CHAPTER 5

Competition between Wild Oats and Crops

RICHARD J. CHANCELLOR AND N. C. B. PETERS

ARC Weed Research, Organization, Oxford

This section reviews the information on (1) the reduction of crop yield and methods of measuring it, (2) the effect of competition upon seed protein and other quality factors and (3) the factors influencing competition between wild oats and cereals. There have been a number of publications on various aspects of competition between wild oats and crops, of which 101 are included in this review. There have been several previous reviews on this subject, eg Dadd (1956, 1957), Stubbs (1956-7), Thurston (1965), Tingey (1965) and Chancellor (1969a).

In general, wild oats can cause serious yield reductions in crops. *A. fatua* emerges mainly in the spring and consequently autumn-planted cereals are more competitive than spring-sown ones because they emerge much earlier. Barley is the most competitive spring cereal with *A. fatua,* while wheat, oats and rye are all much the same and less competitive than barley. Peas and flax are poor competitors.

Yield reductions have been measured by comparing sprayed with unsprayed areas, by using sown populations of wild oats or by hand-weeding natural populations to required densities. Yield-reducing competition probably begins at about the 3-4 leaf stage of spring barley and wheat, but in flax at about the 1 leaf stage. The main factors influencing the competitive interaction are date of sowing the crop, crop and wild oat densities, relative times of emergence of crop and weed, fertiliser usage, moisture, light and pH of the soil. Cereal grain quality appears to be relatively infrequently affected by wild oat competition, but flax seed quality is readily affected.

Much of the experimental work carried out on crop yield losses caused by wild oats was done some years ago, and there is now a need to supplement this work using newer crop varieties. This is especially true in the case of winter wheat, with the introduction of the new dwarf varieties. There has been relatively little work carried out in Europe on how seed rate, fertiliser level and timing of fertiliser application can interact to affect the competition offered by the crop. There is a need for more information on the competition of *A. fatua* and *A. ludoviciana* either in mixture or separately with winter cereals. *Alopecurus myosuroides* is found mixed with both *A. fatua* and *A. ludoviciana* and there is scope here for the study of the interaction of wild oat/blackgrass populations with cereal crops, especially as some of the blackgrass herbicides in current use also show activity on wild oats.

We are indebted to Miss J. M. Thurston, G. W. Cussans and B. J. Wilson for comments and suggestions made in the preparation of the text.

THE REDUCTION OF CROP YIELD AND METHODS OF MEASURING IT

MEASURING WILD OAT COMPETITION WITH HERBICIDES

A common method of assessing wild oat competition is by killing the weed with herbicides and measuring the increase in crop yield above that of adjacent untreated areas. While this method has several features to recommend it in preference to laborious hand-weeding, there is always the possibility of introducing complicating factors with the herbicide. For example, the chemical may have a deleterious effect upon the crop or alternatively it may have a beneficial one. Furthermore, a chemical such as barban, which relies in part upon competition by the crop for its full effect, may not give an accurate measure of the weed's competitive ability. It could give a serious underestimate. A considerable amount of data is available on the effects on crop yield of removing weeds by herbicide and a number of references selected for a range of countries and conditions have been compiled for wheat (Table 5.1), barley (Table 5.2), flax (Table 5.3) and peas (Table 5.4). These give some indication of the wide range of results obtained.

COMPETITION MEASURED BY OTHER METHODS

From the purely practical and economic point of view, it may perhaps be sufficient to measure competition as the difference between the yields from sprayed and unsprayed areas to see whether the value of the increase will cover the cost of spraying or not. For more precise investigations, it is necessary to carry out experiments without the complicating factor of herbicide application mentioned above.

