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COMPETITION AND CONTROL OF CEREAL WEEDS IN BRITISH AND ALGERIAN WHEAT

A THESIS SUBMITTED FOR THE
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IN THE
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BY

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Frontispiece: Algerian winter wheat cv. Bidi 17

I wish to dedicate this work to my brothers and sisters.

With love.

Acknowledgments

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ABBREVIATIONS

Tralkoxydim	=	(2-[1-(ethoxyimino) propyl]-3-hydroxy mesitylcyclohex-2-enine).
Flamprop-isopropyl	=	(isopropyl (+)-2-(N-benzoyl-3-chloro- 4-fluorophenyl-2-amino) propionate.
2,4-D	=	2,4 diclorophenoxy acetic acid).
MCPA	=	(2-methyl-4-phenoxyacetic acid).
L	=	Litre.
g	=	Gram.
Kg	=	Kilogram.
mm	=	Millimetre.
cm	=	Centimetre.
Ha	=	Hectare.
L	=	Litre.
No	=	Number.
cvs	=	Cultivars.
GS	=	Growth stage.

Abstract

The study compared weed competition and weed control in cereal/weed systems, contrasting throughout Algerian and British wheat cultivars. Cultivars of winter wheat cv. Bidi 17 and spring wheat cv. Broom, wild oat (*Avena fatua* L.) and charlock (*Sinapis arvensis* L.) were planted separately in order to examine the response of individual plants to competitive stress in a simple system incorporating varying population densities: 1, 2, 4, 8, and 16 plants/pot. Total dry weight production per plant (above ground) decreased as the density increased for each species. The reduction was greatest with both wheat cvs, followed by charlock and wild oat, which was least affected. Competition affected shoot dry weight, leaf number and, especially tiller number.

Addition series experiments, using four wheat plants from each of two cultivars (Aquila and Inrat) were set up adding wild oat and charlock plants to the crop population at densities of 1, 2, 4, 8, and 16 plants/pot. Effects on the early growth stages of wheat were examined. High densities of charlock decreased the dry weight of wheat cvs drastically and the competition effect was also manifested in reducing tillering, in both cultivars.

Comparing the effects of both weeds with these wheat cultivars charlock caused a larger reduction in plant weight for Aquila than for Inrat, at comparable densities. Charlock competition increased the losses in the vegetative

growth of both Aquila and Inrat with increasing density of seedlings, to an extent greater than wild oat. A charlock density of 8 plants/pot reduced the wheat shoot dry weight of Aquila by 64% and of Inrat by 75%, compared to the weed free check. A similar density of wild oat reduced the vegetative growth of Aquila by 50% and of Inrat by 61%.

In replacement series experiments, the interaction between wheat cultivars and wild oat and charlock densities was significant for shoot dry weight, leaf and tiller number.

To study the nature of competition between the plants mentioned above in more detail, three further experiments were set up, using the growth partioning approach. Four growth boxes were used for each experiment. Wild oat and charlock were grown with wheat, under either full competition, root competition only, shoot competition only, or no interspecific competition. Over the period from planting until the plants reached the top of the boxes, root and full competition gave the largest suppression of wheat shoot dry weight; root competition was greater than shoot competition.

The herbicides tralkoxydim (2-[1-(ethoxyimino) propyl]-3-hydroxy mesitylcyclohex-2-enine) flamprop-isopropyl (isopropyl (+)-2-(N-benzoyl-3-chloro-4-fluorophenyl-2-amino) propionate, 2,4-D (2,4 dichlorophenoxy acetic acid, and MCPA (2-methyl-4-phenoxyacetic acid) were applied to wild oat and charlock, and to wheat cvs: Norman, Aquila, Bidi 17 and Inrat, in order to investigate their effects on the early stages of weed growth, and to determine the tolerance of winter wheat cvs to these herbicides. Of these chemicals, tralkoxydim had the greatest effect on wild oat while 2,4-D and MCPA followed the same pattern with charlock. When applied at the recommended rates, both tralkoxydim and flamprop-isopropyl produced significant effects on the dry matter of wild oat above ground. Tralkoxydim in particular gave a prolonged suppression, and high level of kill, of wild oat plants.

Acceptable control was also realized with 2,4-D and MCPA when applied to charlock at a height of 30cm.

Applied under greenhouse conditions at the recommended doses and time, Algerian winter wheat cvs showed a greater susceptibility to damage than did the British cultivars.

CONTENTS

CHAPTER ONE

INTRODUCTION & LITERATURE REVIEW

Chapter 1

Introduction and literature review

1.1. General introduction:

A broad spectrum of troublesome weeds infests wheat fields in Algeria, as in all other major wheat-producing areas of the world. The annual grasses and broad-leaved weeds are most prevalent, bringing about yield reduction by competing directly with crops for space, light, nutrients, and other interference effects (Harper, 1961). The presence of a large number of these weeds in winter wheat can lead to drastic reductions in yield (Fryer and Makepeace, 1977), and huge annual loss of food supplies. The impact of the presence of weeds on crop production is very considerable. Estimates suggest that weeds are responsible for an overall reduction of some what more than 10% in the yield of the major world crops, representing a huge annual loss of food supplies. In 1971, the total cost to agriculture in USA, as a result of weeds was slightly over $5 billion/year, which is 42% of the total amount caused by pests. (as given by U.S.D.A pesticide review; Klingman and Ashton, 1982).

The grass weed wild oat (*Avena fatua* L.) is the most difficult and intractable weed problem that has faced cereal crop production for decades. It, and similar grass weeds, not only reduce yields and profitability (Elliot,

1978) but may threaten future cropping if allowed to produce and shed seeds, and so perpetuate infestations.

Charlock (*Sinapis arvensis* L.) is a broadleaved weed that was at one time assessed as equal to *Avena fatua* as a vigorous competitor with cereal crops (Pavlychenko and Harrington, 1934). This, and other broad-leaved weeds remain serious causes of yield losses in many cereal-growing areas of the world including Algeria.

There are more similarities than differences in the factors that bring about the success of wild oat and charlock as a weed. Both can produce and shed seeds into the soil. These seeds can persist and remain viable, but dormant, for a considerable time through the fallow period between cereal crops (Bunting, 1966; Fogg, 1950; Thurston, 1951). They have high relative growth and are rapidly spread by man's activity, and by natural methods. All of these factors contribute to their success as weeds. Moreover, they are well adapted to grow under a wide range of climatic and edaphic conditions.

Cereals are most sensitive to weed competition in their early stage of growth, i.e between the 3 and 6 leaf stage. (Pavlychenko & Harrington, 1935) demonstrated the impact of early competition by wild oat on cereals. He found that *Avena* spp, exerted irreversible damage in cereals during the first 20 days which resulted in eventual reduction of grain yield (WSSA, 1977). Therefore early control of weeds is usually considered desirable to minimize crop losses due to competition.

Data on crop losses caused by wild oat and other species impacting cereal crops are lacking in Algeria and in many other parts of the world. This study aims to supply information about the competition of wild oat and charlock, weed density effect, nature of competition with wheat (*Triticum aestivum* L.) and to investigate methods of control of these two species with special reference to Algerian wheat.

Wheat was selected for this study because of its economic importance and its tolerance at certain stages of growth to a wide range of herbicides. The weeds used were chosen because of their prevalence in Algeria and their known susceptibility to the herbicides employed in this study.

The main aims of the were to examine the following aspects of cereal weed interactions:

1-The effects of different densities of wild oat and charlock on the growth and survival of crop plants during the early critical period of growth.

2- The competitive ability of wild oat and charlock, in wheat cultivars, with special reference to cultivars grown in Algeria; the effects of differing weed densities on various parameters of crop response.

3- The nature of competition was studied to assess the relative importance of above ground and below ground plant interactions during the crop establishment period .

4- The mechanism and effects of intraspecific competition on the growth of each species, and development and partitioning of dry matter, under greenhouse conditions.

The secondary aim was to contribute an understanding of how best to use different herbicides, in order to choose the most cost effective control measures. This involved:-

1- Comparisons of the effects of different herbicides on weed species; in particular to determine the limits of wild oat and charlock susceptibility and crop safety, as related to growth stages, and to investigate the efficacy of the foliar herbicides chosen i.e; tralkoxydim, flamprop-isopropyl, MCPA and 2,4-D, by dose response and growth stage studies.

2- Analysis of crop tolerance to herbicide damage.

1.2. Literature review:

The literature review is in two parts. The first part covers aspects of competition between wheat, and wild oat and charlock. The second part discusses aspects of the use of some new herbicides for grass and broadleaved weed control, relevant to this study.

1.2.1. Interspecific Competition:

1.2.1.1. Geographical distribution and economic losses of the species:

Wild oat and charlock are extensively distributed throughout the main cereal growing areas of the world and mainly in the temperate regions (Malzew,1930). *A. fatua* is of particular importance in northern Europe, occurring in all parts of England where wheat and barley are grown. It is also common in Scotland but less so in Wales (Thurston, 1956). It is the commonest wild oat species in America and Canada (Friesen, 1974; Behrens *et al.* 1976) and in all Australian states (Paterson,1974), whereas *Avena sterillis* ssp. *ludoviciana* autority is more localised, occurring chiefly in areas with a Mediterranean climate.

Charlock is a common weed in cereal crops in western Canada (Pavlychenko & Harrington, 1934), and has long been recorded as widely distributed in arable lands throughout Britain (Long, 1910). It was commenly considered to be of equal nuisance in Europe generally and in the wheat producing area of North America (Blackman & Templeman, 1938) and extends through most of the temperate regions of the world including north Africa (Fogg, 1950).

Large yield losses occur when crops are infested with high densities of wild oat (Selman, 1970; Wilson, Cussans & Ayres, 1974; Wilson & Cussans, 1978). Up to a million hectares of cereals are infested with wild oat in Algeria, Tunisia and Morocco, according to Shell estimates in 1979, and even in recently developed countries such as Tunisia the weed is a problem: about 350.000 ha (30%) of the Tunisian wheat crop is affected (Anon, 1975 a,b). Over 5 million hectares of cereals are infested in Canada (Bowden, 1971). In England in 1972, 372 000 ha were reported to be heavily infested, a 73% increase from the 215 000 ha in 1967 (Griffiths, 1972).

In Canada, the average annual yield reduction caused by dense infestation of charlock in wheat and barley was reported to be 53 and 69% respectively (Anderson, 1956).

Typical population density of charlock in cereals in the British Isles before the widespread use of herbicides, were estimated at between 65 and 264 plants/m^2 (Blackman & Templeman, 1936).

1.2.1.2. Effects of wild oat and charlock population on crop yields:

The extent of crop yield loss caused by weed interference is closely tied to the number of competing weeds per unit area (density), and their biomass. There is some density or biomass above which loss or damage occurs, and below which it does not, at least to any significant extent. Previous investigations have demonstrated an inverse relationship between weed density and crop yield. As the density of an individual weed species increased, the increased competition caused reduction in crop yield (Alex, 1966; Burrows & Olson, 1955 a,b).

Chancellor & Peters (1976) have summarised many of the studies on crop losses from different densities of wild oat. They reported from England that a wild oat density of at least 150 plants/m^2 at harvest was necesssary to reduce yield of spring wheat (*Triticum aestivum*) or barley (*Hordeum vulgare*). Bell and Nalewaja (1968 b) found that about 70 *Avena .fatua* plants/$yard^2$ were also necessary to cause maximum possible yield reduction in wheat and barley. In Canada, Bowden and Friesen (1967) showed that 100 wild oats/m^2 could reduce wheat yield by 15-60% depending on conditions.

In wheat, low densities of wild oat can cause yield reductions: 4 plants/m^2 reduced yield by 3% (Selman, 1969; McNamara, 1972), 11 plants/m^2 by 140 kg/ha (Cuthbertson,1967); and 12 plants/m^2 can give significant yield reductions (Bowden & Friesen, 1967).

At intermediate densities of wild oats (up to 100 plants/m^2 in wheat), larger yield reduction have been recorded. A density of 48 wild oats/m^2 reduced yield by 16% with fertiliser and 23% without fertiliser (Bowden & Friesen, 1967). In eastern England, the average yield reduction of wheat from 40 wild oat plants/m^2 was about 40% (Selman, 1969) but, in America, 84 wild oat plants/m^2 reduced yields by 22% (Bell & Nalewaja,1968b).

At higher densities in wheat, above 100 plants/m^2, crop loss is greater than that given by lower densities. In England, a mean density of 157 stems/m^2 (at harvest) reduced the yield of wheat by 33% (Chancellor & Peters, 1974). In America 192 plants/m^2 caused a 39% loss of yield (Bell & Nalewaja, 1968b). However at densities higher than 480 plants/m^2 there is little further reduction in wheat yield (Paterson, 1969).

Low wild oat densities have given similar yield reduction in barley to those occurring in wheat. As few as 4-15 wild oat plants/m^2 have given an average of reduction in yield between 3% and 15% in one year (Selman, 1969).

At intermediate wild oat densities (up to 100 plants/m^2) in barley, various yield losses have been recorded: 48 plants/m^2 reduced yield by 17% (De Gournay, 1964) and by 40% (Selman, 1969), while 84 plants/m^2 reduced yield by only 7% (Bell & Nalewaja, 1968b).

At higher wild oat densities in barley yield losses increase at harvest, 192 plants/m^2 caused a reduction of 26% (Bell & Nalewaja, 1968b), and 306 plants/m^2 a loss of 32% (Chancellor & Peters, 1974).

Other reports indicate a closer relationship between yield reduction and total wild oat dry weight at harvest (Wilson & Peters, 1982) or wild oat panicle dry weight (Baldwin, 1979).

Controlled competition studies in wheat initiated at the

University of Manitoba in 1952 demonstrated that as few as 50 charlock plants per yard^2 in wheat caused significant reductions in yield (Burrows & Olson, 1955 a, b). Shebeski (1955) reported that charlock at densities of 50, 100 and 200 plants/0.85 m^2 reduced wheat yield by 17, 36 and 45% respectively, compared to weed free plots. Elimination of competition from even moderate infestations of *S. arvensis* resulted in increases in crop yields of the order of 100%.

At Regina in Canada, the yield reduction due to a dense infestation of charlock in wheat and barley over a 9 year period was determined to be 53 and 69% respectively (Anderson, 1956).

Pavlychenko & Harrington (1934) reported that a heavy infestation of charlock reduced the yield of barley by 22.8% and the yield of wheat by 44.9% in comparison with weed-free plots.

1.2.1.3. <u>Crop density effect:</u>

Crop density may also influence weed competition. Increased cereal density or seeding rate has been shown to decrease both weed growth, and weed-caused crop losses (Godel, 1935; Pfeiffer & Holmes, 1961; Thurston, 1962). One suggestion is that, where a high level of weed competition is expected, appropriate levels of seeding should be used to ensure a cereal population density of at least 250 seedlings/m^2 (Roberts, 1982).

An early study by Godel (1935) indicated that increased cereal seeding rates on heavy soils partially controlled annual weeds. He advocated shallow, early seeding and use of fertiliser. Thurston (1962) has stated that *A. fatua* is best controlled by a dense autumn crop, the density of plants being more important than the crop grown. Granstrom (1959) stated that wild oat is strongly retarded by cereals planted at more than 400 plants/m^2. Increasing the seed rate of wheat from 180-250 kg/ha reduced the growth of wild oat and increased crop yield (Catizanes& Toderi, 1974).

The importance of high cereal plant densities at an early stage has been emphasized by Thurston (1962) who found that the effectiveness of cereal crops in competing with wild oat was determined by the crop density when the wild oat was germinating.

Burrows *et al.* (1955) determined that increased wheat seeding rate also increased yield from weedy plots, but not from plots either weeded by hand or sprayed with 2,4-D. They concluded that the minimum weed density justifying spraying depended on seeding rate. At 1 bu/A the critical weed density was 5.5 charlock plants/ft^2. However at 2 or 3 bu/A, the weed densities needed to justify spraying were 22 and 44 mustard plants/ft^2, respectively. With a constant amount of weediness from *S.arvensis*,increasing barley density diminished yield losses (Mann & Barnes, 1945, 1947, 1949). Fogelfors (1977) found that barley suppressed 93% of the growth of charlock as this species appeared to be poorly adapted to low light conditions under the barley canopy.

Increasing the density of a crop is generally considered to be a useful way of suppressing both wild oat and charlock (Godel, 1938-39; Granstrom, 1957; Burrows & Olson, 1955 a).

1.2.1.4 Effects of period of competition of wild oat and charlock.

The competitive effect of crops and weeds on each other may depend on when and how fast each starts growing in relation to the other. The length of time that a crop must be kept free of weeds in order to avoid yield reduction has been termed " the critical period ". (Nieto *et al.* 1968). This term can also describe the early period crop growth, when weeds need to be controlled to prevent yield reduction. Their method has since been applied to many annual, biennial and perennial crops and Nieto's concept of critical period has been found to be of general application (Scott *et al.* 1979). Thurston (1963) showed that the growth of wild oats in cereal crops depends on the size of the cereal plants when wild oats germinate. The largest increases in yield came from autumn removal by herbicide treatments, with greater yield differences between autumn and spring removal treatments if the wild oat density was high. At one site with 435 panicles/m^2 at harvest, herbicide removal of wild oat in December-January increased yields by 102% compared with the unsprayed control.

Studies in Italy (Catizans and Toderi, 1974) with *A. sterilis* ssp *ludoviciana*.in wheat, and in Australia (McNamara, 1976) with A. fatua in wheat indicate a mean loss of crop yield of about 7 to 10 kg/ha per day if the weed is present. There was no indication in the second instance of any severe effect of early competition, such as was found by Chancellor and Peters (1974). Other determinations of the timing of competition were carried out in pot experiments by Haizel and Harper (1973). They found that wild oat plants present in barley lowered yields right from the start of growth. In barley Lake (1971) found that competition began at the 3 leaf stage, Chancellor and Peters (1974), using natural populations of wild oats, with 150 stems/m^2 at harvest found that competition did not begin until the 4 leaf stage. Koch (1967) found that competition was most intense between barley and wild oat grown in pots up to the middle of the shooting stage. The time of greatest reduction in crop weight through competition was during shooting, when losses amounted to 25-32% (Koch, 1967). Similarly in Canada a large wild oat population in wheat (120 *A. fatua* plants/m^2) caused crop loss if present up to the crop 2-3 leaf stage. If plant density was increased from 120 to 359 wild oat plants/m^2 the onset of competition changed from before the 4-5 leaf stage to before the 1-2 leaf stage (Bowden and Friesen, 1967). Significant competition is generally accepted to start before the 2 to 3 leaf stage of wild oats (Chancellor & Peters, 1976; Sharma & Hunter, 1975).

This competition pattern for wild oats is quite different from that observed with charlock (Shebeski and Friesen, 1955). In studies with charlock competition did not become severe until the 5-6 leaf stage of the wheat crop and then the full impact of competition was realized in less than 6 days.

From the aforementioned studies, it can be concluded that those weeds which emerge late in the season are less competitive than those emerging early in the season. Competition effects were manifested in reduced tillering of wheat if the weeds were not removed with a herbicide, or by hand, before the grain passed beyond the 4 leaf growth stage.

1.2.1.5. The effect of shoot and root competition of wild oat and charlock on the vegetative growth of wheat cultivars:

Workers who have isolated the effects of competition above and below ground, have generally found that the effects of root competition are greater than shoot competition at least during the first few months after planting. (eg:Donald, 1958; Aspinall, 1960; Idris & Milthorpe, 1966; King, 1971; Snaydon, 1971; Eagles, 1972; Remisson & Snaydon, 1980; Schreiber, 1967; Rhodes, 1968; Barrett & Campbell, 1973). The usual experimental approach involves modifications of Donald's technique to study the nature of competition between arable crops and weeds, and between grass species and pasture plants. (Pavlychenko & Harrington, 1935) found that competition began under the soil surface when root systems mingled and water and nutrients became limiting. Barley competed more effectively than wheat because it provided a large number of seminal roots 5 days after emergence and developed more crown roots than any other cereal by 22 days . Wheat was more severely depressed by *A.fatua* which had a root area four times greater than wheat.

The greater competitive ability of wild oat, relative to wheat, is mainly due to its greater root competitive ability according to Martin & Field (1987), as shown by the greater aggression of wild oat under conditions permitting root competition than under shoot competition. They also found a greater increase in relative yield of wild oat and greater decrease in relative yield of wheat under root competition conditions than under conditions of shoot competition alone. These results show that competition by wild oat with wheat was caused mainly by root interference during vegetative development leading to reduced crop yield (Peters and Wilson, 1983) and high wild oat seed production (Peters, 1984). Experiments on competition between charlock and cereal in artificially constructed communities in the field (Pavlychenko & Harrington, 1934; Blackman & Templeman, 1938; Burrows & Olson, 1955; Welbank, 1963; Idris & Milthorpe, 1966; Alex, 1970) have used much greater densities of charlock plants than those typically found in the field. Studies by Edwards (1980) have been useful in relating charlock competitive effects to the availability of light, water and nutrients.

1.2.1.6. **<u>Predicting crop yield reduction from wild oat competition:</u>**

Researchers have derived several equations to estimate the crop losses caused by specific weed infestations (Dew, 1972; Noda *et al.* 1968; and Zakhrenko, 1968). The relationship between yield of a given crop and the density of a specific weed has usually been expressed as a simple regression equation. To use these equations, the weed free yield must be known, as well as the density of the stand or the weight of the weed species.

Using wheat grain yield data, collected by Bell & Nalewaja (1968 a,b) and Bowden and Friesen (1967), Dew (1972)constructed a regression model of wheat yields in wild oat infested field. His equation y = a+bx relates actual yield (y), to the weed free yield (a), and the slope b of the regression line of crop yield on weed density (x). The ratio of the regression coefficient over the intercept (b/a) has been termed the competitive index (b1). Using it, Dew calculated that the competitive indices of *A. fatua* in barley, wheat and flax as 0.021, 0.031, and 0.0601 respectively which means the numerical order of b1 (index of competition) is barley < wheat < flax, indicating that barley is the best competitor against wild oat and flax is the poorest.

Information on yield loss due to *A.fatua* is also available from experiments with selective herbicides. (Gummeson, 1968; Wilson *et al.*, 1974). Zakharenko (1968) developed a formula to calculate probable crop losses from *Avena* spp, or probable yield increases from herbicide use in wheat.

The value of the competition index was found to be specific for each crop/weed situation, and not related to the weed free crop yield. No values of crop density were available and therefore no allowance could be made in the index (b1) for high or low crop densities. O'Donovan *et al.* (1985) reported that each day of emergence of wild oats (*Avena fatua*), before or after emergence of barley or wheat, changed crop yield by about 3%. Several estimates of yield loss have been produced from development programmes in Europe. Studies in France (Loubaresse *et al.* 1975) using the yield response in wheat achieved with flamprop-methyl in trials showed yield losses up to 25%.

