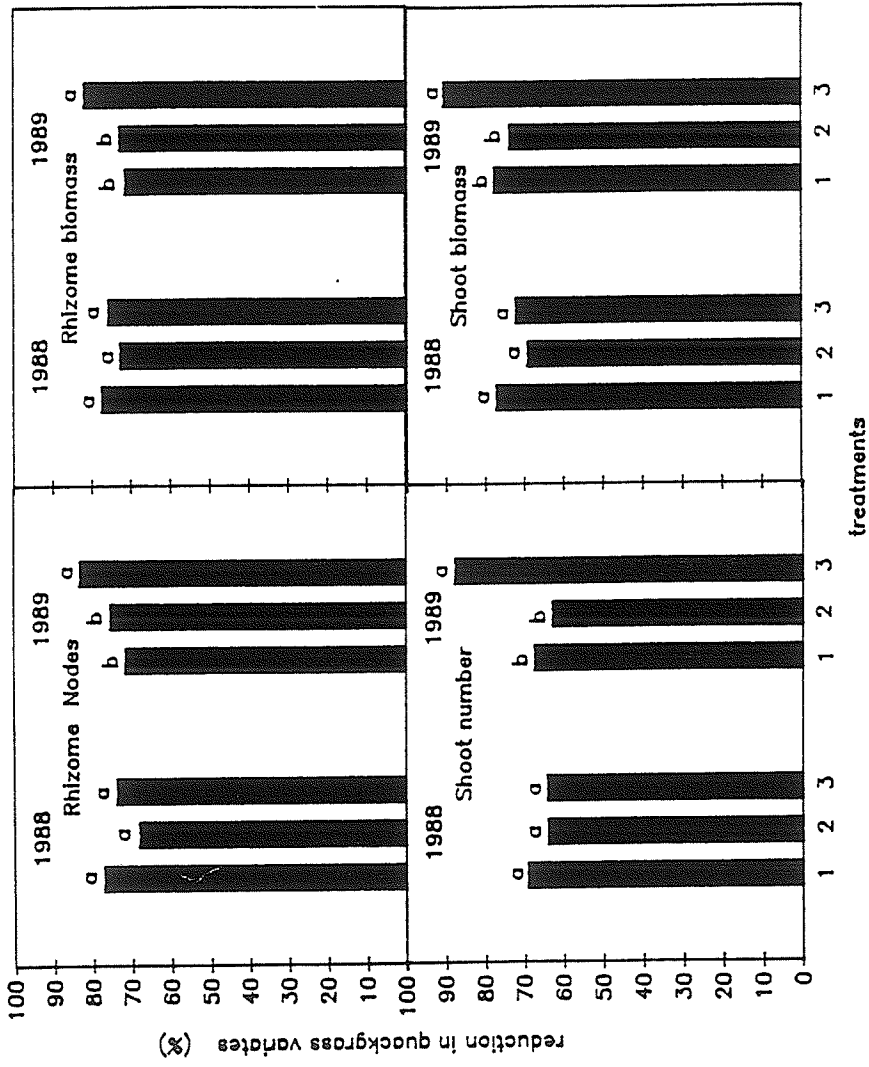


Figure 16. Efficacy of sethoxydim and adjuvants on control of quackgrass. Averages of 6 and 13 replications. Means followed by the same letter(s) in a given year are non-significant at  $p=0.05$  as determined by Duncan Multiple Range Test. Treatments: 1.  $0.5 \text{ kg ha}^{-1}$  Sethoxydim + 2% (v/v) Assist +  $2 \text{ kg ha}^{-1}$  ammonium sulphate; 2.  $0.5 \text{ kg ha}^{-1}$  sethoxydim + 2% (v/v) Assist; 3.  $0.81 \text{ kg ha}^{-1}$  + 2% (v/v) Assist.

fold increase at  $0.87 \text{ kg ha}^{-1}$ . Adjuvants increase sethoxydim penetration into the plants which allows for use of reduced chemical dosages.

The current study was successful in showing the differential response of quackgrass selections sethoxydim. For further studies the author would like to recommend a few changes in the methodology. Quackgrass develops new rhizome at the 3-4 leaf stage and becomes difficult to control thereon. Allowing quackgrass to grow to the ten leaf stage during the establishment period, makes quackgrass more difficult to control. The establishment period should be cut to the 5-6 leaf stage which is close to the recommendation of fragmenting the rhizomes before sethoxydim is applied.

## 6. GENERAL SUMMARY

The study demonstrated the adverse effects of quackgrass on flax growth and seed yield. Coupled with weed survey data, the generalized yield loss model developed in the present study would be useful in predicting crop losses due weeds in southern Manitoba. To improve the usage of such descriptive models, it is important that research addresses the contribution of each of the many factors that affect the competitiveness of quackgrass.

The evidence that sethoxydim results in increased sprouting of rhizome buds one year after application suggests that effective control of quackgrass by sethoxydim is primarily in the year of application since increased sprouting of buds on the treated plants the following year could lead to rapid reinfestation. This observation could be of serious consequences under zero-till operations where the soil is not disturbed for most of the growing season. Under conventional operations, tillage is likely to reduce the rate of quackgrass reinfestation.

However, it should be noted that the increased sprouting of rhizome buds in treated plots could be density related. The fact that bud number in treated plots is low, there is less bud crowding compared to untreated plots in which bud densities are relatively high. Because of the low initial bud density in the treated plots it is likely that more bud sprouting occurs compared to plots where there is a high bud density initially.

It is evident from the study that crop competition has significant effects on reducing quackgrass stands. However, the contribution of crop competition is also affected by environmental factors and management practices. Herbicide control measures supplemented by growing of relatively more competitive crops like canola and wheat are likely to lead to substantial quackgrass reductions in the long term.

There are indications that quackgrass populations in Manitoba vary in their growth habits.

This variation seems to influence the herbicide response of quackgrass. Quackgrass selections differ in leaf pubescence, shoot and rhizome growth, all which could affect herbicide absorption and translocation. It is necessary that further studies be conducted to determine how widespread this quackgrass variation to herbicide response is and determine the mechanisms involved. This information would help formulate more effective quackgrass control measures.

The present study mainly evaluated individual quackgrass control methods which is not representative of the general farming practices. For further research it is suggested that the various control methods be evaluated simultaneously. This would require an integrated program involving herbicides, crop competition, crop rotation, fall and spring tillage.

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