Some investigators have planted wild oats into clean crops. Bell and Nalewaja (1968b) sowed ungerminated wild oat seed, which in one experiment was apparently dormant and gave very few plants and in another a proportion was dormant resulting in a population of half the desired density. To overcome this problem, Bowden and Friesen (1967) broadcast seeds at two and a half times the required density. This technique is useful for achieving approximate densities and for altering wild oat emergence relative to that of the crop (McBeath *et al* 1970). Another way to avoid the difficulties of dormancy is to plant germinated seed. Hoepfner (1969) found that when the weed was planted at the same time as a barley crop, the crop dominated the weed and only one third of the wild oat plants survived. Planting pre-germinated seeds in an algal gel has also been tried (Bate *et al* 1970, Lake 1971), but this has not proved particularly successful, although it does help in positioning wild oat plants in relation to crop rows (Bate *et al* 1970). To avoid difficulties of germination and contamination, cultivated oats have been planted instead of wild ones (Pfeiffer and Holmes 1961a).

Table 5.1. *The effects of chemical control measures on the yield of wheat crops*

Wild oat density	Chemical treatment and dose (kg/ha)		% control of weed	Yield increase kg/ha	%	Reference	Country
–	barban	0.56	50-100%	544		Banting 1960	Canada
–	barban	0.18-1.12	70-86%		86%	Carder 1960	Canada
High density	barban	–	–	3136		Edwards 1961	UK
762/m²	barban	0.28	86%		177%	Friesen 1960b	Canada
Medium-high	barban	0.56-1.12	–	349-418		Gull *et al* 1959	US and Canada
–	barban	0.35	–		12-100%	Holmes and Pfeiffer 1962	UK
–	barban	0.35	–	376-1881		Holmes and Pfeiffer 1963	UK
–	barban	0.4	80%	270	33%	Kudasheva 1966	USSR
V. light-v. heavy	barban	0.28	–		0-14%	Pfeiffer and Phillips 1960	UK
Medium-heavy	barban	0.28	–		5-23%	Pfeiffer and Phillips 1960	UK
–	barban	0.84	c.88%		35%	Sexsmith 1960	Canada
–	di-allate	1.5	87%	220-320		Kozlov 1967	USSR
160/m²	di-allate	0.28-1.12	85%	976	48%	Molberg and Banting 1960a	Canada
762/m²	tri-allate	1.7	99%		344%	Friesen 1960b	Canada
200/m²	tri-allate	2.0	90%	550-740		Lysenkov and Kozlov 1966	USSR
–	tri-allate	2.0	83%	890-1310		Lysenkov and Kozlov 1966	USSR
–	tri-allate	1-2	93%	310		Kozlov 1967	USSR
–	tri-allate	1.4	85%		14%	Slater 1969	USA

Table 5.2. *The effects of chemical control measures on the yield of barley crops*

Wild oat density	Chemical treatment and dose (kg/ha)		% control of weed	Yield increase		Reference	Country
				kg/ha	%		
–	barban	0.56	–	244		Banting 1961	Canada
Medium-heavy	barban	0.56-1.12	–	376-941		Gull *et al* 1959	US and Canada
<20->100/m²	barban	0.5	35-39%		2-13%	Gummesson 1968	Sweden
Heavy-v. heavy	barban	0.42	80%		0-25%	Pfeiffer and Phillips 1960	UK
80-122/m²	di-allate	1.12-2.24	–		48%	Holroyd 1960	UK
–	di-allate	2.0	82-92%	390-580		Kozlov 1967	USSR
96-120/m²	di-allate	2.24	86%		25-30%	Friesen 1960a	Canada
–	di-allate	2.8	79-97%	388		Molberg and Banting 1960b	Canada
–	di-allate	2.8	79-97%	552		Molberg and Banting 1960b	Canada
22-864/m²	di-allate	1.12-2.24	75-88%		47-72%	Selleck and Althaus 1960	USA
175/m²	tri-allate	–	95-99%		60-110%	Bullen 1967	UK
–	tri-allate	1.14	90%		25%	Göpp *et al* 1966	Germany
<20->100/m²	tri-allate	1.6	56-75%		2-28%	Gummesson 1968	Sweden
200/m²	tri-allate	2.0	90%	640-1120		Lysenkov and Kozlov 1966	USSR
–	tri-allate	1.2	93%	540		Kozlov 1967	USSR