Another method for predicting crop yield losses caused by weeds is the replacement series method of de Wit (1960) which allows for estimating the relative yield total of two species in competition. A relative yield for each species in each mixture may be calculated from its yield in the mixture divided by its yield in the pure stand.

$$\text{Relative yield of A in the mixture A:B} = \frac{\text{Yield of A in mixture}}{\text{Yield of A in pure stand}}$$

The sum of these relative yields for the mixture a:b gives us the relative yield total (RYT) which is a useful index of the interactions between A and B in a particular mixture. It also allows examination of the relationship between the share of the total seed yield and the share of the plant density, as a means of quantifying aggressiveness of one species relative to another. In a later paper, Hill (1973) developed a theoretical model to identify conditions under which a 50:50 mixture could be expected to exceed the average of component monoculture or surpass the better monoculture. (Breese & Hill, 1973) proposed that the general competitive ability of a species could be measured by it general vigour, sensitivity to competition, and aggressiveness.

1.2.2. Intraspecific competition

1.2.2.1. The effect of intraspecific competition between species:

The influence of intraspecific competition in monocultures, results in a reciprocal relationship between mean yield per plant and density (Shinozaki & Kira, 1956). Watson and his collegues at Rothamsted, in particular, have made a very full study of the growth and development and yield in cereals. They have suggested that high grain yield is dependent upon having high leaf area and leaf area duration, especially after ear emergence (Watson, Thorn & French, 1963).

Puckridge and Donald (1967) reported that at high densities of wheat plants there was an extreme reduction in the yield of dry matter and grain per plant. This was associated with marked reductions in the number of tillers, in the proportion of fertille tillers, and in the weight of grain per ear.

Puckridge (1968) showed that at high density no tillers were produced by any of the plants, and suggested that this was an effect of competition for light, since tillers were produced when plants were transferred into a low plant density before day 18. Even for plants at low density tillering was restricted by a low nutrient supply, particularly of nitrogen.

A significant reduction in the density of charlock populations in British cereals has been found in recent years (Roberts & Stokes, 1966; Fryer & Chancellor, 1970; Audus, 1976). Because a positive correlation was found between plant size and density when the number of charlock plants was less than 20 plants/m^2, charlock does not appear to be highly competitive at low population densities. At higher charlock density, competition between neighbouring plants resulted in a diminution of individual plant size.

1.2.3. Control of weeds by herbicides:

The main object of using herbicides is to exclude weeds from entering and infesting new areas, and to avoid losses of crop yield. To achieve a higher yield response, the weeds must be controlled by applying the correct herbicide, at a period when the crop will not suffer unacceptable phytotoxic damage.

Herbicides for control of broadleaved weeds in wheat have not changed in recent years and growers still use 2.4-D, MCPA and other such products alone or in various combinations, depending on the predominant species in the field. Early research on the use of these herbicides identified the safest time of application as the 4 to 5 leaf stage and established rates of application especially for winter wheat (Klingman, 1953; Olson *et al.*, 1951), and more recently, for newer cultivars (Robinson & Fenster, 1973) A number of new post emergence herbicides have recently been developed for the control of wild oat. Tralkoxydim and flamprop-isopropyl are registered for *A.fatua* control as herbicides.

Wide variation in the stage of application and cost make selection of herbicides difficult. Bowden & Friesen (1967) reported that competition of wild oats might possibly be initiated prior to their emergence from the soil. If competition from wild oat is initiated in the early growth stages, post emergence herbicides applied at the early leaf stage produce greater yield benefits than herbicides which are applied at a later leaf stage.

In conclusion, the earlier the weeds can be removed the greater the benefit to the crops. Even with the increasing range of herbicides available to the farmer it is essential to obtain an accurate application to achieve the best economic return.

1.2.3.1. The effect of some post emergence herbicides on the yield of winter wheat cultivars in the absence of weeds:

The variation in the tolerance of different cereal growth stages to phenoxyacetic acid herbicides (2,4-D & MCPA) has long been known (eg. Anderson, 1952; Derscheid, Stahler & Kvatochovil, 1952; Derscheid, 1952; Elliot, 1953; Hagsand, 1954; Klingman, 1953; Large & Dillon Wetson, 1951; Longchamp, Roy & Gautheret, 1952; Olson, Zalik, Breakey & Brown 1951; Pinthus & Natwitz, 1967; Robinson & Fenster, 1968; Scragg, 1952). Results of research conducted by Tottman (1976, 1977) and Tottman and Duval (1978) in England have indicated that the external appearance of winter wheat could be used to determine the tolerance period to growth regulator herbicides. Olson *et al.* (1951) found that in wheat and barley, there were two widely separated periods during which damage was done by 2,4-D. The first was at early seedling stage and the second a late pre-heading. They concluded that plants were more tolerant to 2,4-D during the tillering stage and again after flowering. Tottman and Duval (1978) found that phenoxyacetic acid herbicides applied before the top of the highest leaf sheath reached 5 cm from the soil caused spike deformities in wheat at harvest. The same authors indicated that herbicide application should be completed before the leaf sheath height is 10 cm to avoid risk of poorly filled grain spikes which occurs from later application. Friesen & Olson (1953) have conducted experiments to show the difference in susceptibility of the main shoot and their tillers, or a particular deformity occured first in the main shoot, and later treatments induced similar deformities in successive tillers.

However, the recommendations for the use of most phenoxyacetic acid herbicides in wheat stipulate that application should be between the "end of tillering" or "fully tillered" and the "jointing" stages (Fryer and Makepeace, 1972).

Removal of wild oats from winter wheat with different herbicides at stages up to flag leaf emergence of the crop gave, much less effective (Baldwin & Livingston, 1976).

With herbicide removal of wild oats some crop damage may have occured, but early removal of wild oats was better than later removals. The importance of the assimilates formed during the grain filling period as a major source of grain dry weight (Sampson, 1968) could, however, indicate that late removal treatment would still be worthwile in very dense infestations of wild oats, as their removal would diminish shading during the grain filling.

CHAPTER TWO

MATERIALS & METHODS

Chapter 2

Materials and methods

2.1. Competition Experiments

Pot and growth box experiments were carried out under greenhouse conditions to study the effect of competition from wild oat (*Avena fatua*) and charlock (*Sinapis arvensis*) on the vegetative growth of British and Algerian wheat cultivars.

The effects of weed density on wheat growth were studied using additive experiments in plastic pots. In this set of experiments a crop planted at a fixed density was sown with wild oat or charlock planted at a range of densities. This method is perhaps the commonest approach used to study weed-crop competition (Stewart, 1981; Zimdahl, 1980). Further work was carried out using a replacement series approach (de Wit, 1960; de Wit & Van den Bergh, 1965, in which the total plant density is held constant while the mixture proportions of two species vary. Pure stands (monoculture) of each species are also included in the experiment.

The nature of above and below ground components of weed-crop competition was studied using growth boxes. Four modes of competition between species were used : no interaction, root interaction only, shoot interaction and full interaction (root and shoot). The independent effects of shoot and root competition were investigated using a technique devised by Snaydon (1979) modified from that of

Donald (1958). It is similar to those of Schreiber (1967), Rhodes (1968), and Eagles (1972). The competing plants were grown in alternate rows with moveable partitions which were used to separate roots and shoots of neighbouring plants, so that competition can be limited either between "above ground", "below ground", "both" or "neither" set of plant interaction. .

Finally, the intraspecific competition between each species, at a wide range of densities, was recorded in a series of plastic pot experiments.

2.1.1. Plant material

A simple method for germination testing:

Prior to the greenhouse studies the germination rate of seed samples was tested for each species. The germination rate of dehusked wild oats and wheat seeds may be readily determined by placing at least 100 seeds of each species on 3 layers of Whatman filter paper (9.0cm diameter) wetted with distilled water, in sterile plastic Petri-dishes. To prevent any complicating interaction with light, the Petri-dishes, in a randomized design. were covered with aluminium foil and placed in darkness in an incubator at varying temperature and examined daily.

Germination was assessed as having occurred when the radicle attained a length of approximately 1 cm.

Charlock germination rates were determined by placing more than 200 seeds in trays filled with vermiculite in a greenhouse, in a randomized design. Germination was assessed as having occurred when leaves had appeared from the surface of the vermiculite (usually after a period of 6-8 days).

2.1.2 Pot competition experiments:

2.1.2.1. Additive experiments

WILD OAT

Material and methods:

Two experiments were set up to examine the effects of increasing density of wild oat on the early stage of growth of wheat cultivars .

Seeds of winter wheat var:Inrat (Algerian) and Aquila (British) and wild oat were planted in a heavy clay loam soil mixed with peat and sand in a 4:1:1 ratio, in 7 inch diameter pots with bottom drainage. The plants were grown in a glasshouse at 21-23^{0}C, and with 16 hours photoperiod supplemented by artificial light .

The experiment was a completely random block design with six densities of wild oat and three replicates. The six weed densities were 0, 1, 2, 4, 8 and 16 plants per pot with 4 crop plants per each pot .

All pots were given a basic fertiliser of P, K and N from superphosphate muriate of potash and amonium sulphate respectively (60 kg/ha P_2O_5; 45 kg/ha K_2O and 125 kg/ha N). The plants were kept well supplied with water during growth. Two months after planting the plants in each pot were harvested individually. Tiller and leaf counts were made. Fresh weight was obtained by separating all parts (leaves, stems, and spikes) of the plant wich were than oven dried at 90^{0}C for two days. The data were subjected to Analysis of variance using the GENSTAT program (GENSTAT Manual, 1977).

CHARLOCK

A second set of two experiments was conducted to assess the effects of charlock density on the growth of wheat cultivars. Experimental techniques and design were as described in section 2.1.2.1, with 6 densities of weed (0 to 16 plants per pot) and 4 crop plants/pot of wheat cultivars Bidi 17 (Algerian) and Aquila. After eight weeks of growth, the weed and crop plants in each pot were harvested at ground level. The number of leaves and tillers were recorded, and fresh and dry weight values for leaf and stem components were obtained, as previously. Analysis of variance was carried out using GENSTAT.

2.1.2.2. Replacement experiments

WILD OAT

Material and methods:

A replacement series approach was used with two wheat cultivars (Avalon and Bidi 17), grown in plastic pots under greenhouse conditions.The planting system was 0, 1, 2, 3, and 4 plants of the crop cultivar, combined with 4, 3, 2, 1, and 0 plants of wild oat respectively, to give a constant of 4 plants per pot. The greenhouse conditions, planting and culture conditions were as in section 2.1.2.1. Treatments were arranged in a randomised block design with three replicates. The two experiments were sown on April 21 and harvested after two months of growth.

After harvesting, measurements were made of the dry and fresh weights of shoots of the two species. Leaf and tiller counts were made. Analysis of variance was carried out on all data collected.

CHARLOCK

Material and methods:

Experimental design was as described in section 2.2.2.1. Winter wheat (cv. Avalon) plus *Sinapis arvensis* seeds were sown in plastic pots 18cm in diameter containing a greenhouse soil mixture of four parts soil, one part sand, and one part potting compost. Plants were thinned out one week after planting and any missing plants were replaced by subsequent transplanting . Seeds were planted in a square pattern to give a population density of four plants per pot. After two months of growth in the greenhouse (16 hours light, 19^{0}C), above ground plant parts were harvested by cuting at ground level, and fresh and dry weights of leaves, and stems were recorded.

2.1.2.3. Growth box competition experiments

WILD OAT

There has been little concern in most agronomic experiments to identify whether competition is between the above or below ground portions of plants from different origins. Donald (1958), Rhodes (1968), Snaydon (1971), Eagles (1972), Remison & Snaydon(1980), Scott & Lowther(1980) studied the nature of competition between populations of pasture plants. Studies by Aspinall (1960) and Idris & Millthorpe (1966) of competition between crops and weeds and by Martin and Snaydon (1982) of cereal legume mixture, have shown that the effects of root competition are usually greater than those of shoot competition, at least during the first few months after planting.

Wild oat competes very strongly with wheat, reducing yields when present in large numbers (Bell & Nalewaja 1968, Chancellor & Peters 1974). Furthermore, there has been little concern in most agronomic experiments to study the competition between wild oat and wheat (Hannah 1964; Chancellor & Peters 1974).

According to Martin & Field (1987), very little work has been done on the nature of competition between wild oat and wheat.

Experimental procedure:

A greenhouse experiment was conducted to study the nature of wild oat competition in the early establishment phase of wheat cultivar Bidi 17. Four modes of competition were studied in relation to the development of wheat alone, and in competition with wild oat. The species are used to examine the effects of no competition, below-ground competition , above-ground and full competition between species. Eight square wooden growth boxes (42cm x 42cm x 15cm) with shoot partitions 30cm high were used. In addition, there two end piecies, also 30cm high , to reduce edge effect. Shoot partitions and end species were covered with aluminium foil to increase light supply to the plants. The boxes were filled with John Innes No.1 potting compost. Pre-germinated weed and crop seedlings were transferred first into trays in the greenhouse, and then the seedlings were pricked into the boxes. Each species was planted with the same density to give conditions of equal competition. Thirty six seedlings were planted in each box (6 plants in 6 rows) with an inter-plant spacing of 5cm. Each box consisted of three within-treatment replicates. Boxes were arranged in a randomised design on the bench. The 36 seedlings of a box consisted of two border rows of plants to be discarded and the remaining 24 to be harvested. The approximate night and day temperature were 16 and 24^{0}C with 16 hours supplementary lighting provided each day. The boxes were watered regularly and kept free of pests (aphids, powdery mildew) by spraying with pesticide. Any extraneous weeds were hand- removed.

<u>Measurements:</u>

Plants were harvested, fifty four days after sowing when growth had reached the top of the competition box (above ground partitions). Care was taken to recover as much of the root system as possible. The harvested plants were divided into shoot and root material and shoot dry weight was recorded. Before oven drying at 90^0C for 48 hours, shoot fresh weight, plant height and leaf area were measured.

CHARLOCK

Experimental procedure:

In this experiment, the nature of competition was studied between a winter wheat cultivar Broom, and *Sinapis arvensis*, using exactely the same techniques, experimental design, growing conditions and harvesting details as those described in the previous experiment with wild oat.

2.1.2.4. Intraspecific competition experiments:

Introduction:

Intraspecific competition was investigated to determine how individuals of the same species interfere with each other, before attempting to investigate interspecific competition. The study focuses on factors which may regulate the response of plants to increasing density. As density increases and interference becomes more intense, growth per plant decreased drastically. Two varieties of wheat and weeds were seeded separately at five different densities under greenhouse conditions. Competition affected shoot fresh and dry weights and leaf and tiller number of all species.

Experimental methods:

Seeds from several sources were used in this experiment. Seeds of wheat cv Bidi 17 and cv Broom, wild oat (*Avena fatua*) and charlock (*Sinapis arvensis*) were grown separately in a sandy/loam/peat mixture in 7 inch diameter plastic pots. Five densities were used in all experiments, namely 1, 2, 4, 8, and 16 plants/pot. The equivalent field sowing rates for these densities are 20, 40, 80, and 320 plants/m^2 respectively. This competition experiment was performed in a greenhouse at 20^0C. Each pot was watered daily to maintain field conditions as much as possible. Fertiliser was added to the pots two weeks before sowing. There were three replicates per treatments and the experiments were set up on the benches of the greenhouse in a randomized complete block design.

Measurements and records:

The harvest was carried out nine weeks after sowing. Plants were cut at ground level and the following measurements and records were made on each pot: number of tillers and of green, versus yellow leaves, stem fresh and dry weight and the number.

2.2. Weed Control experiments:

Results from the literature suggest that wild oat and charlock competition begins at an early stage of growth in wheat. Early control of these weeds is therefore desirable in order to minimize wheat yield losses due to weed competition.

A large number of specific grass and broadleaved herbicides are available for use in wheat but, all has specific limitations. Dose, rate and timing of application are critical for most herbicides.

Three experiments were carried out. The first one examined the response of wild oat to the foliar application of the new herbicide tralkoxydim (2-[1-(ethoxyimino)propyl]-3-hydroxy mesitylcyclohex-2-enone), code number PP604, and flamprop isopropyl (isopropyl (+)-2-(N-benzoyl-3-chloro-4-fluorophenyl-2- amino) propionate, code number WL29762 at two different stages of growth and three different rates of application. The second experiment followed the same methods but with charlock and 2,4-D (2,4-dicloro phenoxy acetic acid) and MCPA (2-methyl-4-phenoxyacetic acid).

The third experiment was carried out to study the tolerance of wheat cultivars (Bidi 17, Inrat, Aquila, and Norman) to four foliar herbicides i.e (tralkoxydim, flamprop-isopropyl, 2,4-D and MCPA).

2.2.1. Effect of two post-emergence herbicides on wild oat:

Material and methods:

Soil was sifted to remove large stones and mixed with peat and sand at a ratio of 4:1:1. Twenty four pots of 18 cm diameter were filled planted with germinated wild oat seeds and thinned to four plants per pot one week after planting.

One week before sowing, the pots were fertilised and kept in a heated greenhouse under supplementary lighting and supplied with water throughtout the growth of the plants. The experiment was a randomized block design with three replicates, plus untreated control pots (3) in each replicate. The two herbicides were applied at low and high rates at an early (Zadoks 21-22) and late (Zadoks 33-34) stage of growth. (2 treatments x 2 herbicides x 2 growth stage x 3 replicates = 24 pots).

Both herbicides were applied with an Oxford precision sprayer delivering 300 l/ha at a pressure of 210 KPa through a single 800 Teejet at constant speed, from 30 cm above foliage. Each herbicide treatment was applied with the recommended rates of the following additives:2 l/ha and 4 l/ha herbicide tralkoxydim or flamprop isopropyl with 1 l/1000 litres of diluted spray of agral. Thirty four days after spraying, the foliage was cut to soil level, fresh weights recorded and dried at 90^0C for 24 hours prior to recording of dry weights. Before harvesting a visual assessment of weed damage was made on at least two occasions.

2.2.2. Effects of post-emergence herbicides on charlock:

Influence of application of 2,4-D and MCPA on the control of charlock at three doses and two different timings of spray application.

Material and methods:

Charlock(*Sinapis arvensis*) is recorded as a strong competitor in wheat and can seriously reduce crop yields (Burrows & Olson 1955).The successful control of this weed in grain crops was achieved by the use of hormone killers 2,4-D and MCPA. In mid April seeds of charlock were grown in 180mm diameter pots. These were filled with soil, sand, and peat with base fertiliser over a layer of gravel sand. The pots were placed in the heated greenhouse in a fully randomized design. The spray treatment were applied to three replicate pots when the plants reached a height of 17cm, with 3 replicate unsprayed control pots.

Post emergence treatments of 2,4-D and MCPA were applied in 250l/ha of water at a pressure of 207 KPa using an Oxford precision sprayer with 8002 teejet nozzles at constant speed at height of 300mm above the foliage. Four weeks after spraying, plants in each pot were harvested, oven dried at 90^0C for 48 hours and biomass per pot (dry wt) determined.

2.2.3. Response of four wheat cultivars to four herbicides applied post-emergence:

The tolerance of wheat cultivars to most herbicides for both grass and broad leaved weed control varies with their stage of growth at the time of spraying.

Four varieties of wheat (Norman, Aquila, Bidi 17, and Inrat) were sown in plastic pots 6" in diameter and thinned to three plants per pot one week after sowing. Treatments were replicated four times in a randomized block design. Tralkoxydim, flamprop- isopropyl, 2,4-D, and MCPA were applied at doses commonly used to control weeds. Full details of the rates, times of application, and growth stage are given in the Table 2.1 as below:

Table 2.1: Full details of wheat cultivars, growth stages, rates and time of herbicides application.

Wheat cultivar	Growth stage	Herbicide and dose (l/ha) Tralkoxydim	Flamprop-isopropyl	2,4-D	MCPA
Aquila	28-29	3	3	1.4	1.68
Norman	26-27	3	3	1.4	1.68
Bidi 17	23-24	3	3	1.4	1.68
Inrat	26-27	3	3	1.4	1.68

CHAPTER THREE

INTERSPECIFIC COMPETITION: RESULTS

Chapter 3

Interspecific competition: results

3.1. Additive experiments.

3.1.1. Effect of wild oat density:

There were some interesting differences between the effects of wild oat and charlock on British and Algerian wheat cultivars. The data for wild oat will be considered first. The performance of the wheat cultivars in terms of the parameters investigated: (tillers per plant, leaves per plant and dry weight per plant) showed that there were significant differences between wheat cultivars grown alone and in combination with different densities of wild oat (Table 3.1).

Increasing the density of wild oat caused marked and progressive reductions in the vegetative production of wheat cultivars.

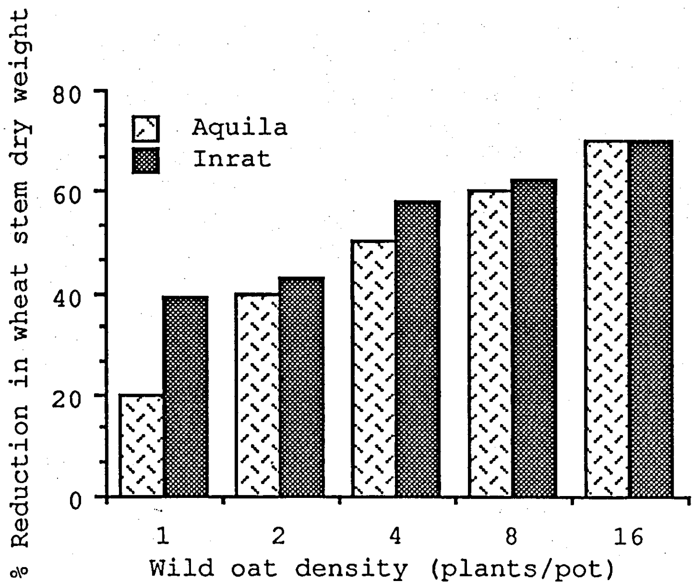
The primary data on the relationships between mean stem and leaf dry weight, and mean leaf and tiller numbers of the two wheat cultivars are presented in Figure 3.1. It may be seen that an increase in the number of weeds per pot led to significant decreases in the means of dry weight and number of tillers and leaves of the wheat cultivars.

<u>Table 3.1:</u> Effects of wild oat density on a) shoot dry weight (g/plant) b) leaf dry weight (g/plant) and c) leaf and tiller numbers of wheat cultivars.

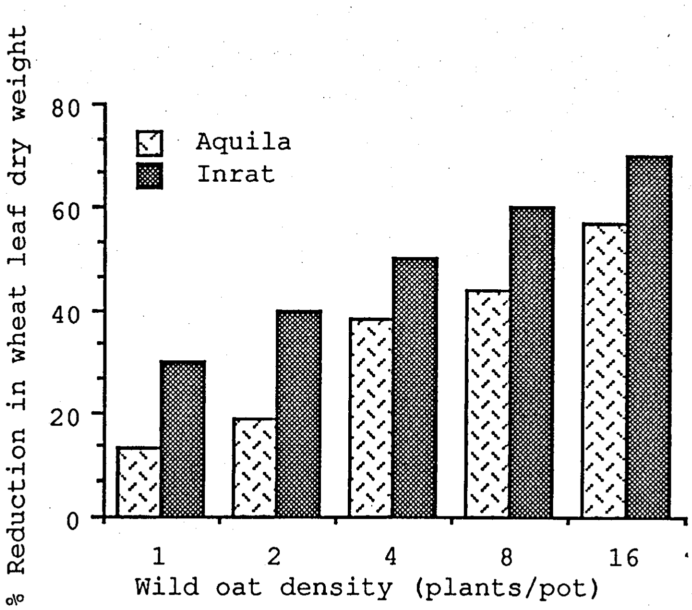
Wild oat Density Plants/pot	Stem dry weight		Tiller No		Leaf dry wt		Leaf No	
	Aquila	Inrat	Aquila	Inrat	Aquila	Inrat	Aquila	Inrat
0	1.0	2.6	2.1	1.2	1.6	1.0	22	16
1	0.8	1.6	1.9	1.0	1.4	0.7	21	13
2	0.6	1.5	1.5	0.9	1.3	0.6	18	12
4	0.5	1.1	1.3	0.8	1.0	0.5	14	10
8	0.4	1.0	1.0	0.5	0.9	0.4	12	7
16	0.3	0.8	0.2	0.2	0.7	0.3	7	6
S.E.D.	0.06	0.21	0.17	0.12	0.10	0.06	1.4	0.6

Figure3.1: **Percentage reduction of wild oat density (plants/pot) on the dry matter, leaf and tiller number of wheat cultivars:**

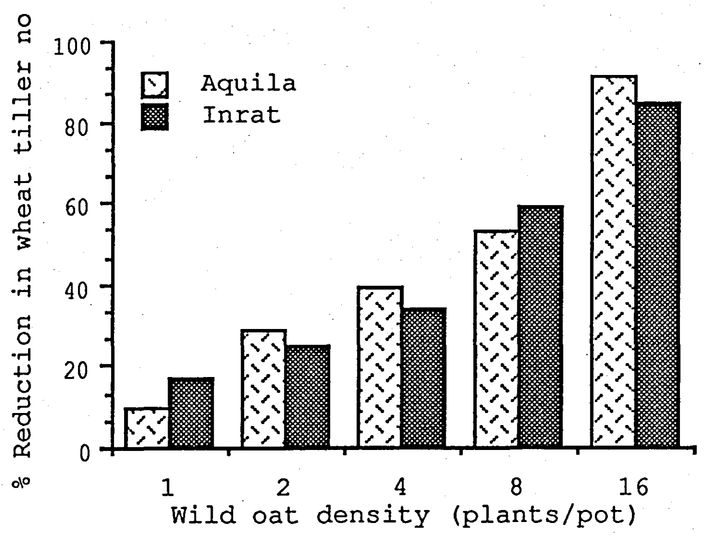
a) Stem dry weight



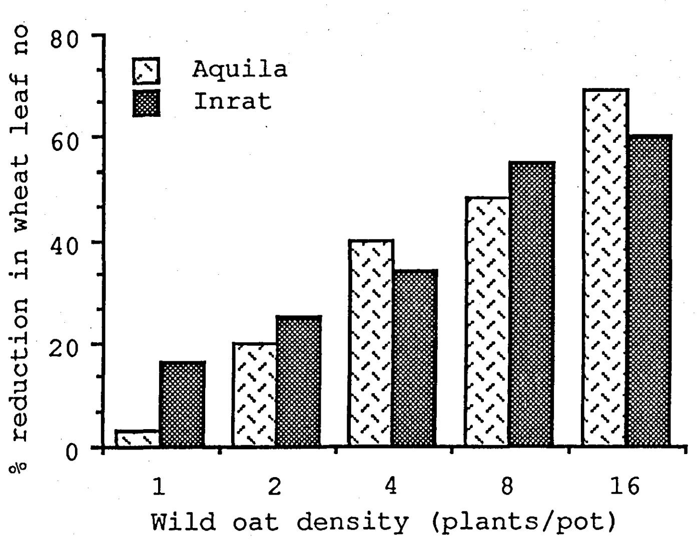
b) Leaf dry weight.



c) Tiller no.



d) Leaf no.



3.1.2. Effect of charlock density:

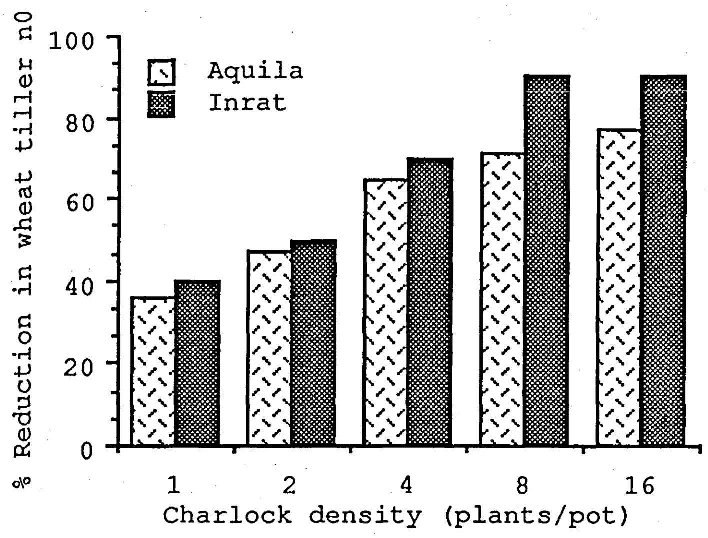
charlock also caused a marked reduction of above ground dry matter of wheat cultivars, with increasing density. Both wheat cultivars were affected by changes in charlock density (Table 3.2).

Table 3.2: Effects of charlock on a) stem dry weight (g/plant) b) leaf dry weight (g/plant) and c) leaf and tiller number of wheat cultivars

Charlock density plants/pot	Stem dry weight		Tiller no.		Leaf dry weight		Leaf no.	
	Aquila	Inrat	Aquila	Inrat	Aquila	Inrat	Aquila	Inrat
0	0.8	1.1	1.7	1.0	1.4	0.9	17.8	15.7
1	0.7	0.5	1.1	0.6	0.9	0.4	11.4	8.3
2	0.5	0.4	0.9	0.4	0.7	0.3	8.6	6.2
4	0.4	0.4	0.6	0.3	0.7	0.2	7.3	5.3
8	0.3	0.3	0.5	0.1	0.5	0.2	6.3	4.3
16	0.3	0.2	0.4	0.1	0.5	0.2	5.5	3.5
S.E.D.	0.10	0.04	0.10	0.15	0.08	0.05	0.40	0.51

The results for tiller production per pot are presented in the table above. A greater proportional decrease in tiller number was evident with increase in density. However, tillers per wheat plant decreased from 6 to 1 plants/pot. These results suggest that wheat yield reduction caused by competition of charlock was most effective early in the development of the wheat, i.e. in tillering (Fig 3.2).

Figure3.2: Percentage reduction of charlock density (plants/pot) on the tiller number of wheat cultivar



3.1.3. Comparison of weed effects on the yield of wheat cultivars:

From the results of these experiments, it is evident that charlock caused greater yield reduction in wheat than did wild oat at comparable densities (Table 3.3).

Table 3.3: The effects of wild oat and charlock density on the shoot dry weight of wheat cultivars.

Weed density plants/pot	Wheat cv: Aquila		Wheat cv: Inrat	
	W.oat	Charlock	W.oat	Charlock
0	2.6	2.2	3.6	2.0
1	2.1	1.6	2.3	0.9
2	1.9	1.2	2.1	0.6
4	1.5	1.0	1.6	0.6
8	1.3	0.8	1.4	0.5
16	0.9	0.8	1.2	0.4
S.E.D	0.16	0.12	0.24	0.07

The amount of reduction varied considerably, because wild oat and charlock differ in their growth habits (eg: the ability to take up nutrients, water and light.). At a density of 4 plants/pot, charlock reduced the yield of wheat cv: Aquila by 54.5% and wheat cv: Inrat by 70%, compared to the weed free-check, but similar wild oat density reduced the yield of Aquila by 42% and of Inrat by 56%. The wheat yield loss was greater with charlock than with wild oat. Charlock, at densities up to 16 plants/pot resulted in 64% and 80% reduction in yield of Aquila and Inrat respectively. However 16 wild oat plants/pot resulted in a yield reduction of Aquila and Inrat by 65 and 67% respectively (Table 3.4).

Table 3.4: **Percentage reduction of shoot dry weight of two wheat cultivars grown with wild oat and charlock.**

Weed density plants/pot	Wheat cv: Aquila		Wheat cv: Inrat	
	W.oat	Charlock	W.oat	Charlock
1	19	27	36	55
2	27	45	42	70
4	42	55	56	70
8	50	64	61	75
16	65	64	67	80

Wild oat competition was not as severe as that of charlock at the lower densities. The difference between the response of wheat cultivars was also less marked at higher densities, although Inrat was badly affected by charlock at the highest densities.

The presence of charlock depressed the number of tillers of wheat cultivars to a greater extent than did wild oat (Tables 3.1 and 3.2). The number of tillers seems to have been much more liable to reduction in the Algerian wheat than in the British wheat cultivars, although significantly ($P<0.001$) fewer were produced, anyway in the weed-free controls. In the presence of either wild oat or charlock at the highest density, the tiller number of both wheat cultivars was depressed to a fairly similar extent. The number of tillers decreased with charlock at all weed density and appearing to produce a greater proportional reduction than wild oat, in both wheat cultivars.

Wheat dry matter production was also decreased by both weeds. The loss in dry matter caused by charlock was much larger than the loss in dry matter caused by wild oat. charlock was more competitive and caused greater reduction in leaf production. The general effect was similar to the effect on tiller production.

3.1.4. Discussion

Early work by Borrows & Olson (1955a,b) and Alex (1968) showed the existence of a quantitative inverse relationship between weed density and crop yield. As the density of each individual weed species increased, the increased competition resulted in reduced crop yield. The different experiments reported here provided evidence for a positive yield loss: weed density relationship between Algerian and British wheat cultivars as a result of increasing weed. However, this study also showed that charlock was more competitive with wheat cultivars than was wild oat. Further, it caused greater yield reduction of Algerian wheat than for the British wheat. The superiority of charlock with both cultivars may be due to its seedlings, which were more vigorous than those of wild oat early in the growing season. Also, its plants grew more rapidly, were more uniform in size and produced a dense leaf canopy giving shading which may well have been responsible for the severe depression of tillering produced in wheat cultivars.

The different growth habit of the two weed species probably influenced the degree of competition. This supports the findings of Welbank (1963) that charlock had a much larger effect on wheat than the other species used in his study.

3.1.5.<u>CONCLUSIONS:</u>

1- Wild oat and charlock interference was highly detrimental to the production of two cultivars of winter wheat. Therefore, their control should be a high priority of any management system in areas of infestation.

2- Both weeds in wheat intended for certification could result in large economic losses. If wheat seed containing wild oat or charlock are planted, infestations lasting many years could result.

3- From these results the primary detrimental effect of these two weeds was to decrease the vegetative growth of the wheat cultivars. No data on grain yield were collected in these experiments. However both weed density, and the combination of weed and crop species involved, clearly had strong effects on the early-stage of crop growth, with likely implications for eventual yield.

4- The emphasis of the present work was to compare the early response of two wheat cultivars to growth stage. It is concluded that the exact density which will cause a yield reduction of economic importance will depend upon the weed species, weed density and the crop species.

3.2. Replacement series experiments:

3.2.1. Results

: To analyse further the relative competitiveness of each wild oat or charlock treatments a replacement diagram (Fig 3.3) for the total shoot dry weight per pot of both wheat cultivars (Bidi 17 and Avalon), wild oat and charlock was drawn up (de Wit, 1960). The early growth of both wheat cultivars was slow in comparison with that of wild oat and charlock; wheat seedlings were probably subjected to shading from the weeds at an early stage of growth. Diagrams of the shoot dry weight response of the four species show that wheat in monoculture made as much growth as wild oat or charlock but when any of the weed species were combined with wheat cultivars, shoot dry weight was greatly reduced, while shoot dry weight of both weeds was little affected by wheat. Where the wheat cvs are grown with either wild oat or charlock treatment, the yields of both species are proportional to the sowing densities i.e. the relative replacement rate equals unity. However in other treatments, the wild oat or charlock are the gaining species, and wheat cultivars are the losing species i.e. the curve of the lines curve is convex for both weeds, and concave for both wheat cultivars. This leads to the result that the relative yield total is unity, with one species almost exactly replacing the space of the other.

In each treatment, the number of tillers per wheat plant was reduced as the severity of the competition increased.

The wheat plants produced more tillers when grown alone than when grown with the 25%, 50% or 75% proportions of wild oat or charlock

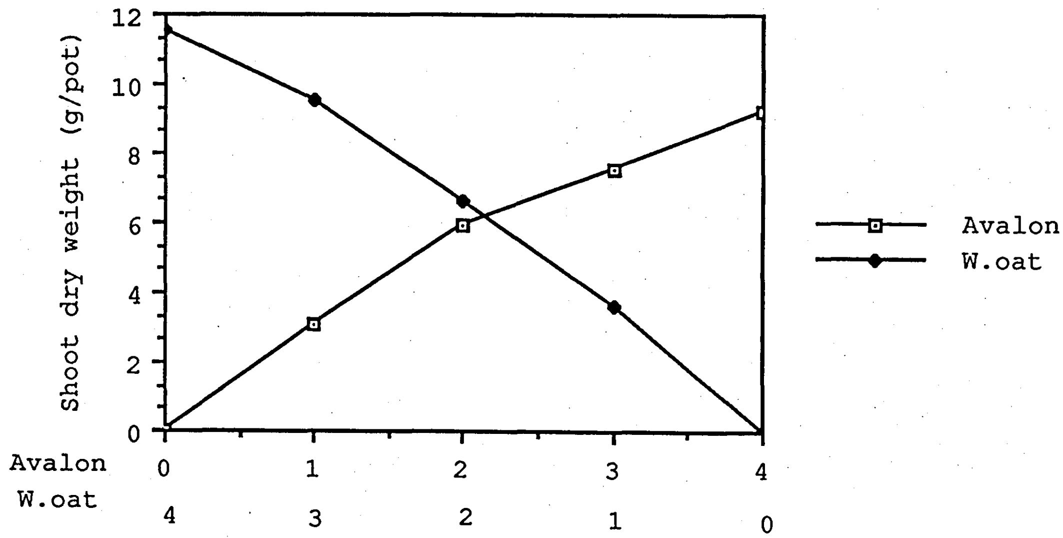
Each of the wheat cultivars had fewer leaves when grown in monoculture rather than in mixed culture (Table 3.5) with wild oat, but they had a greater number of leaves when grown with charlock, so charlock reduced leaf numbers of wheat cultivars more than did wild oat. There were significant differences between species and their effects in reducing the number of leaves per wheat plant when the species were grown in mixed culture. Also each species produced greater leaf weights when grown in mixture than in monoculture (Table 3.5).

Table 3.5: Means (per pot) of three measures of vegetative growth for winter wheat cultivars grown in monoculture and mixed culture.i.e is '1'= A; '2,3'= mixed A+B; '4'= monoculture B.

Factors	Plant density	Wheat cv:Avalon		Wheat cv: Bidi 17	
		W.oat	Charlock	W.oat	Charlock
Stem weight (g/pot)	1	0.7	0.1	1.4	0.2
	2	1.3	0.2	1.7	0.4
	3	1.7	0.3	3.7	1.0
	4	2.3	1.4	4.1	2.2
Leaf weight (g/pot)	1	1.1	0.3	0.6	0.3
	2	2.1	0.4	1.2	0.6
	3	2.5	0.7	2.1	1.3
	4	3.7	3.5	4.8	3.2
Leaf number	1	20	6	21	6
	2	41	7	32	12
	3	48	18	67	27
	4	72	61	79	70

Fig 3.3: **a)** (Overleaf) Shoot dry weight (g/pot) of wheat cv. Avalon and wild oat grown in competition.

b): (Overleaf) Relative yield total of wild oat and wheat cv. Avalon grown in competition.


Shoot dry weight (g/pot)
12
10
8
6
4
2
0
Avalon
W.oat
0
1
2
3
4
4
3
2
1
0
Avalon
W.oat

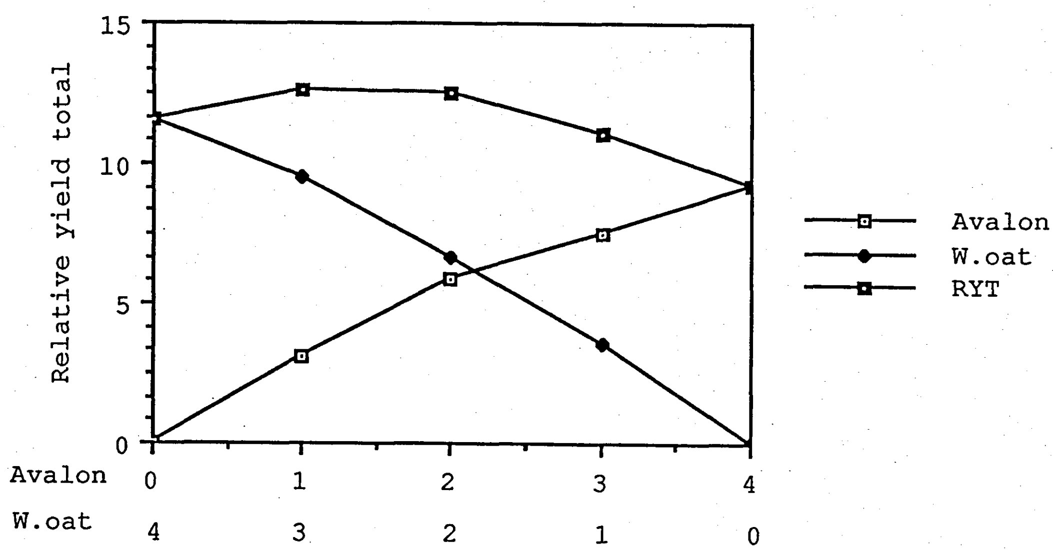
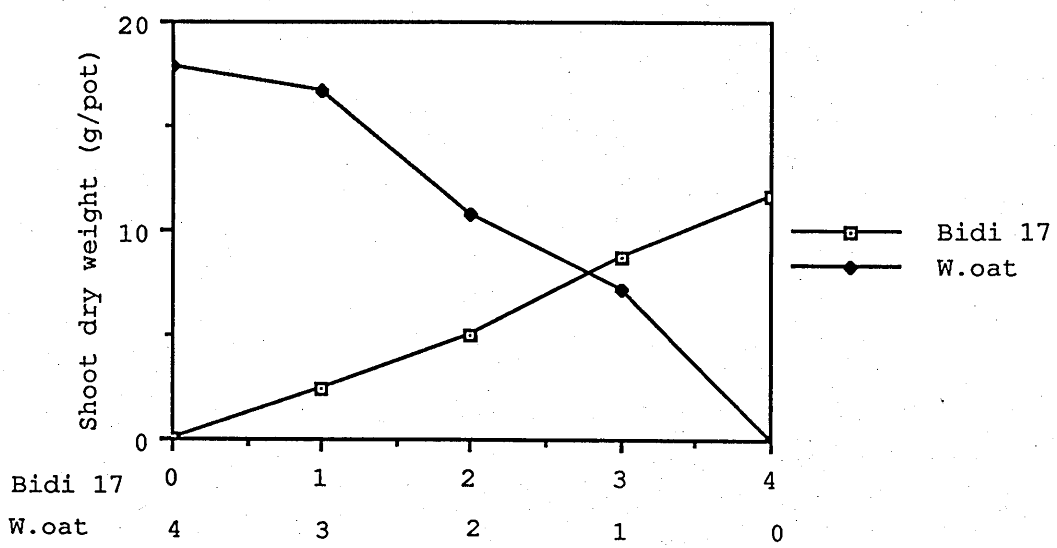

Relative yield total
15
10
5
0
Avalon
W.oat
0
1
2
3
4
4
3
2
1
0
Avalon
W.oat
RYT

Fig 3.4: a) (Overleaf) Shoot dry weight (g/pot) of wheat cv. Bidi 17 and wild oat grown in competition.

b): (Overleaf) relative yield total of wild oat and wheat cv. Bidi 17 grown in competetion.


20
10
0
Shoot dry weight (g/pot)
Bidi 17
W.oat
0 1 2 3 4
4 3 2 1 0
Bidi 17
W.oat

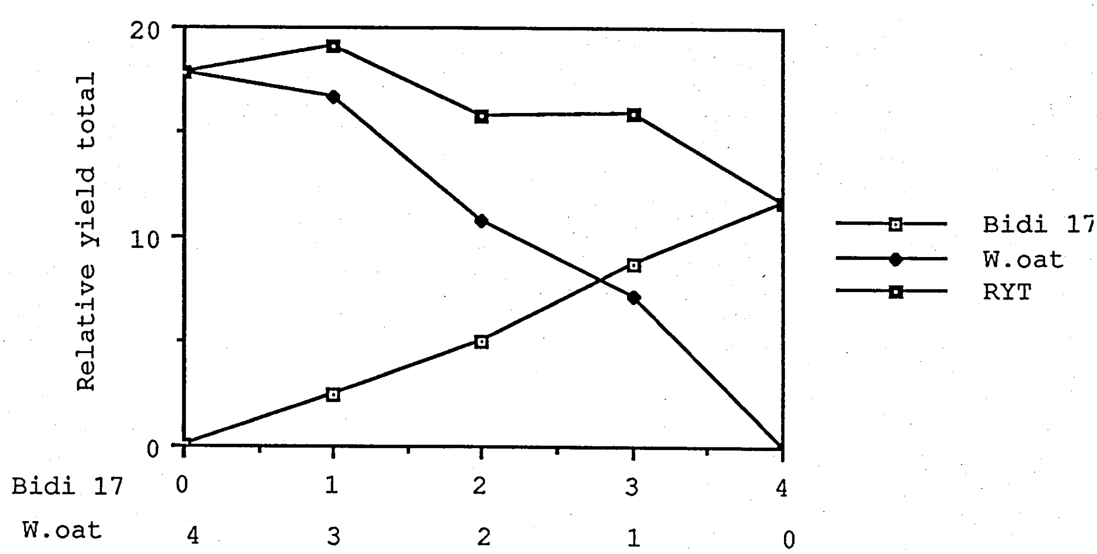
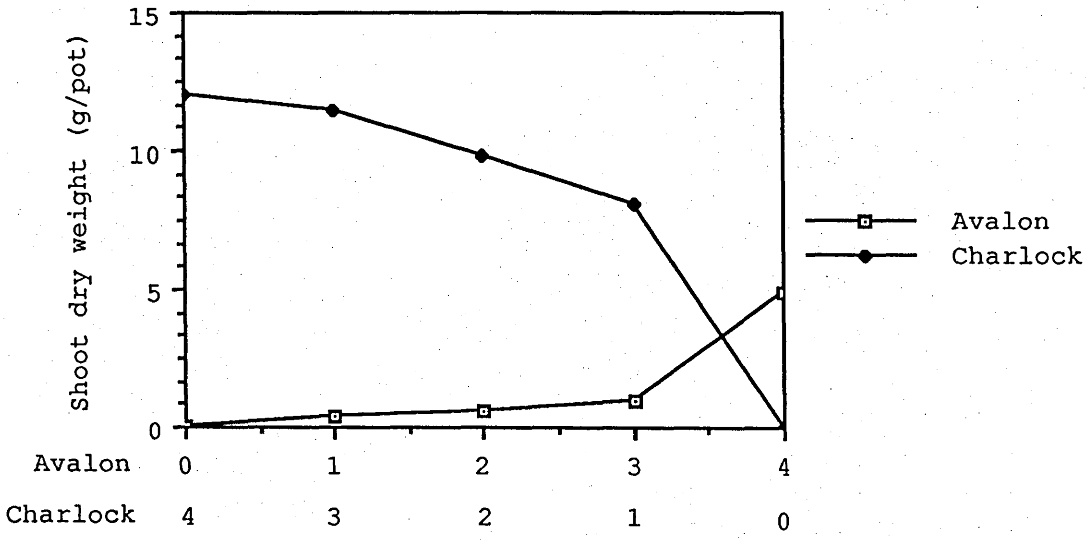

20
10
0
Relative yield total
Bidi 17
W.oat
0 1 2 3 4
4 3 2 1 0
Bidi 17
W.oat
RYT

Fig 3.5: **a)** (overleaf) Shoot dry weight (g/pot)of wheat cv. Avalon and charlock grown in competition.

b): (overleaf) Relative yield total of charlock and wheat cv. Avalon grown in competition.