Table 5.3. *The effects of chemical control measures on the yield of flax*

Wild oat density	Chemical treatment and dose (kg/ha)		% control of weed	Yield increase kg/ha	%	Reference	Country
–	barban	0.56	–	94-99		Banting 1961	Canada
Medium-heavy	barban	0.56-1.12	–	117-351		Gull *et al* 1959	US and Canada
–	di-allate	1.12-2.8	–		133%	Leggett 1960	Canada
145/m²	di-allate	1.12-1.4	75-95%	175-468	55-148%	Molberg and Banting 1960c	Canada
88/m²	di-allate	1.12-1.4	75-95%	58-205	17-60%	Molberg and Banting 1960c	Canada
–	tri-allate	2.87	–		28%	Rataj and Smirous 1968	Czech
–	tri-allate	2.87	–		21%	Rataj and Smirous 1968	Czech

Table 5.4. *The effects of chemical control measures on the yield of peas*

Wild oat density	Chemical treatment and dose (kg/ha)		% control of weed	Yield increase kg/ha	%	Reference	Country
–	barban	5.0	–		81%	Chesalin and Ramazanov 1963	USSR
100/m²	barban	0.56-1.12	good		59-62%	Sexsmith 1960	Canada
–	chlorpropham	6.0	–		50%	Chesalin and Ramazanov 1963	USSR
240/m²	di-allate	–	–	1129		Great Britain 1963	UK
–	di-allate	1.12-1.4	–		10-40%	Rydrych *et al* 1965	USA
–	TCA	11.2	85-93%		107%	Great Britain 1957	UK

The other alternative is to use natural populations of wild oats. These can be accepted at the density that emerges naturally, or weeded down to the required densities. Weeding does disturb the soil and may thereby influence germination or development of other plants, but the controls have to be hand-weeded anyway (Nakoneshny and Friesen 1961). The greatest use of the hand-weeding technique is to determine the onset of the 'critical period' of competition (Nieto *et al* 1968) in which weed populations are removed from weedy plots at intervals of time (Bell and Nalewaja 1968c, Chancellor and Peters 1974).

Results from the various reports quoted above are detailed in the review of factors influencing competition between wild oats and crops.

TIME OF ONSET OF COMPETITION

Nieto *et al* (1968) have called the period, during which weeds must not compete with a crop if yield reductions are to be avoided, the 'critical period'. For wild oats in cereals at least, it is important to know when yield-reducing competition begins, because once damage is done full recovery is unlikely to occur even if the weeds are subsequently removed (Koch 1967).

In barley it was found that competition began at the three leaf stage (Lake 1971), although Chancellor and Peters (1974) using natural populations of wild oats, which had more than 150 stems/m^2 at harvest found that competition did not begin until the 4-leaf stage. The time of greatest reduction in crop weight through competition was during shooting, when losses amounted to 25-32% (Koch 1967).

In wheat, it has been reported from Canada that competition might occur before crop and weed emerge (Bowden and Friesen 1967) or at least before the two to three leaf stage (Hannah 1964). In England, competition started at about the four and a half leaf stage in one experiment (Chancellor and Peters 1974). In Italy it was calculated that the mean loss of yield in wheat amounted to 7 kg/ha for each day that wild oats were present in the crop (Catizone and Toderi 1974), although the time of onset was not determined.

In flax, severe competition in one year occurred before the 2-3 leaf stage and some competition before the 1-2 leaf stage (Hannah 1964, Bowden and Friesen 1967). Bell and Nalewaja (1968c) found that up to the 5-leaf stage the yield reduction gradually approached 15%, but later on it increased rapidly and reached 75% reduction by maturity.

In a natural population of wild oats in peas, if the weed was removed when it had $2\frac{1}{2}$-3 leaves the yield was reduced by 11% and if left until harvest the reduction was 40%. In a planted wild oat population the reductions from a similar experiment were 10% and 60% respectively (Gargouri and Seeley 1972b). In a crop of field beans competition effects did not become evident until the crop had 9 leaves (Lake 1971).

EFFECT OF COMPETITION UPON CROP SEED PROTEIN AND OTHER QUALITY FACTORS

In cereals it appears that, although substantial yield reductions can be caused by wild oats, protein content is relatively infrequently affected. In flax, however, definite reductions in oil content and of other measures of seed quality have been recorded even at low wild oat densities.