15
10
5
0
Shoot dry weight (g/pot)
Avalon
Charlock
Avalon 0 1 2 3 4
Charlock 4 3 2 1 0

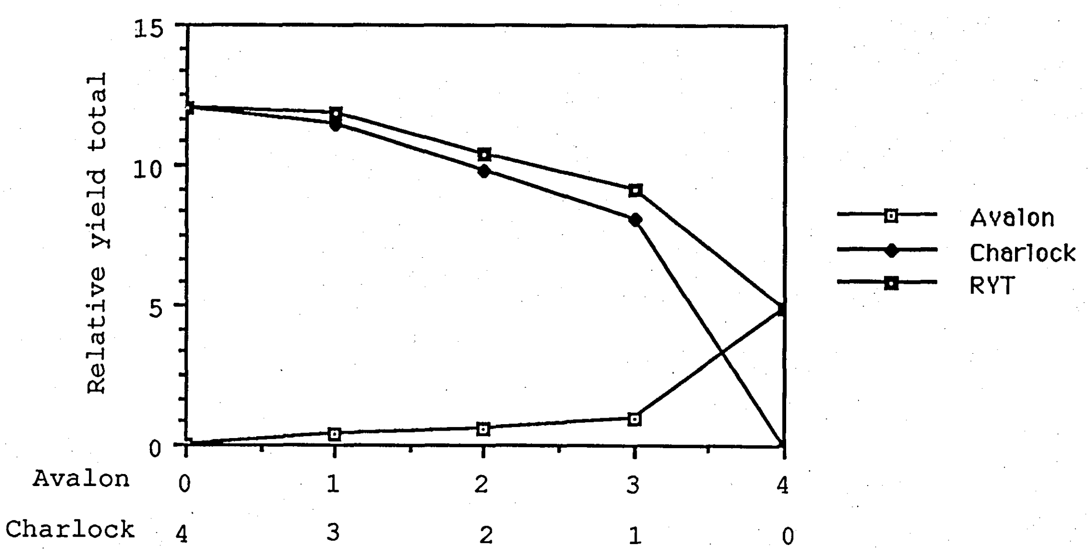
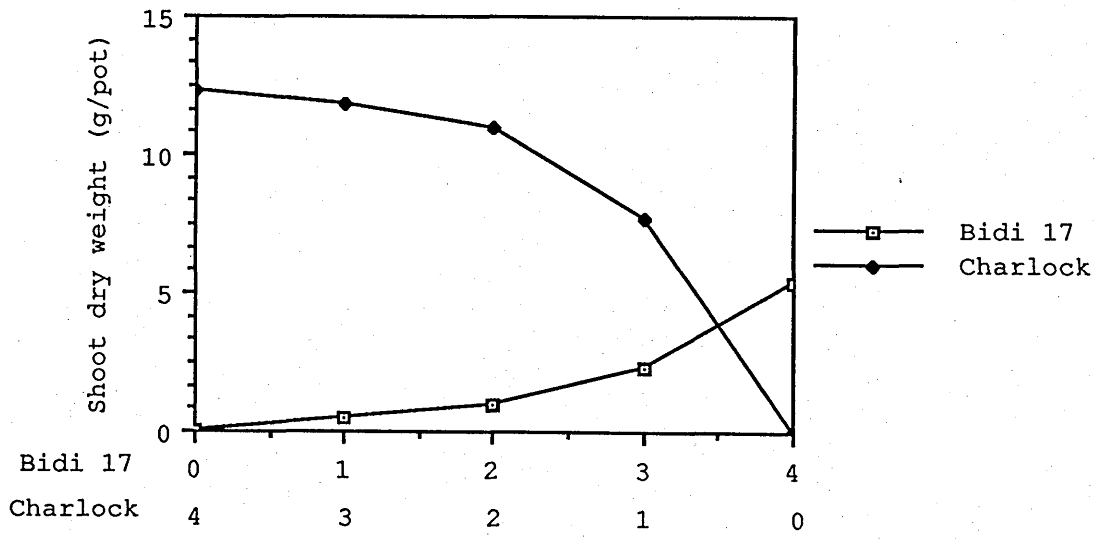
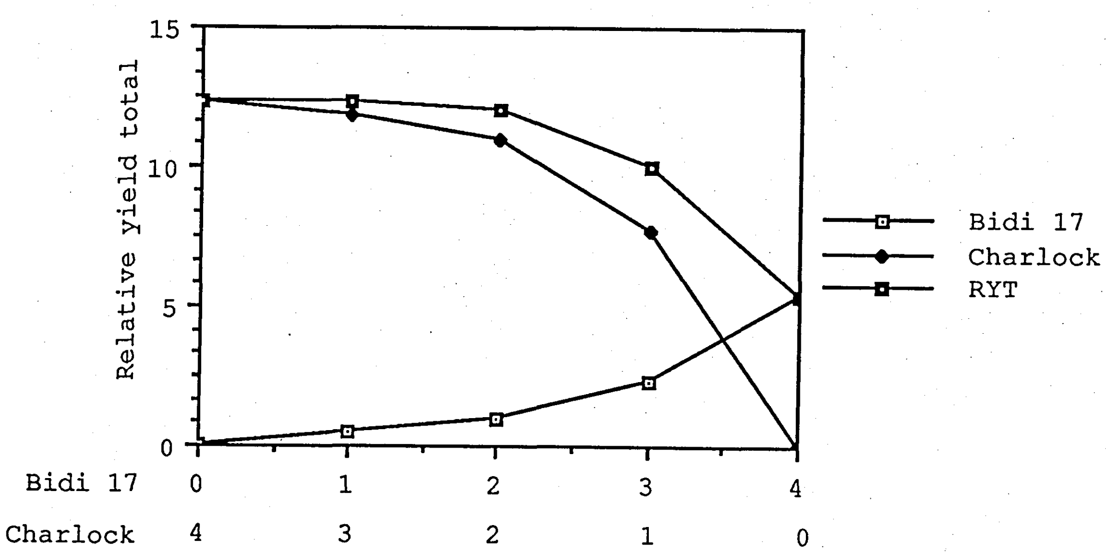

15
10
5
0
Relative yield total
Avalon
Charlock
RYT
Avalon 0 1 2 3 4
Charlock 4 3 2 1 0

Fig 3.6: **a)** (overleaf) Shoot dry weight (g/pot) of wheat cv.Bidi 17 and charlock grown in competition.

b):(Overleaf) Relative yield total of charlock and wheat cv. Bidi 17 grown in competition.


15
10
5
0
Shoot dry weight (g/pot)
Bidi 17
Charlock
Bidi 17
Charlock
0
1
2
3
4
4
3
2
1
0


15
10
5
0
Relative yield total
Bidi 17
Charlock
RYT
Bidi 17
Charlock
0
1
2
3
4
4
3
2
1
0

In each treatment where the wheat was grown with wild oat the total (weed + wheat) dry weight per pot (ie:total yield) was slightly greater than when wheat was grown alone. At the 1:3 ratio of wheat:weed, the only mixture to produce a significantly greater total yield than wheat alone was Avalon + wild oat (Table 3.5).

In this experiment although the value of the relative yield total (RYT) slightly exceeded unity for wheat cultivars grown with wild oat or charlock, there was no difference between any of the RYTs Therefore, although the dry weight production of the wheat in mixture with both weeds was significantly greater than wheat in monoculture, the RYT did not exceed unity by a large enough quantity to indicate that the two plants were exploiting different environments. The yield per pot of charlock alone at the double density was significantly greater than the monoculture of wheat grown with both weeds, so charlock was therefore more productive of dry matter than any of the other species under study.

3.2.2. Discussion:

A greater proportional decrease in all cereal growth parameters measured was evident with increasing proportion of weed density, in mixed culture with either wild oat or charlock, than in monoculture. The tiller production of all species was suppressed in both mixed culture densities.

Both wheat cultivars produced more dry matter in both mixed cultures than in monoculture, while both cultivars were more productive in association with wild oat than with charlock. The proportional decrease in dry matter with increase in density was much more severe in mixed culture than in monoculture, and with charlock than with wild oat. The most consistent effect was given by the different weed species weights, the wheat plants grown with wild oat always formed more spikes, had more tillers and a greater dry weight and had less damage than of wheat species grown with charlock.

3.2.3.Conclusions:

1- When wheat species were grown in mixture 1:1 with both wild oat and charlock, wheat species produced more dry weight per plant than wild oat or charlock, but when the wheat was planted at 25% or 75% mixture, the weed species produced more dry weight per pot.

2- The competitive ability of weed plants to wheat cultivars therefore depends upon the weed species and the density of the weed.

3- charlock, the species with the greatest leaf numbers and weight when grown in monoculture, was most competitive when grown with other species.

4- All of the plant characteristics of species grown in mixture were affected by interspecific competition. stem dry weight was more severely affected by competition from charlock than the other characteres studied. These findings support those of Rhodes (1968) who reported that all components of seedling development were affected by competition, although to various degrees. However, the relative competitive abilities and growth habits of a plant species changed when grown in different proportion density.

3.3. Growth box experiments:

The design of these experiments, did not encompass between-treatment replication, and the data have not, therefore, been subject to inferential statistical analysis. However, general trends in the data are discussed.

Examination of the means relating to these competition experiments reveals that wheat cultivar shoot dry weight was reduced by all modes of competition from the two species (Table 3.6).

__Table 3.6:__ Effects of four modes of competition between plant species on shoot weight of wheat cultivars two months after planting in the greenhouse.

Modes of Competition	Shoot dry weight (g/plant)					
	Broom	W.oat	Broom	W.mustard	Bidi 17	W.oat
No competition	0.6	0.8	0.7	2.5	0.6	0.6
Soil competition	0.3	0.4	0.5	1.4	0.5	0.5
Light competition	0.5	0.6	0.6	2.0	0.4	0.5
Full competition	0.2	0.3	0.3	1.1	0.3	0.4

The plants undergoing soil competition were generally smaller and less leafy than those grown under light competition. This reflected the pattern found by Milthorpe (1961) who pointed out that several previous studies had led to the conclusion that root competition usually begins before shoot competition in an establishing association of plants. The present study has also shown the greater importance of root competition during the early stages of gramineous association. However it is evident that, in the mixture of wild oat and wheat, by the time a stable tiller mixture of wild oat and wheat, by the time a stable tiller density was reached, shoot competition had become as important as root competition in bringing about the suppression of wheat. Thus, over this early stage of growth period charlock appeared to be better able than wild oat to compete for light.

In the mixture of wild oat and wheat cultivars, suppression of the latter species was due entirely to the superior ability of wild oat to compete for mineral nutrients (growth of roots).

King (1971), using a different experimental technique, also demonstrated that below ground competition was more important than above ground competition, when grass seedlings were grown with established plants. Other studies with crop species (Martin and Snaydon, 1980; Martin & Field 1987) have also shown that root competition has more effect than shoot competition.

Wheat cultivar shoot weight were reduced by all modes of competition from the two species (Table 3.6). Full competition from the two weed species also reduced wheat cultivars shoot dry weight more than did light competition conditions.

The results for charlock competition reflected the pattern shown with wild oat competition, but show more marked differences. For most factors, the mean values of the reading plants were greater than those in competition with wild oat, however, shoot dry weight were greater for the light competition (Table 3.6).

3.3.1.<u>Effect of wild oat on wheat cultivars under four modes of competition:</u>

A possible explanation can be put forward to explain these results. The most severe reduction in wheat plants cv:Broom success was from soil competition as shown in reduced shoot dry weight.

The possible reason for the increased occurrence of soil competition is due to the dense production of roots from wild oat. Also, full competition with wild oat caused a reduction in shoot weight (Table 3.6) when compared with soil or root competition.

In comparison with no competition the dry weight of both wheat species was greatly reduced by full competition and root competition.

In general, the effect of competition was to increase the yield of weeds (wild oat and charlock) and to decrease that of wheat cultivars. Soil and root competition operating similtineously increased the yield of weeds and decreased that of wheat cultivars and had greater effect than either shoot or root competition operating independently (Table 3.6). This is clearly shown by the ratio of shoot dry weight wild oat and charlock to wheat cultivars under various forms of competition. Eight weeks after sowing, soil competition had a greater effect in reducing the yield of wheat cultivars from both weeds than did light competition, as is shown by ratio 2.8 to 3.3, 1 to 1.3 and 1.3 to 1.2 under soil and light competition respectively.

3.3.2. Discussion:

During the first 8 weeks growth these results suggest that the greater competitive ability of wild oat was probably due to its greater root system, and of charlock due to its greater shoot competitive ability. Further on in growth, charlock had a greater rate of growth and a higher canopy of upright leaves within which light was well distributed.

Both wild oat and charlock suppressed the growth of wheat cultivars under all conditions in this experiment. The suppression was greatest when both root and shoot systems of the two species were in competition. There is evidence that, when plants develop from seeds, soil competition began before light competition (Aspinall, 1960; Idris and Milthorpe, 1966; King, 1971; Litav and Isti, 1974).

CHAPTER FOUR

INTRASPECIFIC COMPETITION: RESULTS

Chapter 4

Intraspecific Competition: Results.

4.1. General:

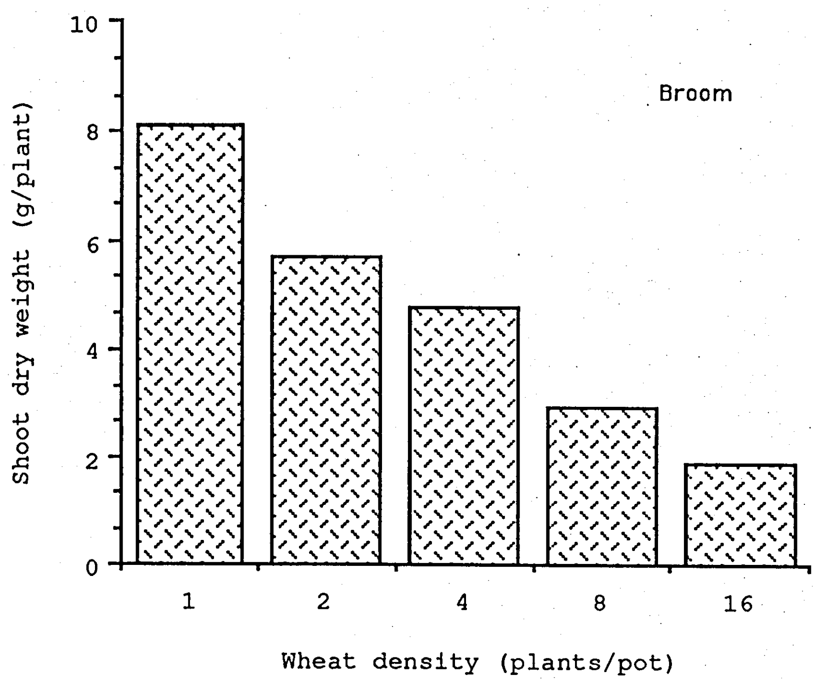
The data obtained for each species (Wheat cvs: Bidi 17 and Aquila; wild oat; charlock) grown at a wide range of densities indicated that each species responded in the same way, with a significant reduction in individual plant biomass, to increasing competition, even though the above-ground dry matter production per unit area (i.e. per pot) increased with increasing plant density.

Table 4.1: Shoot dry weight in relation to density of wheat cultivars cv: Bidi 17 and Broom, wild oat and charlock. [values represent the mean of three replicates]

Number of plants/pot	Shoot dry weight (g/plant)			
	Wheat cv: Bidi 17	Wheat cv: Broom	Wild oat	Charlock
1	9.7	8.1	9.6	9.7
2	6.9	5.7	9.4	6.5
4	4.5	4.8	4.6	6.2
8	2.6	2.9	3.5	5.1
16	2.1	1.9	2.2	3.3
S.E.D	0.23	0.20	0.71	0.62

The four species reacted to increasing intraspecific competition through a plastic response of above-ground dry matter production.

Fig 4.1: Effects of wheat cultivar population density (Broom & Bidi 17) on shoot dry weight per wheat plant.



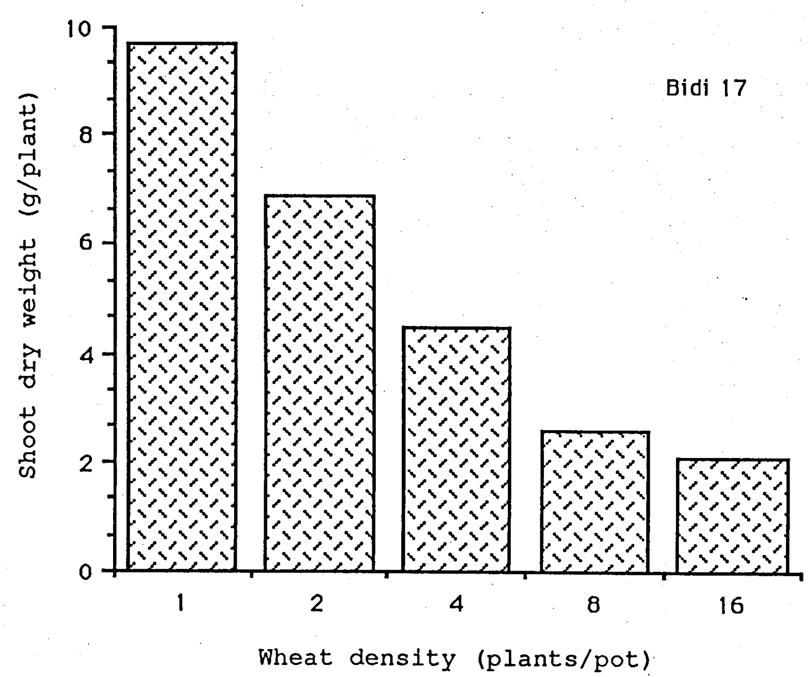
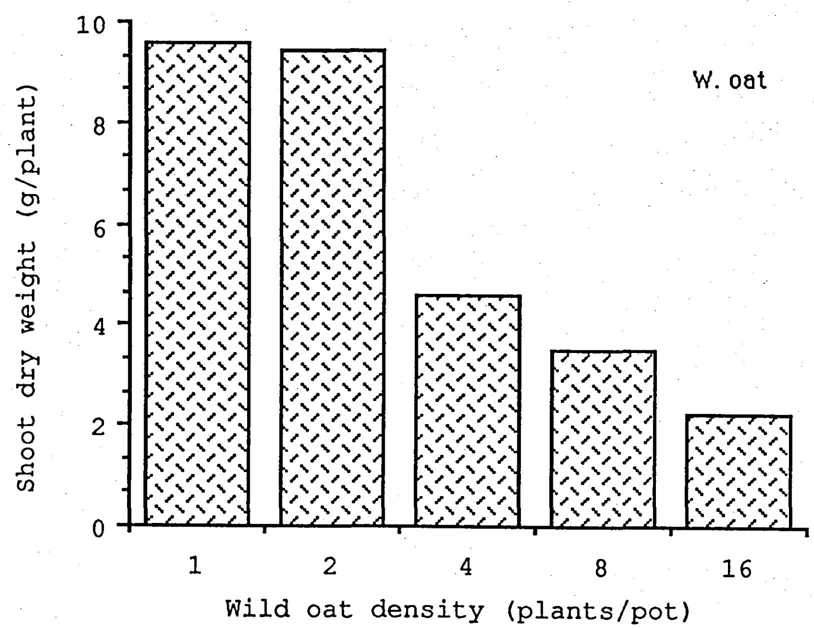
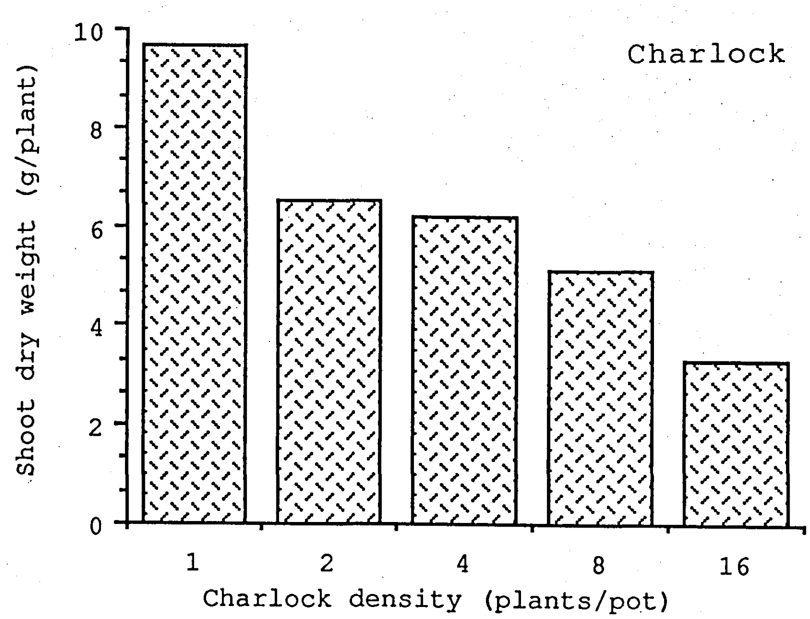


Fig 4.2: Effect of weed species population density (Wild oat & charlock) on shoot dry weight per weed plant.





(Table 4.1).

Statistical analysis showed significant competitive effect with the interaction between species and plant density significant at P< 0.05.

4.2. Intraspecific competition in wheat cultivars:

For both wheat cultivars, the highest population density used in this experiment (16 plants per pot) maximized biomass production per pot (Table 4.1). However one plant per pot produced as much or more above ground growth, on a per plant basis, as any of the higher densities. Wheat plants had the ability to produce tillers to "fill" the available space in the pots used, thereby maximizing production for individual plants as far as possible.

Analysis of variance showed a significant difference (P<0.05) for the competitive effects between each species for the leaf and tiller numbers. So the number of tillers per plant decreased drastically with increasing population density. This result confirms the finding of Puckridge & Donald (1967), in which the dry weight of wheat plants decreased with increasing density and this was associated with a marked reductions in the number of tillers per plant.

Wheat cultivars at all densities produced different amounts of dry matter per pot at harvest . There was less total dry weight per pot at the higher densities than the lower. This was caused by two factors. First, there was a decrease in the average shoot dry weight per plant with increasing density (Table 4.2). Second there was a delay in inhibition of tillering with increasing density.

The increase in dry matter production per pot at the lower densities was also due to the larger individuals, which resulted from greater tiller production (Table 4.2). Similar results have been demonstrated for red fescue (*Festuca rubra* L.) by Deschenes (1974).
Stem weight per plant displayed the same trends as total dry weight. The production of tillers at the lower densities was reflected in the increased average of individual shoot weight.(Table 4.2).

The difference in dry matter of above ground parts between the density treatments became progressively less as population density increased from the first single plant/pot upwards, so that by the last density (16 plants/pot), the two highest density treatments (8 and 16 plants/pot) had almost the same dry matter production.

Table 4.2: **Effect of intraspecific competition on tiller numbers of wheat cultivars.**

Density (plants/pot)	Tiller number	
	Wheat cv: Bidi 17	Wheat cv: Broom
1	7.0	4.0
2	4.6	2.0
4	3.6	1.0
8	2.0	1.0
16	1.0	0.0
S.E.D	0.01	0.09

4.3. Intraspecific competition in wild oat:

As in the study, the largest amount of root growth occured early in the plant development, so at greater densities (16 plants/pot) were there is a limited supply of nutrients and space, the activity of root system was reduced. This was illustrated by a decrease in shoot root production per plant (Table 4.1). Shoot dry matter of wild oat plants per pot decreased significantly with increasing density. However it can be stated that intraspecific competition between wild oat plants was observed through the response of vegetative part at all densities used in this experiment (Table 4.1). This may be explained by the interaction between root production and the nutrient level playing a role in the affect of shoot production.

4.4.Intraspecific competition in charlock:

The actual effect of intraspecific competition on the growth and development of charlock was examined particularly with reference to the vegetative production. The leaf dry weight of this plant decreased with increasing density. This result confirmed the finding of Sahai & Das (1974), that dry weight of purple mutsedge decreased with increasing density. The charlock plants grew rapidly and produced large quantities of leaves. This abundant aerial growth at all densities suggests light to be a limiting factor.

4.5.Discussion:

In all the species, an increase in population density led to a progressive decrease in leaf and tiller number for the grass species involved, and a decrease in leaf number for charlock. This findings show a display of plasticity by the various weed species. Such plasticity in intraspecific competition with respect to size, has been observed by Harper & Gajic (1961) for corn cockle (*Agrostemma githago* L.), and Harper (1965) and Deschenes (1974) in three weed species. Hinson and Hanson (1962) reported that different varieties of soybeans displayed different degrees of plasticity with increasing population density.

The present study has shown that differences in population density can have marked effects on the growth of the plants even when the soil volume available to the individual plants is the same. Dry matter yields of shoots of wheat cultivars per plant increased significantly with an increase in the density from 1 to 16 plants/pot. This increase was noticeable for the all characteristics, except for tiller number which was reduced by increasing density. In contrast, the leaf dry weight of wild oat showed a significant decrease of weight at a densities of more than 8 plants per pot (Table 4.1).

4.6. Conclusions:

1- The experimental findings confirmed the concept of increased severity of intraspecific competitive effects with increasing population density of a given plant species in a given area. Different species, however, respond differently to various degrees of intraspecific competition. Such differences could be due to the specific growth habits which include vegetative characteristics.

2- Characteristics associated with growth, such as tiller and leaf numbers, shoot dry weight, were all affected by intraspecific competition, although to differing degrees. Tiller number per plant was generally more severely affected by enhanced competition than other characteristics

CHAPTER FIVE

WEED CONTROL: RESULTS

Chapter 5

Weed control experiments: Results

In the foregoing chapters, the severity of wild oat and charlock competition with wheat cultivars has been discussed. The effects of established and more recently developed herbicides on crop and weeds are discussed in this chapter.

5.1 The effect of tralkoxydim and flamprop-isopropyl on wild oat:

Tralkoxydim gave good control of wild oat at the early (GS 23: main shoot and 3 tillers) than at the late (GS 34: 4 nodes detactable) stage of growth. In terms of weed biomass reduction, tralkoxydim decreased wild oat dry weight significantly ($P<0.01$) at 2 and 4 l/ha (compared with untreated controls by respectively about 81 and 86% (Table 5.1). The wild oat plants were shorter and had fewer tillers and poorly developed leaves compared with untreated control. At the higher rate of tralkoxydim, the growth of wild oat was severely suppressed. Control of wild oat with flamprop-isopropyl was acceptable at rates 2 and 4 l/ha at GS 23 and GS 34. Control was slightly better at the later stage. The dry weight of wild oat decreased with increasing rates of this herbicide, but by visual assessment, only the higher rate (4 l/ha) gave acceptable control. Sprayed with the rate of 4 l/ha of flamprop-isopropyl, wild oat plants were markedly reduced in size compared to untreated control check (Table 5.1)

<u>Table 5.1:</u> Effects of two post emergence herbicides on wild oat at two different doses and two different timings of spray application (SED values refer to dry wt, data, for both growth stages; % reduction is compared with untreated control).

Treatments	Rate l/ha	Time of spraying: GS 23		GS 34	
		Dry wt g/pot	% Reduction	Dry wt g/pot	% Reduction
Tralkoxydim	0	9.0	-	14.4	-
	2	1.7	81	6.7	53.5
	4	1.3	86	6.1	57.6
S.E.D.					
Dose (D)				0.32	
Timing (T)				0.17	
D.T. interaction				0.46	
Flamprop-isopropyl	0	14.2	-	15.7	-
	2	2.7	81	6.5	58.6
	4	2.5	82.4	4.7	70.1
S.E.D.					
Dose (D)		0.2200		0.22	
Timing (T)		0.1796		0.17	
D.T. interaction		0.3112		0.31	

Increasing the rate of herbicide from 2 to 4 l/ha increased wild oat control. Effective control was obtained when tralkoxydim was applied at the higher rate (4 l/ha). Also application at GS 23 gave better control than at GS 34. This result confirms the findings of Warner *et al.* (1987) who found that in field trials tralkoxydim gave effective control of *Avena* species from early growth stage to the end of tillering and the begining of stem extension. Tralkoxydim gave almost complete control of *Avena fatua* up to the end of tillering, and control extended into the stem extension stage.

Early cessation of growth of wild oat is caused by the herbicides used in this study, followed by chlorosis and other colour changes. Complete kill of the plant usually takes 4 weeks with flamprop-isopropyl, and two weeks with tralkoxydim, but may take several weeks longer depending on environmental conditions.

5.1.1. Conclusions:

Under the, growing conditions of this study higher rates than 4 l/ha of flamprop-isopropyl were required for the control of wild oat in the greenhouse.

Wild oat control with these two herbicides is restricted by the time of application, efficacy and rates.

Greenhouse-grown wild oat showed yellowing of leaf tips 4 days after treatment (d.a.t.) with tralkoxydim and 8 d.a.t. with Flamprop-isopropyl.

5.2. The Effect of 2,4-D and MCPA on charlock:

After the application of 2,4-D, charlock showed yellowing of the outer leaves and wilting of all the plant at both rates used (0.7 and 2.8 l/ha) 2 days after treatment. By visual assessment, the higher rates appeared to be more effective than the lower rates. Seven d.a.t. all the plants had died at the higher rates, but some parts of the stem were still green at the low and medium rates. Twelve d.a.t. all the plants were dead at the medium and high rates with both herbicides, while at the low rate some parts of the stem were still green. Fourteen d.a.t. all plants had died in all herbicide treatments. (Table 5.2). Significant reductions in the dry weight of charlock were obtained at all rates with the application of 2,4-D and MCPA at harvest.

Table 5.2: Effects of two post emergence herbicides on charlock at three different doses (SED values refer to dry wt data for both herbicides; % reduction is compared with untreated control).

Treatments	Rate l/ha	Dry wt (g/pot)	% reduction of untreated control
2,4-D	0	7.7	-
	0.7	1.9	75
	1.4	1.5	80
	2.8	0.7	91
MCPA	0	8.1	-
	0.8	1.7	79
	1.7	1.4	83
	3.4	0.8	90
S.E.D.			
Herbicide (H).		0.11	
Doses (D).		0.16	
H.D interaction.		0.23	

2,4-D and MCPA at the recommended rates proved to be effective when applied post emergence to charlock. A rate 4 l/ha gave much better control than 2 l/ha of charlock against weeds at a height of 30cm. These data fully support the earlier result of Olson *et al.*(1951).

5.2.1. Conclusions:

1- Under the growing conditions of this experiment, acceptable control of charlock was realized by 2,4-D and MCPA applied to the plant at a height of 30cm.

2- Application of these two herbicides at a rate of 2,8 l/ha gave effective and consistent control of charlock.

3- Greenhouse experiments showed welting and yellowing of the plants two days after treatment with 2,4-D and MCPA.

5.3. Crop tolerance to cereal herbicides.

The majority of weeds which infest grain crops can be destroyed or suppressed by using herbicides. It is vital to apply the correct spray at a period when the crop will not suffer damage. Spraying at periods earlier or later than the recommended time may damage the crop.

5.3.1. Results:

Data on mean total shoot biomass per pot (3 plants per 6 inch pot), of wheat cultivars Norman, Aquila, Inrat and Bidi 17, harvested 14 d.a.t., subjected to analysis of variance. The cultivar worst affected was Bidi 17 followed by Inrat, Aquila and Norman. For Bidi 17 both 2,4-D and MCPA caused severe crop damage, with percentage biomass reduction of 63 and 51% respectively. With the other cultivars, total shoot dry weight was also affected by all herbicides except flamprop-isopropyl but did not show symptoms of serious damage, and appeared to be growing out of the stunting effect (Table 5.3). This results are in line with accepted knowledge on the use of 2,4-D and MCPA in winter wheat which identifies the crop safe period of application as the four to five leaf stage, at normal of application (Klingman, 1953; Olson *et al.*, 1951; Robinson and Fenster, 1973).

Table 5.3: Effects of herbicides on total dry weight (g/pot) of winter wheat cultivars applied during tillering stage. Plants were harvest at 21 d.a.t.

		Wheat cultivars and % reduction							
Herbicides	Rate l/ha	Norman	% R	Aquila	% R	Inrat	% R	Bidi 17	% R
Control	0	8.8	-	7.0	-	7.2	-	8.0	-
Tralkoxydim	3	7.2	18	6.2	11	5.1	29	5.2	35
Flamprop-isopropyl	3	9.4	-7	8.0	-14	7.6	-5.5	6.7	16.2
2,4-D	1.4	5.3	40	4.0	43	3.7	49	3.0	62.5
MCPA	1.7	5.8	34	5.0	29	4.7	35	3.9	51
S.E.D. (biomass)									
Herbicides (H)						0.14			
Cultivars (C)						0.12			
H.C interaction.						0.27			

5.3.3. Discussion and conclusion:

The results of this study indicated that British wheat cultivars were fairly tolerant of damage from tralkoxydim and flamprop-isopropyl, which agrees with the previous findings of (Stoddart & Sutton, 1987; Sutton, Verrier & Heckele, 1987; Warner *et al*, 1987) and from flamprop-isopropyl, agreeing with Skoda (1974) who found with trials in Greece that wheat is tolerant to this herbicide when sprayed at mid-tillering. and susceptible to herbicide damage i.e. 2,4-D and MCPA at the stage of the main shoot and 7 tillers which also agreed in showing that wheat was most sensitive to treatment at two widely separated growth periods. The first was an early seedling stage when the plants were 1 to 5 inches tall while the second extended from the time that the plants were well into booting stage until a few days prior to heading. Some other workers show the time difference in suscebtility of the main shoots and their tillers (Friesen & Olson, 1953). A particular deformity occurred first in the main shoot and later treatment induced similar deformaties in successive tillers. Tottman & Phillipson (1974), and also Evans (1974) showed a yield loss with late spraying of winter wheat with growth regulator herbicides.

MCPA and 2,4-D herbicides, applied at the recommended doses and recommended times caused large reductions in the vegetative growth of Algerian wheat cultivars, reducing above ground dry weight by an average of 43 and 56% respectively in comparison with untreated control when harvested 21 d.a.t. Tralkoxydim also caused a major check to growth of 31% at the same time of harvest. The Algerian wheat cultivars tested were aprite of flamprop-isopropyl, with a reduction of only 5.2%. Overall, the British wheat cultivars showed much lower levels damage from the four herbicides, when compared with the Algerian varieties. Flamprop-isopropyl caused no damage at all; tralkoxydim produced less than half the growth check seen in the Algerian cultivars; and the broad-leaved herbicides also showed much lower levels of crop damage. It is likely that the fairly large degree of injury seen in some of these herbicide/cultivar combinations may in part be due to to the artificial growing conditions of the greenhouse environment, which may enhance crop damage. Nevertheless it is interesting to note the consistent pattern of higher susptibility to higher damage in the Algerian cultivars.

CHAPTER SIX

GENERAL DISCUSSION & CONCLUSIONS

Chapter 6

General discussion and conclusions

To evaluate the competitiveness of wild oat and charlock with wheat cultivars, manipulative experiments were carried out in the greenhouse using 3 approaches: addition, replacement experiments, and a growth-partioning approachs.

In additive experiments wheat cultivars are planted at fixed density either with wild oat or charlock added to it at a range of densities. This interaction determined the competitive ability of both weeds with wheat cultivars. From this it has been found that competition begins early over the growth of wheat. Severe shoot biomass reductions in wheat plants occurred when either of these two weed densities was allowed to compete with wheat for two months after planting. Charlock was the most, and wild oat the least competitive with both wheat cultivars used under the conditions of these experiments. This may be due to a shading effect, related to the morphology of charlock tall plants, with big leaves.

The data from the first set of experiments gave an indication of the way in which the yield of one species is reduced when varying numbers of the second species are introduced.

Under the conditions of these experiments, it was established that charlock is a more competitive weed in winter wheat than wild oat. Densities as low as 2 plants per 7 inch pot decreased yield by 70% whereas wild oat caused 42% reduction in above ground dry matter (Table 3.4) compared to weed free pots. These results are broadly in line with previous findings.

A useful approach in competition experimentation is the replacement series technique (de Wit, 1960). This type of experiment excludes the variable density effects found in addition series experiments. In replacement studies the total density of both wheat and wild oat or charlock is held constant and the proportions of the two species in competition are varied. Typically there might be five treatments in which the total density of plants held constant, but with the proportion of species varying.

The results from the intraspecific competition experiments with wheat cultivars, wild oat and charlock suggest that intraspecific interference is a potential important process in population of these species. There was a significant decrease in per plant biomass for all the species used due to intraspecific interference. It is likely that still higher population densities would caused greater intraspecific competition in the experimental set up used here.

These intraspecific experiments examined net interference between plants of the some species (weed/or cultivar). Donald (1963) and others have suggested that such experiments may produce more valuable results if related to competition for specific resources. Such studies would be a logical extension of the work reported here, for example in relation to intraspecific competition for light in Sinapis arvensis.

The greater effect from charlock is likely explained by their more spreading growth form and more horizontal leaves that make them relatively more competitive for light.

Discussing the nature of competition between wheat cultivars and both weeds, the results suggested that below-ground competition between crop and weeds is important, as suggested by several authors (Snaydon, 1971; Remisson & Snaydon, 1980; Scott & Lowter, 1980; Martin & Snaydon, 1982) since the early findings of Blackman & Templeman (1938). Rhodes (1968) reported on the competive abilities and response to stress of a number of species grown in monoculture and in mixed culture. He found that density and tiller development greatly influenced the competitive abilities of seedlings of various species.

Tralkoxydim at the recommended rates proved to be an effective herbicide when applied post emergence to wild oat 4 l/ha gave much better control than 2 l/ha. These data fully support the result of Warner et al. 1987. With timely application and under favourable growth conditions tralkoxydim can provide excellent grass weed control in cereals.

Wheat is most tolerant of 2,4-D in the tillering and early jointing stages and most susceptible to 2,4-D injury in the seedling, pre-tiller, boot and flowering stage of growth. Detailed studies by Tottman (1982) of the growth stages sensitive to 2,4-D and MCPA revealed the late tillering, jointing and post heading stages as the most tolerant. The tolerance of wheat cultivars to most herbicides for grass and broad leaved weeds varies with their stage of growth at the time of spraying.

Conclusions:

In general terms, competition varies greatly depending upon the crop, the weed, and the growing conditions. The competitive effect of weeds is generally minimised by their removal in the life of the crop. The earlier the weeds can be removed the greater the benefit to the crop. The two weed species studied here, wild oat and charlock, caused substantial reduction in vegetative growth of wheat. These weeds are large erect plants and make rapid growth at a time when the crop is susceptible to competition. Competition from wild oat and charlock was serious early in the life of the crop over the first few months after planting. The relationship of dry weight of above ground parts, loss to weed numbers is interesting, and all the experiments suggest quite a large dry weight of above ground loss at comparatively low weed densities. For example about 2 plants per 7 inch pot may reduce the dry weight by 27 and 42%, and about 8 plants per 7 inch pot provided sufficient competition to make herbicide applications worthwhile in terms of yield response.

Conclusions based on herbicides study are as follows:

1- Applications of herbicides (tralkoxydim, flamprop-isopropyl, 2,4-D and MCPA) post emergence were generally more effective for weed control and wheat species become increasingly tolerant.

2- Applied as a post emergence treatment, at doses of 4 l/ha, tralkoxydim and flamprop-isopropyl effectively controlled wild oat. Post emergence foliar treatments at 4 l/ha were more effective than at 2 l/ha.

3- It is deserable to spray charlock infested wheat cultivars when this weed is in an early stage of growth, because it affected the growth of wheat before the latter had reached the 5 leaf stage of growth, at which the weed can be destroyed with 2,4-D.

4- Shoot growth inhibition was observed in all treated species after post emergence herbicides application, this suggests that translocation of herbicides had taken place

5- The difference in tolerance may depend on the ability of the crop species to recover, more rapidly from the growth check caused by the treatment.

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Appendix 1

The effects of wild oat and charlock planted at 0,1,2,4,8 and 16 plants with 4 plants of winter wheat cultivars (British & Algerian) in 7 inch pots for two months in the green house.

1- The effect of wild oat (*Avena fatua*) density on growth parameters of winter wheat cvs: Aquila & Inrat.

i) Stem dry weight (Fig A1.1).

ii) Leaf dry weight (Fig A1.2).

iii) Tiller number (Fig A1.3).

iv) leaf number (Fig A1.4).

2- The effect of charlock (*Sinapis arvensis*) density on growth parameters of winter wheat cvs: Aquila & Inrat.

i) Stem dry weight (Fig A1.5).

ii) Leaf dry weight (Fig A1.6).

iii) Tiller number (Fig A1.7).

iv) Leaf number (Fig A1.8).

Fig A1.1: The effect of wild oat on stem dry weight of wheat cultivars.

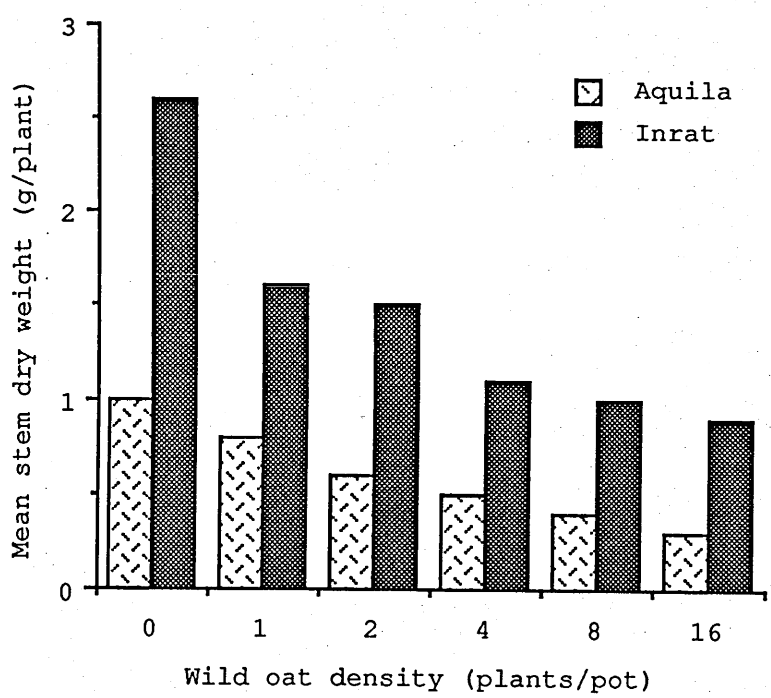


Fig A1.2: The effect of wild oat density on leaf dry weight of wheat cultivars.

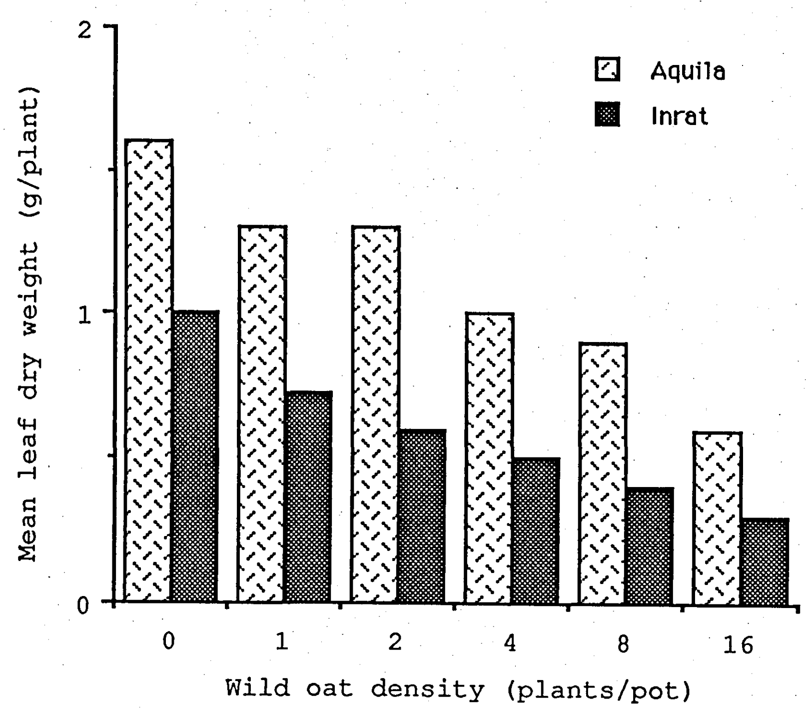


Fig A1.3: The effect of wild oat density on tiller number of wheat cultivars.

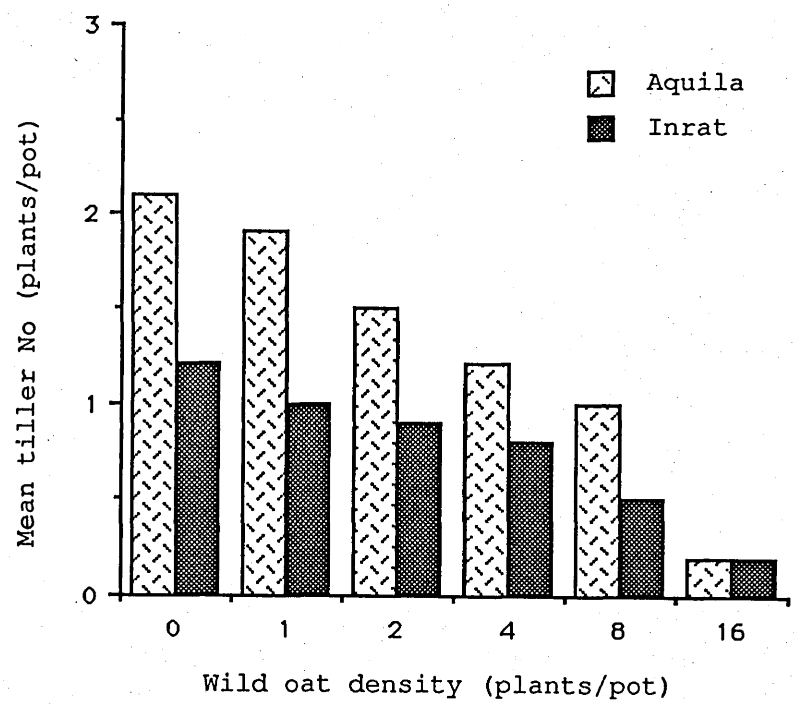


Fig A1.4: The effect of wild oat density on leaf numbers of wheat cultivars.

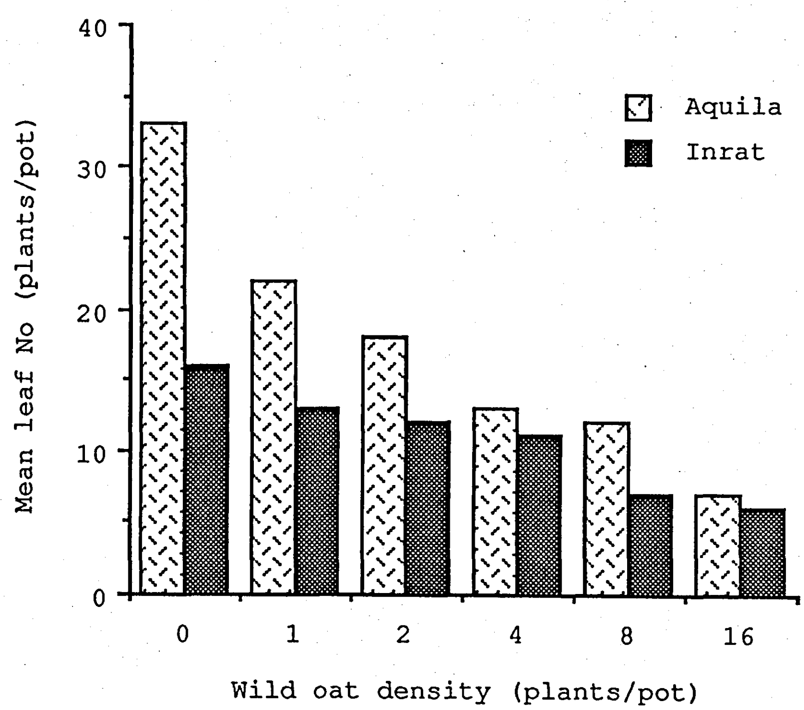


Fig A1.5: The effect of charlock density on stem dry weight of wheat cultivars.

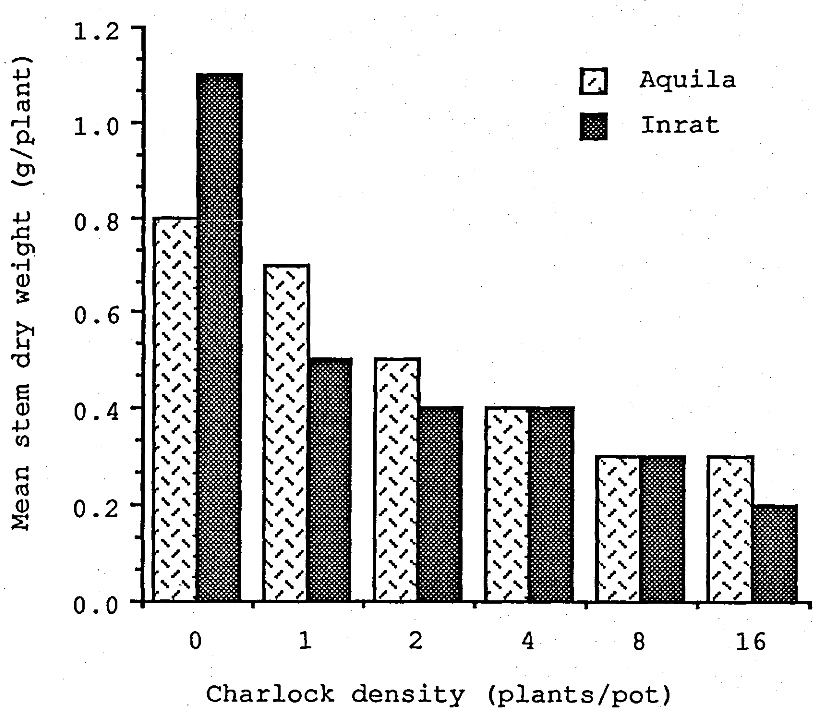


Fig A1.6: The effect of charlock density on leaf dry weight of wheat cultivars.

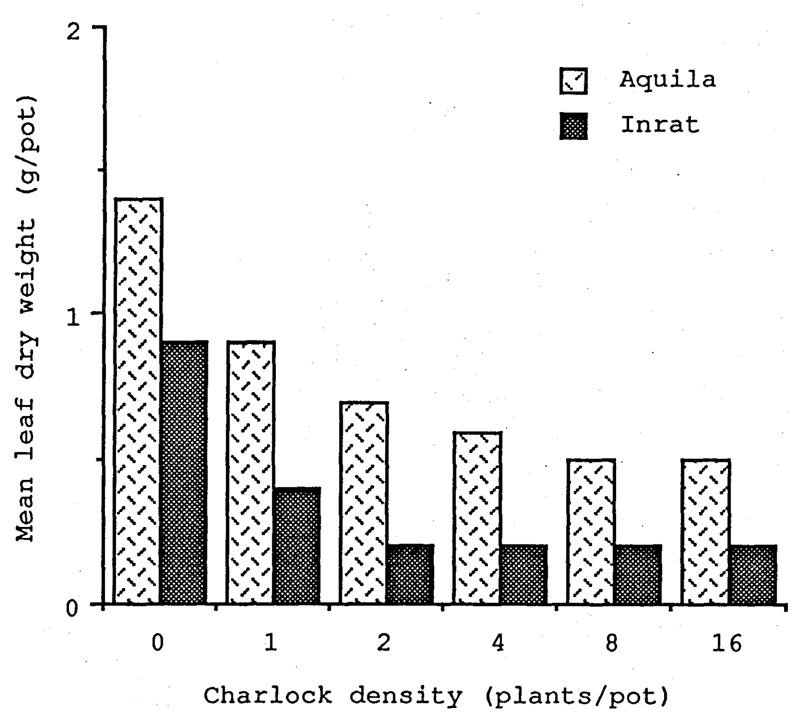


Fig A1.7: The effect of charlock density on tiller number of wheat cultivars.

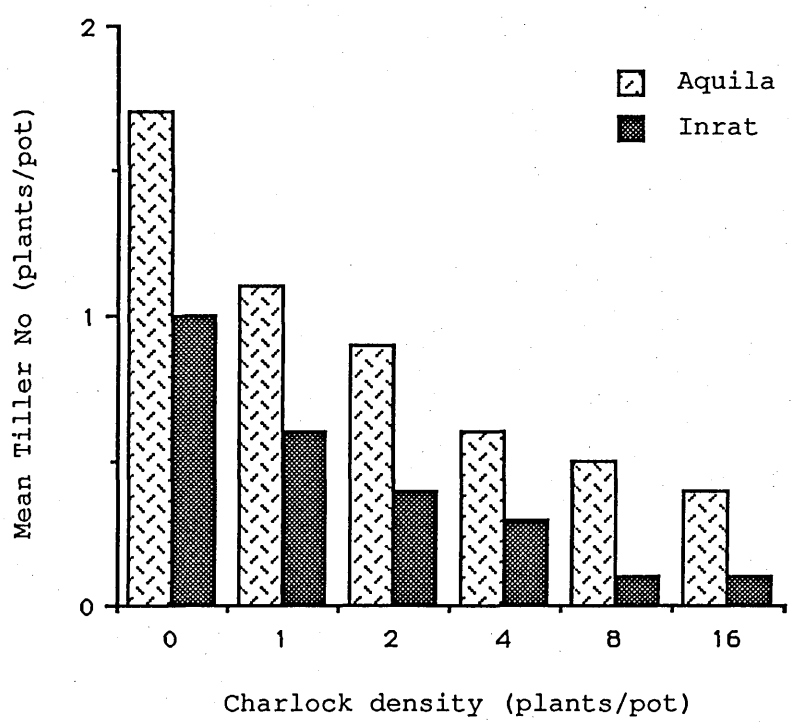
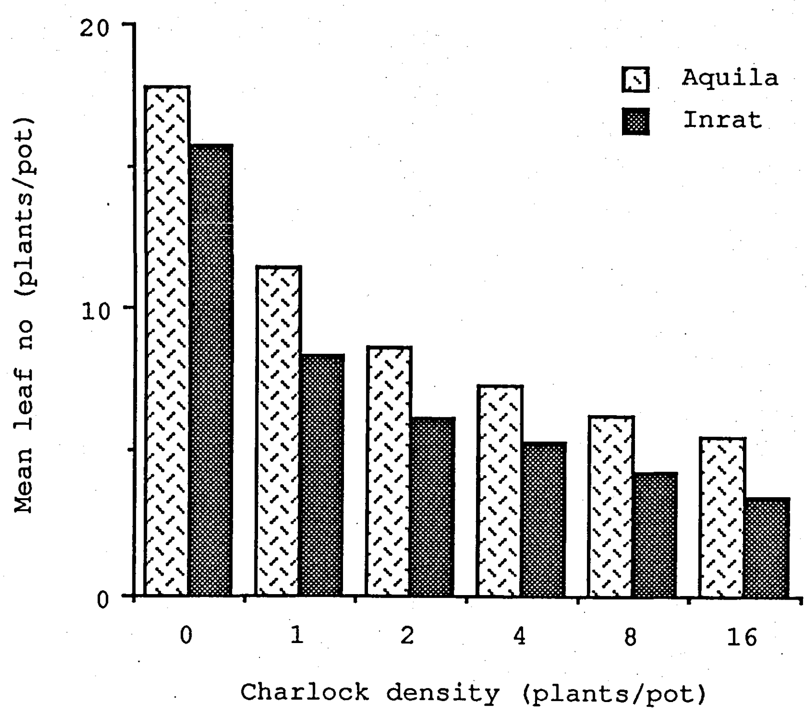


Fig A1.8: The effect of charlock density on leaf number of wheat cultivars.



Appendix 2

A- Statistical analysis (analysis of variance) of above ground dry weight (plants/pot) of wheat cultivars (Aquila & Inrat) in competition with different densities of wild oat and charlock.

1. Experimental design: general notes.

2. The effect of wild oat density on:
   - i) Stem dry weight of wheat cv. Aquila.
   - ii) Leaf dry weight of wheat cv. Aquila.
   - iii) Tiller number of wheat cv. Aquila
   - iv) Leaf number of wheat cv. Aquila
   - v) Shoot dry weight of wheat cv. Aquila
   - vi) Stem dry weight of wheat cv. Inrat.
   - vii) Leaf dry weight of wheat cv. Inrat.
   - viii) Tiller number of wheat cv. Inrat.
   - viiii) Leaf number of wheat cv. Inrat.
   - x) Shoot dry weight of wheat cv. Inrat.

3. The effect of charlock density on:
   - i) Stem dry weight of wheat cv. Aquila.
   - ii) Leaf dry weight of wheat cv. Aquila.
   - iii) Tiller number of wheat cv. Aquila.
   - iv) Leaf number of wheat cv. Aquila.
   - v) Shoot dry weight of wheat cv. Aquila.

vi) Stem dry weight of wheat cv. Inrat.

vii) Leaf dry weight of wheat cv. Inrat.

viii) Tiller number of wheat cv. Inrat.

viiii) Leaf number of wheat cv. Inrat.

x) shoot dry weight of wheat cv. Inrat.

B- Statistical analysis (analysis of variance) of wheat cultivars, wild oat and charlock populations density effects on growth parameters per plant.

4) Effects of wheat cv.Broom population density on:

i) Shoot dry weight.

ii) Stem dry weight.

iii) Tiller number.

iv) Leaf number.

5) Effects of wheat cv. Bidi 17 population density on:

i) Shoot dry weight.

ii) Stem dry weight.

iii) Tiller number.

iv) Leaf number.

6) Effects of wild oat population density on:

i) Shoot dry weight.

ii) Leaf dry weight.

iii) Leaf number.

7) Effects of charlock population density on:

i) Shoot dry weight.

ii) Stem dry weight.

iii) Leaf dry weight.

1. Experimental design:

Each experiment was laid out in the form of a randomized block design with three replicates, and six treatment levels. Analysis of variance was carried out using GENSTAT. The total biomass per plant was analysed separately for all the characters investigated.

Key: *** = Significant at 0.1% points ($P<0.001$).

** = Significant at 1% points ($P<0.01$).

* = Significant at 5% points ($P<0.05$).

N.S. = Not significant ($P>0.05$).

THE EFFECT OF WILD OAT DENSITY ON STEM DRY WEIGHT OF WINTER WHEAT CV. AQUILA.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: STDWA1
SOURCE OF VARIATION              DF        SS        SS%        MS         VR
*UNITS* STRATUM
  DENS                            5    0.951111    93.76    0.190222    38.257 ***
  BLOCK                           2    0.013611     1.34    0.006806     1.369 N.S.
  RESIDUAL                       10    0.049722     4.90    0.004972
TOTAL                            17    1.014443   100.00    0.059673
GRAND TOTAL                      17    1.014443   100.00
GRAND MEAN                          0.606
TOTAL NUMBER OF OBSERVATIONS           18
***** TABLES OF MEANS *****
VARIATE: STDWA1
    GRAND MEAN    0.606
          DENS      1        2        3        4        5        6
                0.983    0.817    0.567    0.533    0.433    0.300
         BLOCK      1        2        3
                0.625    0.625    0.567
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                     DENS       BLOCK
-----------------------------------------------
REP                          3           6
SED                     0.0576      0.0407
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                     DF          SE        CV%
*UNITS*                     10      0.0705       11.6
```

THE EFFECT OF WILD OAT DENSITY ON LEAF DRY WEIGHT OF WINTER WHEAT CV. AQUILA.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: LDWA1
SOURCE OF VARIATION              DF        SS        SS%        MS         VR
*UNITS* STRATUM
  DENS                            5     2.22578    92.71     0.44516    30.306 ***
  BLOCK                           2     0.02804     1.17     0.01402     0.955 N.S.
  RESIDUAL                       10     0.14689     6.12     0.01469
TOTAL                            17     2.40071   100.00     0.14122
GRAND TOTAL                      17     2.40071   100.00
GRAND MEAN                          1.118
TOTAL NUMBER OF OBSERVATIONS           18
***** TABLES OF MEANS *****
VARIATE: LDWA1
    GRAND MEAN    1.118
          DENS      1        2        3        4        5        6
                1.600    1.433    1.267    0.973    0.867    0.567
         BLOCK      1        2        3
                1.167    1.117    1.070
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                     DENS       BLOCK
-----------------------------------------------
REP                          3           6
SED                     0.0990      0.0700
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                     DF          SE        CV%
*UNITS*                     10      0.1212       10.8
```

THE EFFECT OF WILD OAT DENSITY ON TILLER NO OF WINTER WHEAT CV. AQUILA.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: TILLNA1
SOURCE OF VARIATION                DF        SS        SS%         MS         VR
*UNITS* STRATUM
  DENS                              5   7.22458      93.93     1.44492    32.169  ***
  BLOCK                             2   0.01750       0.23     0.00875     0.195  N.S.
  RESIDUAL                         10   0.44917       5.84     0.04492
TOTAL                              17   7.69124     100.00     0.45243
GRAND TOTAL                        17   7.69124     100.00
GRAND MEAN                            1.325
TOTAL NUMBER OF OBSERVATIONS            18
***** TABLES OF MEANS *****
VARIATE: TILLNA1
    GRAND MEAN    1.325
          DENS        1         2         3         4         5         6
                  2.100     1.917     1.483     1.250     1.033     0.167
         BLOCK        1         2         3
                  1.367     1.292     1.317
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                 DENS       BLOCK
--------------------------------------
REP                      3           6
SED                 0.1730      0.1224
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                    DF          SE          CV%
*UNITS*                    10      0.2119         16.0
```

THE EFFECT OF WILD OAT DENSITY ON LEAF NO OF WINTER WHEAT CV. AQUILA.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: LANO1
SOURCE OF VARIATION                DF        SS        SS%         MS         VR
*UNITS* STRATUM
  DENS                              5   524.142      93.26     104.828    36.791  ***
  BLOCK                             2     9.382       1.67       4.691     1.646  N.S.
  RESIDUAL                         10    28.493       5.07       2.849
TOTAL                              17   562.017     100.00      33.060
GRAND TOTAL                        17   562.017     100.00
GRAND MEAN                            15.40
TOTAL NUMBER OF OBSERVATIONS            18
***** TABLES OF MEANS *****
VARIATE: LANO1
    GRAND MEAN    15.40
          DENS        1         2         3         4         5         6
                  22.00     21.25     17.58     13.17     11.50      6.92
         BLOCK        1         2         3
                  16.12     15.67     14.42
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                 DENS       BLOCK
--------------------------------------
REP                      3           6
SED                  1.378       0.975
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                    DF          SE          CV%
*UNITS*                    10       1.688         11.0
```

THE EFFECT OF WILD OAT DENSITY ON STEM DRY WEIGHT OF WINTER WHEAT CV. INRAT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: STEMDW1
SOURCE OF VARIATION             DF        SS       SS%        MS         VR
*UNITS* STRATUM
  DENS                           5   6.67333     88.51   1.33467     20.746 ***
  BLOCK                          2   0.22333      2.96   0.11167      1.736 N.S.
  RESIDUAL                      10   0.64333      8.53   0.06433
TOTAL                           17   7.54000    100.00   0.44353
GRAND TOTAL                     17   7.54000    100.00
GRAND MEAN                        1.433
TOTAL NUMBER OF OBSERVATIONS         18
***** TABLES OF MEANS *****
VARIATE: STEMDW1
    GRAND MEAN    1.433
          DENS        1         2         3         4         5         6
                  2.633     1.633     1.467     1.100     1.000     0.767
         BLOCK        1         2         3
                  1.583     1.400     1.317
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                 DENS       BLOCK
-----------------------------------------
REP                      3           6
SED                 0.2071      0.1464
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                     DF          SE         CV%
*UNITS*                     10      0.2536        17.7
```

THE EFFECT OF WILD OAT DENSITY ON LEAF DRY WEIGHT OF WINTER WHEAT CV. INRAT .

```
***** ANALYSIS OF VARIANCE *****
VARIATE: LEAFDW1
SOURCE OF VARIATION             DF        SS       SS%        MS         VR
*UNITS* STRATUM
  DENS                           5  1.011110     94.40  0.202222     38.723 ***
  BLOCK                          2  0.007778      0.73  0.003889      0.745 N.S.
  RESIDUAL                      10  0.052222      4.88  0.005222
TOTAL                           17  1.071109    100.00  0.063006
GRAND TOTAL                     17  1.071109    100.00
GRAND MEAN                        0.578
TOTAL NUMBER OF OBSERVATIONS         18
***** TABLES OF MEANS *****
VARIATE: LEAFDW1
    GRAND MEAN    0.578
          DENS        1         2         3         4         5         6
                  1.000     0.733     0.567     0.500     0.400     0.267
         BLOCK        1         2         3
                  0.600     0.550     0.583
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                 DENS       BLOCK
-----------------------------------------
REP                      3           6
SED                 0.0590      0.0417
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                     DF          SE         CV%
*UNITS*                     10      0.0723        12.5
```

THE EFFECT OF WILD OAT DENSITY ON TILLER NO OF WINTER WHEAT CV. INRAT.

***** ANALYSIS OF VARIANCE *****

VARIATE: TILLN1

SOURCE OF VARIATION	DF	SS	SS%	MS	VR
UNITS STRATUM					
DENS	5	1.91778	88.60	0.38356	17.523 ***
BLOCK	2	0.02778	1.28	0.01389	0.635 N.S.
RESIDUAL	10	0.21889	10.11	0.02189	
TOTAL	17	2.16444	100.00	0.12732	
GRAND TOTAL	17	2.16444	100.00		

GRAND MEAN 0.744

TOTAL NUMBER OF OBSERVATIONS 18

***** TABLES OF MEANS *****

VARIATE: TILLN1

GRAND MEAN 0.744

DENS	1	2	3	4	5	6
	1.167	0.967	0.867	0.800	0.500	0.167

BLOCK	1	2	3
	0.800	0.717	0.717

***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****

TABLE	DENS	BLOCK
REP	3	6
SED	0.1208	0.0854

***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****

STRATUM	DF	SE	CV%
UNITS	10	0.1479	19.9

THE EFFECT OF WILD OAT DENSITY ON LEAF NO OF WINTER WHEAT CV. INRAT.

***** ANALYSIS OF VARIANCE *****

VARIATE: LEAFNO1

SOURCE OF VARIATION	DF	SS	SS%	MS	VR
UNITS STRATUM					
DENS	5	188.9340	97.15	37.7868	74.436 ***
BLOCK	2	0.4653	0.24	0.2326	0.458 N.S.
RESIDUAL	10	5.0764	2.61	0.5076	
TOTAL	17	194.4757	100.00	11.4397	
GRAND TOTAL	17	194.4757	100.00		

GRAND MEAN 10.68

TOTAL NUMBER OF OBSERVATIONS 18

***** TABLES OF MEANS *****

VARIATE: LEAFNO1

GRAND MEAN 10.68

DENS	1	2	3	4	5	6
	15.58	13.08	11.75	10.25	7.08	6.33

BLOCK	1	2	3
	10.75	10.46	10.83

***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****

TABLE	DENS	BLOCK
REP	3	6
SED	0.582	0.411

***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****

STRATUM	DF	SE	CV%
UNITS	10	0.712	6.7

THE EFFECT OF CHARLOCK DENSITY ON STEM DRY WEIGHT OF WINTER WHEAT CV. AQUILA.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: SDM1
SOURCE OF VARIATION            DF        SS        SS%         MS         VR
*UNITS* STRATUM
  DENS                          5   0.56000     77.78    0.11200      7.467  **
  BLOCK                         2   0.01000      1.39    0.00500      0.333 N.S.
  RESIDUAL                     10   0.15000     20.83    0.01500
TOTAL                          17   0.72000    100.00    0.04235
GRAND TOTAL                    17   0.72000    100.00
GRAND MEAN                        0.517
TOTAL NUMBER OF OBSERVATIONS         18
***** TABLES OF MEANS *****
VARIATE: SDM1
    GRAND MEAN    0.517
          DENS        1        2        3        4        5        6
                  0.817    0.667    0.517    0.433    0.333    0.333
         BLOCK        1        2        3
                  0.533    0.483    0.533
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                 DENS       BLOCK
-----------------------------------------
REP                      3           6
SED                 0.1000      0.0707
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                    DF          SE          CV%
*UNITS*                    10      0.1225         23.7
```

THE EFFECT OF CHARLOCK DENSITY ON LEAF DRY WEIGHT OF WINTER WHEAT CV. AQUILA.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: LDM1
SOURCE OF VARIATION            DF        SS        SS%         MS         VR
*UNITS* STRATUM
  DENS                          5   1.580027    91.32    0.316005    31.742  ***
  BLOCK                         2   0.050711     2.93    0.025356     2.547 N.S.
  RESIDUAL                     10   0.099555     5.75    0.009956
TOTAL                          17   1.730292   100.00    0.101782
GRAND TOTAL                    17   1.730292   100.00
GRAND MEAN                        0.771
TOTAL NUMBER OF OBSERVATIONS         18
***** TABLES OF MEANS *****
VARIATE: LDM1
    GRAND MEAN    0.771
          DENS        1        2        3        4        5        6
                  1.350    0.900    0.733    0.667    0.507    0.467
         BLOCK        1        2        3
                  0.725    0.742    0.845
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                 DENS       BLOCK
-----------------------------------------
REP                      3           6
SED                 0.0815      0.0576
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                    DF          SE          CV%
*UNITS*                    10      0.0998         12.9
```

THE EFFECT OF WILD OAT DENSITY ON SHOOT DRY WEIGHT OF WINTER WHEAT CV. AQUILA.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: SHDWA1
SOURCE OF VARIATION              DF         SS        SS%          MS          VR
*UNITS* STRATUM
  DENS                            5    5.73166      92.37     1.14633      29.904  ***
  BLOCK                           2    0.09000       1.45     0.04500       1.174  N.S.
  RESIDUAL                       10    0.38333       6.18     0.03833
TOTAL                            17    6.20500     100.00     0.36500
GRAND TOTAL                      17    6.20500     100.00
GRAND MEAN                         1.717
TOTAL NUMBER OF OBSERVATIONS          18
***** TABLES OF MEANS *****
VARIATE: SHDWA1
    GRAND MEAN    1.717
          DENS        1         2         3         4         5         6
                  2.567     2.233     1.767     1.567     1.300     0.867
         BLOCK        1         2         3
                  1.767     1.767     1.617
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                  DENS       BLOCK
---------------------------------------
REP                       3           6
SED                  0.1599      0.1130
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                     DF          SE        CV%
*UNITS*                     10      0.1958       11.4
```

THE EFFECT OF CHARLOCK DENSITY ON SHOOT DRY WEIGHT OF WINTER WHEAT CV. AQUILA.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: SHND1
SOURCE OF VARIATION              DF         SS        SS%          MS          VR
*UNITS* STRATUM
  DENS                            5    4.19777      93.99     0.83955      41.009  ***
  BLOCK                           2    0.06361       1.42     0.03181       1.554  N.S.
  RESIDUAL                       10    0.20472       4.58     0.02047
TOTAL                            17    4.46611     100.00     0.26271
GRAND TOTAL                      17    4.46611     100.00
GRAND MEAN                         1.278
TOTAL NUMBER OF OBSERVATIONS          18
***** TABLES OF MEANS *****
VARIATE: SHND1
    GRAND MEAN    1.278
          DENS        1         2         3         4         5         6
                  2.167     1.567     0.967     1.333     0.833     0.800
         BLOCK        1         2         3
                  1.258     1.217     1.358
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                  DENS       BLOCK
---------------------------------------
REP                       3           6
SED                  0.1168      0.0826
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                     DF          SE        CV%
*UNITS*                     10      0.1431       11.2
```

THE EFFECT OF CHARLOCK DENSITY ON TILLER NO OF WINTER WHEAT CV. AQUILA.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: TN01
SOURCE OF VARIATION             DF        SS        SS%         MS         VR
*UNITS* STRATUM
  DENS                           5   3.33500      93.03    0.66700     42.574 ***
  BLOCK                          2   0.09333       2.60    0.04667      2.979 N.S.
  RESIDUAL                      10   0.15667       4.37    0.01567
TOTAL                           17   3.58500     100.00    0.21088
GRAND TOTAL                     17   3.58500     100.00
GRAND MEAN                         0.867
TOTAL NUMBER OF OBSERVATIONS          18
***** TABLES OF MEANS *****
VARIATE: TN01
    GRAND MEAN     0.867
          DENS         1        2        3        4        5        6
                   1.700    1.083    0.850    0.600    0.533    0.433
         BLOCK         1        2        3
                   0.767    0.933    0.900
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                   DENS       BLOCK
--------------------------------------------
REP                        3           6
SED                   0.1022      0.0723
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                     DF          SE         CV%
*UNITS*                     10      0.1252        14.4
```

THE EFFECT OF CHARLOCK DENSITY ON LEAF NO OF WINTER WHEAT CV. AQUILA.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: LMN01
SOURCE OF VARIATION             DF        SS        SS%         MS         VR
*UNITS* STRATUM
  DENS                           5  311.4861      99.24    62.2972    265.408 ***
  BLOCK                          2    0.0278       0.01     0.0139      0.059 N.S.
  RESIDUAL                      10    2.3472       0.75     0.2347
TOTAL                           17  313.8608     100.00    18.4624
GRAND TOTAL                     17  313.8608     100.00
GRAND MEAN                          9.47
TOTAL NUMBER OF OBSERVATIONS          18
***** TABLES OF MEANS *****
VARIATE: LMN01
    GRAND MEAN      9.47
          DENS         1        2        3        4        5        6
                   17.75    11.42     8.58     7.33     6.25     5.50
         BLOCK         1        2        3
                    9.42     9.50     9.50
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                   DENS       BLOCK
--------------------------------------------
REP                        3           6
SED                    0.396       0.280
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                     DF          SE         CV%
*UNITS*                     10       0.484         5.1
```

THE EFFECT OF CHARLOCK DENSITY ON STEM DRY WEIGHT OF WINTER WHEAT CV. INRAT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: STDW1
SOURCE OF VARIATION              DF         SS       SS%          MS         VR
*UNITS* STRATUM
  DENS                            5   1.606665     96.79    0.321333    107.111  ***
  BLOCK                           2   0.023333      1.41    0.011667      3.889  *
  RESIDUAL                       10   0.030000      1.81    0.003000
TOTAL                            17   1.659997    100.00    0.097647
GRAND TOTAL                      17   1.659997    100.00
GRAND MEAN                          0.500
TOTAL NUMBER OF OBSERVATIONS           18
***** TABLES OF MEANS *****
VARIATE: STDW1
    GRAND MEAN    0.500
          DENS        1        2        3        4        5        6
                  1.133    0.533    0.433    0.367    0.300    0.233
         BLOCK        1        2        3
                  0.533    0.450    0.517
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                   DENS       BLOCK
---------------------------------------
REP                        3           6
SED                   0.0447      0.0316
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                     DF          SE          CV%
*UNITS*                     10      0.0548         11.0
```

THE EFFECT OF CHARLOCK DENSITY ON LEAF DRY WEIGHT OF WINTER WHEAT CV. INRAT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: LDW1
SOURCE OF VARIATION              DF         SS       SS%          MS         VR
*UNITS* STRATUM
  DENS                            5   0.982778     96.25    0.196555     54.015  ***
  BLOCK                           2   0.001944      0.19    0.000972      0.267  N.S.
  RESIDUAL                       10   0.036389      3.56    0.003639
TOTAL                            17   1.021111    100.00    0.060065
GRAND TOTAL                      17   1.021111    100.00
GRAND MEAN                          0.372
TOTAL NUMBER OF OBSERVATIONS           18
***** TABLES OF MEANS *****
VARIATE: LDW1
    GRAND MEAN    0.372
          DENS        1        2        3        4        5        6
                  0.867    0.433    0.267    0.233    0.233    0.200
         BLOCK        1        2        3
                  0.383    0.358    0.375
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                   DENS       BLOCK
---------------------------------------
REP                        3           6
SED                   0.0493      0.0348
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                     DF          SE          CV%
*UNITS*                     10      0.0603         16.2
```

THE EFFECT OF CHARLOCK DENSITY ON TILLER NO OF WINTER WHEAT CV. INRAT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: TILLNO1
SOURCE OF VARIATION              DF         SS        SS%          MS          VR
*UNITS* STRATUM
  DENS                            5    1.67833      82.07     0.33567     10.381 **
  BLOCK                           2    0.04333       2.12     0.02167      0.670 N.S.
  RESIDUAL                       10    0.32333      15.81     0.03233
TOTAL                            17    2.04500     100.00     0.12029
GRAND TOTAL                      17    2.04500     100.00
GRAND MEAN                          0.400
TOTAL NUMBER OF OBSERVATIONS          18
***** TABLES OF MEANS *****
VARIATE: TILLNO1
    GRAND MEAN      0.400
          DENS          1         2         3         4         5         6
                    0.950     0.633     0.350     0.267     0.133     0.067
         BLOCK          1         2         3
                    0.350     0.383     0.467
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                     DENS       BLOCK
---------------------------------------------
REP                          3           6
SED                     0.1468      0.1038
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                        DF          SE         CV%
*UNITS*                        10      0.1798        45.0
1
```

THE EFFECT OF CHARLOCK DENSITY ON LEAF NO OF WINTER WHEAT CV. INRAT.

```
1
***** ANALYSIS OF VARIANCE *****
VARIATE: LNO1
SOURCE OF VARIATION              DF         SS        SS%          MS          VR
*UNITS* STRATUM
  DENS                            5   298.6943      98.68     59.7389    153.614  ***
  BLOCK                           2     0.1111       0.04      0.0556      0.143  N.S.
  RESIDUAL                       10     3.8889       1.28      0.3889
TOTAL                            17   302.6941     100.00     17.8055
GRAND TOTAL                      17   302.6941     100.00
GRAND MEAN                            7.19
TOTAL NUMBER OF OBSERVATIONS          18
***** TABLES OF MEANS *****
VARIATE: LNO1
    GRAND MEAN       7.19
          DENS          1         2         3         4         5         6
                    15.67      8.25      6.17      5.25      4.33      3.50
         BLOCK          1         2         3
                     7.25      7.08      7.25
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                     DENS       BLOCK
---------------------------------------------
REP                          3           6
SED                      0.509       0.360
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                        DF          SE         CV%
*UNITS*                        10       0.624         8.7
1
```

THE EFFECT OF WILD OAT DENSITY ON SHOOT DRY WEIGHT OF WINTER WHEAT CV. INRAT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: SDW1  .
SOURCE OF VARIATION              DF(MV)          SS        SS%          MS          VR
*UNITS* STRATUM
  DENS                           5          16.61899    119.65     3.32380     40.126 ***
  BLOCK                          2           0.74795      5.39     0.37398      4.515 N.S.
  RESIDUAL                       8( 2)       0.66267      4.77     0.08283
TOTAL                            15         18.02959    129.81     1.20197
GRAND TOTAL                      15         18.02959    129.81
ESTIMATED GRAND MEAN               1.837
TOTAL NUMBER OF OBSERVATIONS          18
NUMBER OF MISSING VALUES               2
MAXIMUM NUMBER OF ITERATIONS          10 MAXIMUM NUMBER OF ITERATIONS           10
            UNIT       ESTIMATED
          NUMBER           VALUE
              17           0.541
              18           0.422
***** TABLES OF MEANS *****
VARIATE: SDW1
    GRAND MEAN    1.837
          DENS        1        2        3        4        5        6
              3.633    2.367    1.733    1.467    1.200    0.621
         BLOCK        1        2        3
              2.117    1.757    1.637
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                  DENS       BLOCK
---------------------------------------
REP                       3           6
SED                  0.2350      0.1662
(NOT ADJUSTED FOR MISSING VALUES)
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                    DF          SE          CV%
*UNITS*                     8      0.2878         15.7
1
```

THE EFFECT OF CHARLOCK DENSITY ON SHOOT DRY WEIGHT OF WINTER WHEAT CV. INRAT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: SHDW1
SOURCE OF VARIATION              DF          SS        SS%          MS          VR
*UNITS* STRATUM
  DENS                            5    5.166662     97.85    1.033332    147.619 ***
  BLOCK                           2    0.043333      0.82    0.021667      3.095 N.S.
  RESIDUAL                       10    0.070000      1.33    0.007000
TOTAL                            17    5.279995    100.00    0.310588
GRAND TOTAL                      17    5.279995    100.00
GRAND MEAN                         0.867
TOTAL NUMBER OF OBSERVATIONS          18
***** TABLES OF MEANS *****
VARIATE: SHDW1
    GRAND MEAN    0.867
          DENS        1        2        3        4        5        6
              2.000    0.967    0.700    0.600    0.533    0.400
         BLOCK        1        2        3
              0.917    0.800    0.883
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                  DENS       BLOCK
---------------------------------------
REP                       3           6
SED                  0.0683      0.0483
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                    DF          SE          CV%
*UNITS*                    10      0.0837          9.7
1
```

EFFECTS OF WHEAT CV. BROOM POPULATION DENSITY ON STEM DRY WEIGHT OF WHEAT PLANT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: SW1
SOURCE OF VARIATION              DF        SS       SS%         MS         VR
*UNITS* STRATUM
  DENS                            4   37.38399    97.88    9.34600   125.450 ***
  BLOCK                           2    0.21233     0.56    0.10617     1.425 N.S.
  RESIDUAL                        8    0.59600     1.56    0.07450
TOTAL                            14   38.19231   100.00    2.72802
GRAND TOTAL                      14   38.19231   100.00
GRAND MEAN                          3.903
TOTAL NUMBER OF OBSERVATIONS           15
***** TABLES OF MEANS *****
VARIATE: SW1
    GRAND MEAN    3.903
        DENS          1        2        3        4        5
                  6.200    4.700    4.283    2.600   -1.733
       BLOCK          1        2        3
                  3.920    3.750    4.040
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                  DENS      BLOCK
------------------------------------
REP                       3         5
SED                  0.2229    0.1726
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
 TRATUM                   DF          SE          CV%
 UNITS*                    8      0.2729          7.0
```

EFFECTS OF WHEAT CV. BROOM POPULATION DENSITY ON LEAF DRY WEIGHT PER WHEAT PLANT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: LD1
SOURCE OF VARIATION              DF        SS       SS%         MS         VR
*UNITS* STRATUM
  DENS                            4   5.715998    98.88    1.428999   197.104 ***
  BLOCK                           2   0.007000     0.12    0.003500     0.483 N.S.
  RESIDUAL                        8   0.058000     1.00    0.007250
TOTAL                            14   5.780996   100.00    0.412928
GRAND TOTAL                      14   5.780996   100.00
GRAND MEAN                          0.790
TOTAL NUMBER OF OBSERVATIONS           15
***** TABLES OF MEANS *****
VARIATE: LD1
    GRAND MEAN    0.790
        DENS          1        2        3        4        5
                  1.867    1.050    0.567    0.300    0.167
       BLOCK          1        2        3
                  0.760    0.810    0.800
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                  DENS      BLOCK
------------------------------------
REP                       3         5
SED                  0.0695    0.0539
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                   DF          SE          CV%
*UNITS*                    8      0.0851         10.6
```

EFFECTS OF WHEAT CV. BROOM POPULATION DENSITY ON TILLER NUMBER OF WHEAT PLANT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: TW1
SOURCE OF VARIATION               DF          SS         SS%          MS         VR
*UNITS* STRATUM
  DENS                             4    99.14429       99.79    24.78607   1081.574  ***
  BLOCK                            2     0.02500        0.03     0.01250      0.545  N.S.
  RESIDUAL                         8     0.18333        0.18     0.02292
TOTAL                             14    99.35260      100.00     7.09661
GRAND TOTAL                       14    99.35260      100.00
GRAND MEAN                            2.112
TOTAL NUMBER OF OBSERVATIONS            15
***** TABLES OF MEANS *****
VARIATE: TW1
    GRAND MEAN     2.112
          DENS         1        2        3        4        5
                   7.000    2.333    0.917    0.250    0.060
        BLOCK          1        2        3
                   2.112    2.062    2.162
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                   DENS       BLOCK
----------------------------------------
REP                        3           5
SED                   0.1236      0.0957
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                         DF          SE          CV%
*UNITS*                          8      0.1514          7.2
```

EFFECTS OF WHEAT CV. BROOM POPULATION DENSITY ON LEAF NUMBER PER WHEAT PLANT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: LN1
SOURCE OF VARIATION               DF          SS         SS%          MS         VR
*UNITS* STRATUM
  DENS                             4    412.8889       99.64    103.2222    619.111  ***
  BLOCK                            2      0.1451        0.04      0.0726      0.435  N.S.
  RESIDUAL                         8      1.3338        0.32      0.1667
TOTAL                             14    414.3677      100.00     29.5977
GRAND TOTAL                       14    414.3677      100.00
GRAND MEAN                            8.10
TOTAL NUMBER OF OBSERVATIONS            15
***** TABLES OF MEANS *****
VARIATE: LN1
    GRAND MEAN      8.10
          DENS         1        2        3        4        5
                   17.33    10.00     6.42     4.14     2.60
        BLOCK          1        2        3
                    7.99     8.07     8.23
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                   DENS       BLOCK
----------------------------------------
REP                        3           5
SED                    0.333       0.258
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                         DF          SE          CV%
*UNITS*                          8       0.402          5.0
```

EFFECTS OF WHEAT CV. BROOM POPULATION DENSITY ON SHOOT DRY WEIGHT PER WHEAT PLANT.

***** ANALYSIS OF VARIANCE *****

VARIATE: DS1

SOURCE OF VARIATION	DF	SS	SS%	MS	VR	
UNITS STRATUM						
DENS	4	70.49733	99.02	17.62433	297.039	***
BLOCK	2	0.22533	0.32	0.11267	1.899	N.S.
RESIDUAL	8	0.47467	0.67	-0.05933		
TOTAL	14	71.19731	100.00	5.08552		
GRAND TOTAL	14	71.19731	100.00			

GRAND MEAN 4.687

TOTAL NUMBER OF OBSERVATIONS 15

***** TABLES OF MEANS *****

VARIATE: DS1

GRAND MEAN 4.687

DENS	1	2	3	4	5
	8.067	5.733	4.833	2.900	1.900

BLOCK	1	2	3
	4.680	4.540	4.840

***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****

TABLE	DENS	BLOCK
REP	3	5
SED	0.1989	0.1541

***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****

STRATUM	DF	SE	CV%
UNITS	8	0.2436	5.2

EFFECTS OF WHEAT CV. BIDI 17 POPULATION DENSITY ON SHOOT DRY WEIGHT PER WHEAT PLANT.

***** ANALYSIS OF VARIANCE *****

VARIATE: SSD1

SOURCE OF VARIATION	DF	SS	SS%	MS	VR	
UNITS STRATUM						
DENS	4	121.48000	99.45	30.37000	374.938	***
BLOCK	2	0.02533	0.02	0.01267	0.156	N.S.
RESIDUAL	8	0.64800	0.53	0.08100		
TOTAL	14	122.15332	100.00	8.72524		
GRAND TOTAL	14	122.15332	100.00			

GRAND MEAN 5.167

TOTAL NUMBER OF OBSERVATIONS 15

***** TABLES OF MEANS *****

VARIATE: SSD1

GRAND MEAN 5.167

DENS	1	2	3	4	5
	9.733	6.933	4.467	2.633	2.067

BLOCK	1	2	3
	5.160	5.220	5.120

5.160 5.220 5.120

***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****

TABLE	DENS	BLOCK
REP	3	5
SED	0.2324	0.1800

***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****

STRATUM	DF	SE	CV%
UNITS	8	0.2846	5.5

EFFECTS OF WHEAT CV. BIDI 17 POPULATION DENSITY ON TILLER NUMBER PER WHEAT PLANT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: TN1
SOURCE OF VARIATION                  DF          SS         SS%          MS          VR
*UNITS* STRATUM
  DENS                                4  33.8006287       99.99   8.4501572  35208.496  ***
  BLOCK                               2   0.0004800        0.00   0.0002400      1.000  N.S.
  RESIDUAL                            8   0.0019200        0.01   0.0002400
TOTAL                                14  33.8030090      100.00   2.4145002
GRAND TOTAL                          14  33.8030090      100.00
GRAND MEAN                            1.0780
TOTAL NUMBER OF OBSERVATIONS              15
***** TABLES OF MEANS *****
VARIATE: TN1
    GRAND MEAN    1.0780
          DENS         1         2         3         4         5
                  4.0000    1.0000    0.2500    0.1200    0.0200
         BLOCK         1         2         3
                  1.0860    1.0740    1.0740
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE               DENS       BLOCK
---------------------------------------
REP                    3           5
SED              0.01265     0.00980
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                      DF          SE          CV%
*UNITS*                       8     0.01549          1.4
1
```

EFFECTS OF WHEAT CV. BIDI 17 POPULATION DENSITY ON LEAF NUMBER PER WHEAT PLANT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: LN1
SOURCE OF VARIATION                  DF          SS         SS%          MS          VR
*UNITS* STRATUM
  DENS                                4    572.9089       99.45    143.2272     373.717  ***
  BLOCK                               2      0.0840        0.01      0.0420       0.110  N.S.
  RESIDUAL                            8      3.0660        0.53      0.3832
TOTAL                                14    576.0588      100.00     41.1470
GRAND TOTAL                          14    576.0588      100.00
GRAND MEAN                            10.58
TOTAL NUMBER OF OBSERVATIONS              15
***** TABLES OF MEANS *****
VARIATE: LN1
    GRAND MEAN    10.58
          DENS         1         2         3         4         5
                   22.00     11.83      8.25      5.58      5.23
         BLOCK         1         2         3
                   10.48     10.66     10.60
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE               DENS       BLOCK
---------------------------------------
REP                    3           5
SED                0.505       0.392
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                      DF          SE          CV%
*UNITS*                       8       0.619          5.9
```

EFFECTS OF WILD OAT POPULATION DENSITY ON SHOOT DRY WEIGHT PER WILD OAT PLANT.

***** ANALYSIS OF VARIANCE *****

VARIATE: WS

SOURCE OF VARIATION	DF	SS	SS%	MS	VR	
UNITS STRATUM						
DENS	4	137.8227	95.41	34.4557	44.913	***
BLOCK	2	0.4960	0.34	0.2480	0.323	N.S.
RESIDUAL	8	6.1373	4.25	0.7672		
TOTAL	14	144.4560	100.00	10.3183		
GRAND TOTAL	14	144.4560	100.00			
GRAND MEAN	5.84					
TOTAL NUMBER OF OBSERVATIONS	15					

***** TABLES OF MEANS *****

VARIATE: WS

GRAND MEAN 5.84

	1	2	3	4	5
DENS	9.50	9.37	4.60	3.53	2.20

	1	2	3
BLOCK	5.80	5.64	6.08

***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****

TABLE	DENS	BLOCK
REP	3	5
SED	0.715	0.554

***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****

STRATUM	DF	SE	CV%
UNITS	8	0.876	15.0

EFFECTS OF CHARLOCK POPULATION DENSITY ON SHOOT DRY WEIGHT PER CHARLOCK PLANT.

***** ANALYSIS OF VARIANCE *****

VARIATE: WSS

SOURCE OF VARIATION	DF	SS	SS%	MS	VR	
UNITS STRATUM						
DENS	4	66.5093	92.85	16.6273	28.676	***
BLOCK	2	0.4813	0.67	0.2407	0.415	N.S.
RESIDUAL	8	4.6387	6.48	0.5798		
TOTAL	14	71.6293	100.00	5.1164		
GRAND TOTAL	14	71.6293	100.00			
GRAND MEAN	6.13					
TOTAL NUMBER OF OBSERVATIONS	15					

***** TABLES OF MEANS *****

VARIATE: WSS

GRAND MEAN 6.13

	1	2	3	4	5
DENS	9.73	6.20	6.33	5.07	3.30

	1	2	3
BLOCK	6.30	6.20	5.88

***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****

TABLE	DENS	BLOCK
REP	3	5
SED	0.622	0.482

***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****

STRATUM	DF	SE	CV%
UNITS	8	0.761	12.4

EFFECTS OF WILD OAT POPULATION DENSITY ON LEAF DRY WEIGHT PER WILD OAT PLANT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: WL1
SOURCE OF VARIATION              DF        SS       SS%        MS         VR
*UNITS* STRATUM
  DENS                            4   4.40400     82.82   1.10100    15.399 ***
  BLOCK                           2   0.34133      6.42   0.17067     2.387 N.S.
  RESIDUAL                        8   0.57200     10.76   0.07150
TOTAL                            14   5.31733    100.00   0.37981
GRAND TOTAL                      14   5.31733    100.00
GRAND MEAN                          2.453
TOTAL NUMBER OF OBSERVATIONS           15
***** TABLES OF MEANS *****
VARIATE: WL1
    GRAND MEAN     2.453
          DENS         1        2        3        4        5
                   1.500    2.333    2.533    2.800    3.100
         BLOCK         1        2        3
                   2.560    2.560    2.240
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                 DENS       BLOCK
--------------------------------------
REP                      3           5
SED                 0.2183      0.1691
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                  DF          SE          CV%
*UNITS*                   8      0.2674         10.9
```

EFFECTS OF WILD OAT POPULATION DENSITY ON LEAF NUMBER OF WILD OAT PLANT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: NL1
SOURCE OF VARIATION              DF        SS       SS%        MS         VR
*UNITS* STRATUM
  DENS                            4  29240.27     98.34   7310.07   173.567 ***
  BLOCK                           2    157.73      0.53     78.87     1.873 N.S.
  RESIDUAL                        8    336.93      1.13     42.12
TOTAL                            14  29734.93    100.00   2123.92
GRAND TOTAL                      14  29734.93    100.00
GRAND MEAN                           73.9
TOTAL NUMBER OF OBSERVATIONS           15
***** TABLES OF MEANS *****
VARIATE: NL1
    GRAND MEAN      73.9
          DENS         1        2        3        4        5
                    21.3     40.3     65.3     96.0    146.7
         BLOCK         1        2        3
                    76.8     69.4     75.6
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                 DENS       BLOCK
--------------------------------------
REP                      3           5
SED                   5.30        4.10
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                  DF          SE          CV%
*UNITS*                   8        6.49          8.8
```

EFFECTS OF CHARLOCK POPULATION DENSITY ON STEM DRY WEIGHT PER CHARLOCK PLANT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: DWS1
SOURCE OF VARIATION                DF          SS        SS%          MS          VR
*UNITS* STRATUM
  DENS                              4     45.2373      95.52     11.3093      43.111 ***
  BLOCK                             2      0.0213       0.05      0.0107       0.041 N.S.
  RESIDUAL                          8      2.0987       4.43      0.2623
TOTAL                              14     47.3573     100.00      3.3827
GRAND TOTAL                        14     47.3573     100.00
GRAND MEAN                            4.01
TOTAL NUMBER OF OBSERVATIONS            15
***** TABLES OF MEANS *****
VARIATE: DWS1
    GRAND MEAN      4.01
          DENS         1         2         3         4         5
                    2.03      3.17      4.17      3.50      7.20
         BLOCK         1         2         3
                    4.04      3.96      4.04                              4.04      3.96      4.04
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                   DENS       BLOCK
----------------------------------------
REP                        3           5
SED                    0.418       0.324
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                      DF          SE          CV%
*UNITS*                       8       0.512         12.8
```

EFFECTS OF CHARLOCK POPULATION DENSITY ON LEAF DRY WEIGHT PER CHARLOCK PLANT.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: WN1
SOURCE OF VARIATION                DF          SS        SS%          MS          VR
*UNITS* STRATUM
  DENS                              4      3.9427      72.00      0.9857       6.743 *
  BLOCK                             2      0.3640       6.65      0.1820       1.245 N.S.
  RESIDUAL                          8      1.1693      21.35      0.1462
TOTAL                              14      5.4760     100.00      0.3911
GRAND TOTAL                        14      5.4760     100.00
GRAND MEAN                            2.140
TOTAL NUMBER OF OBSERVATIONS             15
***** TABLES OF MEANS *****
VARIATE: WN1
    GRAND MEAN     2.140
          DENS         1         2         3         4         5
                   1.267     1.900     2.300     2.700     2.533
         BLOCK         1         2         3
                   2.260     2.240     1.920
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                   DENS       BLOCK
----------------------------------------
REP                        3           5
SED                   0.3122      0.2418
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                      DF          SE          CV%
*UNITS*                       8      0.3823         17.9
```

Appendix 3

Statistical analysis (Analysis of variance) of the effect of post emergence herbicides applied to wild oat and charlock at different doses and different timings of application on the total biomass production, and the tolerance of winter wheat cultivars (British & Algerian) to these herbicides applied during tillering growth stage.

1- Effects of tralkoxydim on the shoot dry weight of wild oat at two different rates and two timing spray application.

2- Effects of flamprop-isopropyl on the shoot dry weight of wild oat at two different rates and two timing spray application.

3- Total biomass (g/pot) of four winter wheat cultivars treated with grass and broad-leaved herbicides during tillering stage.

Effects of tralkoxydim on wild oat at two rates and two different times of spray application.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: SDW
SOURCE OF VARIATION                DF         SS        SS%          MS          VR
*UNITS* STRATUM
  DOSE                              2   239.8711      66.87    119.9355    380.479 ***
  TIME                              1   114.5089      31.92    114.5089    363.264 ***
  DOSE.TIME                         2     0.2978       0.08      0.1489      0.472 N.S.
  BLOCK                             2     0.8744       0.24      0.4372      1.387 N.S.
  RESIDUAL                         10     3.1522       0.88      0.3152
TOTAL                              17   358.7039     100.00     21.1002
GRAND TOTAL                        17   358.7039     100.00
GRAND MEAN                            6.54
TOTAL NUMBER OF OBSERVATIONS            18
***** TABLES OF MEANS *****
VARIATE: SDW VARIATE: SDW
    GRAND MEAN     6.54
          DOSE        1          2          3
                  11.70       4.20       3.73
          TIME        1          2
                   4.02       9.07
          TIME        1          2
          DOSE
             1     9.00      14.40
             2     1.73       6.67
             3     1.33       6.13
         BLOCK        1          2          3
                   6.68       6.72       6.23
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                  DOSE          TIME         DOSE          BLOCK
                                                  TIME
-----------------------------------------------------------------
REP                       6             9            3              6
SED                   0.324         0.265        0.458          0.324
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                        DF            SE          CV%
*UNITS*                        10         0.561          8.6
```

Effects of flamprop-isopropyl on wild oat at two rates and two different times of spray application.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: DW
SOURCE OF VARIATION                DF         SS        SS%          MS          VR
*UNITS* STRATUM
  DOSE                              2   475.1409      93.24    237.5704   1635.915 ***
  TIME                              1    27.1339       5.32     27.1339    186.844 ***
  DOSE.TIME                         2     4.4344       0.87      2.2172     15.268 ***
  BLOCK                             2     1.4078       0.28      0.7039      4.847 *
  RESIDUAL                         10     1.4522       0.28      0.1452
TOTAL                              17   509.5688     100.00     29.9746
GRAND TOTAL                        17   509.5688     100.00
GRAND MEAN                           7.706
TOTAL NUMBER OF OBSERVATIONS            18
***** TABLES OF MEANS *****
VARIATE: DW VARIATE: DW
    GRAND MEAN    7.706
          DOSE        1          2          3
                 14.950      4.567      3.600
          TIME        1          2
                  6.478      8.933
          TIME        1          2
          DOSE
             1   14.233     15.667
             2    2.667      6.467
             3    2.533      4.667
         BLOCK        1          2          3
                  8.100      7.483      7.533
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                  DOSE          TIME         DOSE          BLOCK
                                                  TIME
-----------------------------------------------------------------
REP                       6             9            3              6
SED                  0.2200        0.1796       0.3112         0.2200
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                        DF            SE          CV%
*UNITS*                        10        0.3811          4.9
```

Effects of tralkoxydim and flamprop-isopropyl on wild oat at three different doses.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: SDW1
SOURCE OF VARIATION                 DF          SS        SS%          MS          VR
*UNITS* STRATUM
  DOSE                               3    594.1030      96.55    198.0343     367.177 ***
  HERB                               1      0.0600       0.01      0.0600       0.111 N.S.
  DOSE.HERB                          3     13.5633       2.20      4.5211       8.383 **
  BLOCK                              2      0.0758       0.01      0.0379       0.070 N.S.
  RESIDUAL                          14      7.5508       1.23      0.5393
TOTAL                               23    615.3525     100.00     26.7545
GRAND TOTAL                         23    615.3525     100.00
GRAND MEAN                               5.33
TOTAL NUMBER OF OBSERVATIONS               24
***** TABLES OF MEANS *****
VARIATE: SDW1
    GRAND MEAN    5.33
          DOSE       1        2        3        4
             13.92     3.18     2.23     2.00
          HERB       1        2
              5.28     5.38
          HERB       1        2
          DOSE
             1   12.57    15.27
             2    3.50     2.87
             3    2.63     1.83
             4    2.43     1.57
         BLOCK       1        2        3
              5.34     5.26     5.40
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                    DOSE        HERB        DOSE        BLOCK
                                                 HERB
-----------------------------------------------------------------
REP                         6          12           3            8
SED                     0.424       0.300       0.600        0.367
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                      DF           SE          CV%
*UNITS*                      14        0.734         13.8
```

EFFECTS OF 2.4-D AND MCPA ON CHARLOCK AT THREE DIFFERENT DOSES.

```
***** ANALYSIS OF VARIANCE *****
VARIATE: SDW2
SOURCE OF VARIATION                 DF          SS        SS%          MS          VR
*UNITS* STRATUM
  DOSE                               3   198.71497      99.28    66.23831     835.438 ***
  HERB                               1     0.01500       0.01     0.01500       0.189 N.S.
  DOSE.HERB                          3     0.31500       0.16     0.10500       1.324 N.S.
  BLOCK                              2     0.00333       0.00     0.00167       0.021 N.S.
  RESIDUAL                          14     1.11000       0.55     0.07929
TOTAL                               23   200.15826     100.00     8.70253
GRAND TOTAL                         23   200.15826     100.00
GRAND MEAN                             2.992
TOTAL NUMBER OF OBSERVATIONS               24
***** TABLES OF MEANS *****
VARIATE: SDW2
    GRAND MEAN   2.992
          DOSE       1        2        3        4
             7.933    1.833    1.417    0.783
          HERB       1        2
             2.967    3.017
          HERB       1        2
          DOSE
             1   7.733    8.133
             2   1.933    1.733
             3   1.467    1.367
             4   0.733    0.833
         BLOCK       1        2        3
             3.000    3.000    2.975
***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****
TABLE                    DOSE        HERB        DOSE        BLOCK
                                                 HERB
-----------------------------------------------------------------
REP                         6          12           3            8
SED                    0.1626      0.1150      0.2299       0.1408
***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****
STRATUM                      DF           SE          CV%
*UNITS*                      14       0.2816          9.4
```

<u>The tolerance of four cultivars of winter wheat to four post-emergence herbicides.</u>

***** ANALYSIS OF VARIANCE *****

VARIATE: SW

SOURCE OF VARIATION	DF	SS	SS%	MS	VR	
UNITS STRATUM						
HERB	4	18.1740	9.56	4.5435	40.551	***
CVS	3	54.1618	28.50	18.0539	161.133	***
HERB.CVS	12	112.9539	59.43	9.4128	84.010	***
BLOCK	2	0.5223	0.27	0.2612	2.331	N.S.
RESIDUAL	38	4.2577	2.24	0.1120		
TOTAL	59	190.0697	100.00	3.2215	TOTAL 59 1	
GRAND TOTAL	59	190.0697	100.00			

GRAND MEAN 6.082

TOTAL NUMBER OF OBSERVATIONS 60

***** TABLES OF MEANS *****

VARIATE: SW

GRAND MEAN 6.082

HERB	1	2	3	4	5
	6.433	6.983	5.633	5.842	5.517

CVS	1	2	3	4
	7.227	6.567	5.873	4.660

HERB \ CVS	1	2	3	4
1	7.200	5.200	9.367	3.967
2	8.000	7.167	8.033	4.733
3	8.333	6.167	3.667	3.867
4	6.967	7.600	3.033	5.767
5	5.133	6.700	5.267	4.967

BLOCK	1	2	3
	5.950	6.140	6.155

***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****

TABLE	HERB	CVS	HERB CVS	BLOCK
REP	12	15	3	20
SED	0.1367	0.1222	0.2733	0.1059

***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****

STRATUM	DF	SE	CV%
UNITS	38	0.3347	5.5

Appendix 4

List of the common names of herbicides used in cereals in the U.K. in 1988 and the weeds controlled.

Herbicides	Weeds controlled
2,4-D.	Annual and perennialdicotyledons
2,4-D + dichlorprop.	Annual andperennial dicotyledons.
2,4-D+dichlorprop + MCPA + mecoprop.	Annual, perennial dicotyledons and cleavers.
2,4-DB + MCPA.	Annual and perennial dicotyledons and polygonums
AC222293.	Wild oats and charlock
Benazolin+bromoxynil + ioxynil.	Annual dicotyledons.
Bentazone+dichlorprop.	Annual dicotyledons.
Bentazone+ dichlorprop + MCPA.	Annual dicotyledons.
Bentazone + mecoprop.	Annual dicotyledons.
Bifenox+chlorotoluron.	Blakgrass, wild oat and annual grasses and dicotyledons.
Bifenox + isoproturon.	Annual grasses and dicotyledons, blakgrass and field pansy.
Bifenox + isoproturon +	Blackgrass, wild oats annual

mecoprop.	grasses and dicotyledons.
Bifonex + mecoprop.	Cleavers, annual dicotyledons.
Bromoxynil + clopyralid.	Annual dicotyledons.
Bromoxynil + clopyralid + fluroxypyr + ioxynil.	Annual dicotyledons.
Bromoxynil + dichlorprop.	Annual dicotyledons.
Bromoxynil +dichlorprop + ioxynil + MCPA.	Mayweeds, chickweed,polygonums, and annual dicotyledons.
Bromoxynil + fluroxypyr.	Annual dicotyledons.
Bromoxynil + fluroxypyr + ioxynil.	Cleavers, Chickweed, hemp-nettle, speedwells and annual dicotyledons
Bromoxynil + ioxynil.	Annual dicotyledons.
Bromoxynil + ioxynil + isoproturon + mecoprop.	Annual dicotylrdons and annual meadow grass.
Bromoxynil + ioxynil + mecoprop	Annual dicotyledons.
Bromoxynil + ioxynil + trifluralin.	Annual grasses and dicotyledons.
Bromoxynil + MCPA.	Annual dicotyledons.
Bromoxynil/ioxynil + chlorsulfuron.	Annual dicotyledons, mayweeds, knotgrass, chickweed and hemp-nettle
Chlorotoluron.	Blackgrass, wild oats and annual grasses dicotyledons.
Chlorsulfuron + methabenzthiazuron.	Annual dicotyledons and grasses, blackgrass,speedwells and cleavers
Clorosulfuron +	Annual dicotyledons and grasses

metsulfuron-methyl.	blackgrass,speedwells and cleavers
Clopyralid + cyanazine.	Annual dicotyledons.
Clopyralid+ dichlorprop + MCPA.	Annual dicotyledons, mayweeds, chickweed,hemp-nettle andn redshank
Clopyralid + fluroxypyr + ioxynil.	Annual dicotyledons, cleavers, chickweed,mayweeds and speedwells.
Clopyralid + ioxynil.	Annual dicotyledons and mayweeds.
Clopyralid + mecoprop.	Annual dicotyledons, mayweeds, corn marigold, and docks.
Cyanazine.	Annual dicotyledons and grasses.
Cyanazine + mecoprop.	Annual and perennial dicotyledons.
Dicamba + dichlorprop + ioxynil.	Annual and perennial dicotyledons.
Dicamba + MCPA + mecoprop.	Annual and perennial dicotyledons, chickweed, cleavers and polygonums
Dichlorprop.	Annual and perennial dicotyledon black bindweed and redshank.
Dichlorprop + MCPA.	Annual and perennial dicotyledons hemp-nettle and black bindweed.
Dichlorprop + mecoprop.	Annual and perennial dicotyledons.
Dichlorprop + mecoprop + 2,3,6-TBA.	Annual dicotyledons, mayweeds, chickweed and polygonums.
Diflufenican + isoproturon.	Annual dicotyledons and grasses, blackgrass and wild oats.
DPX-M6316 + metsulfuron-methyl.	Annual dicotyledons, cleavers, speedwells and polygonums.
Fluroxypyr + ioxynil.	Annual dicotyledons, cleavers, speedwells and red dead nettle.
Ioxynil.	Annual dicotyledons, field pansy

	speedwells and reddead nettle.
Ioxynil + isoproturon + mecoprop.	Annual dicotyledons,grasses and annual meadowgrass, chickweed, cleavers and speedwells.
Isoproturon.	Annual grasses and dicotyledons, blackgrass and wild oats.
Isoproturon + pendimethalin.	Annual grasses and dicotyledons, wild oats and blackgrass.
Isoproturon + trifluralin.	Annual grasses and dicotyledons, and blackgrass.
Isoxaben.	Annual dicotyledons.
Linuron.	Annual dicotyledons,
Linuron + trietazine + trifluralin.	Annual dicotyledons and grasses.
Linuron + trifluralin.	Annual dicotyledons and grasses annual meadow grassand perennial ryegrass.
MCPA.	Annual and perennial dicotyledons charlock, fat-hen and wild radish.
MCPA + MCPB.	Annual and perennial dicotyledons.
Mecoprop.	Annual and perennial dicotyledons, chickweed and cleavers.
Methabenzthiazuron.	Annual dicotyledons, annual meadow grassandrough meadowgrass.
Metoxuron.	Annual grasses and dicotyledons blackgrass, and barren brome
Metoxuron + simazine.	Annual dicotyledons,annual grasses and blackgrass.

Metsulfuron-methyl.	Annual dicotyledons, chickweed and mayweeds.
Pendimethalin	Annual grasses and dicotyledons annual meadow grass, blackgrass, wild oats, cleavers and speedwells
Pyridate.	Annual dicotyledons, cleavers, dead nettle and speedwells.
Terbutryn.	Annual dicotyledons,annual meadow grass and rough meadow grass.
Terbutryn + trifluralin.	Annual dicotyledons, annual grasseschickweed,mayweeds,speed wells blackgrass and annual meadow grass.
Trifluralin.	Annual grasses and dicotyledons.
Benzoylprop-ethyl.	Wild oats.
Bifenox + chlorotoluron.	Blackgrass, wild oats and annual grasses and dicotyledons.
Bifenox+isoproturon+ mecoprop.	Annual grasses and dicotyledons, blackgrass and field pansy.
Chlorotoluron.	Blackgrass, wild oats, annual grasses and dicotyledons.
Diclofop.	Annual wild oats,blackgrass, yorkshire fog ryegrass and rough meadow grass.
Difenzoquat.	Wild oats.
Diflufenican + isoproturon.	Annual dicotyledons, annual grasses blackgrass and wild oats.
Flamprop.	Wild oats.

Glyphosate(wiper glove).	Annual and perennial weeds.
Isoproturon.	Annual grasses and dicotyledons, blackgrass and wild oats.
Isoproturon + pendimethalin.	Annual grasses and dicotyledons Wild oats and blackgrass.
Pendimethalin.	Annual grasses and dicotyledons annual meadow grass and blackgrass
Tri-allate.	Annual grasses, wild oats, chickweed, cleavers and fumitory.

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