Friesen (1957) found that the protein content of wheat and barley was increased when weeds (mainly wild oats) at densities between 16 and $2665/m^2$ were removed. Nakoneshny and Friesen (1961) found that yield increases following fertiliser applications to weedy spring wheat were sometimes associated with protein reduction. They showed that protein reductions could be prevented and often increased significantly by removal of the weeds, whose density averaged $258/m^2$ and which were mainly wild oats. Friesen *et al* (1960) found that weeds significantly reduced both protein content and yield of wheat, barley and oats in 22 out of 60 fields investigated. The weed densities ranged from 18 to $1040/m^2$ and weeds other than wild oats were present. On the other hand, Bell and Nalewaja (1966 and 1968b) found no effect on the 1000 grain weight or protein content of wheat and barley at wild oat densities of up to $300/m^2$. Similarly, Bowden and Friesen (1967) found the protein content of wheat to be unaffected by wild oat populations of up to $228/m^2$.

The fact that other weeds were present in all the instances of protein reduction may indicate that a greater range of nutritional demand than that made by wild oats alone is necessary for it to occur, but it also appears to be a prerequisite that the total weed density should be high.

In flax, Bell and Nalewaja (1966 and 1968a) showed that the oil content, the iodine number of the oil (a measure of quality) and the level of linolenic acid in the seed declined in three separate years as a result of wild oat competition. Conversely the level of oleic acid increased. These changes occurred with wild oat densities as low as $12/m^2$. The effect of duration of competition on flax seed quality was also investigated and, although the number of bolls was reduced by relatively short periods of competition, it was not until the flax had produced bolls and the wild oats were heading that reductions in quality occurred (Bell and Nalewaja 1968c).

FACTORS INFLUENCING COMPETITION BETWEEN WILD OATS AND CROPS

DATE OF SOWING THE CROP AND THE PERIOD OF WILD OAT EMERGENCE RELATIVE TO THAT OF THE CROP

Early sowing of cereals does little to suppress emerging wild oats, for the crop grows slowly when the weather is cool. The wild oats have a long period of emergence and can easily become established. Sowing the crop late enables the main flush of wild oats to emerge and so be killed before the crop is planted. Temperatures are higher and the crop grows much more quickly, thus greatly suppressing any further wild oats that emerge later. The wild oats also have a shorter period of emergence in the crop. However, crop yield is generally reduced by late sowing. In a cereal crop infested with wild oats the earliest emerging plants tend to have the upper hand and keep it (McBeath *et al* 1970). It is the earlier-emerging wild oats that form the largest plants and, in general, a large proportion of the seed (Chancellor and Peters 1972). However, in Australia, where the seed rate of wheat is low, competition from late-emerging wild oats can also be important and competition can occur throughout the whole life of the crop. For example, seed yield and quality are frequently reduced as a result of low moisture levels after the crop has flowered (McNamara 1972).

In general, there were fewer wild oat plants in late-sown spring cereals and early-sown autumn ones than early-sown spring and late-sown autumn ones respectively (Tingey 1965). This is true for both spring wheat and spring barley (Sexsmith 1955, McCurdy 1955, 1958, Brown 1957b, Selman 1970b). A wild oat population after three years of late drilling was reduced by 81% in wheat and 36% in barley (Molberg and Leggett 1955b). Another was reduced by 78% in late-sown wheat and 79% in late-sown barley (Brown 1957a). Another population of 175/m^2 was reduced by 97% in one year by late-sowing spring barley (Bullen 1966, 1967).

The increase or decrease of wild oats from early or late sowing of cereals appears to vary greatly. For example, in Canada, Brown (1957b) found that early sowing of the crop quickly built up an extremely heavy infestation, while McCurdy (1955) found only a gradual increase. This suggests that other factors besides time of sowing are involved. This is borne out by the report that, by heavy seeding and fertiliser usage, wild oats were reduced in an early-sown crop (Sexsmith 1955).

The drawback to late sowing of spring cereals is that yields are almost invariably reduced, although if compared with yields of weedy early-sown ones an increase can be apparent. This increase, in one instance in England, amounted to between 60 and 110% in barley; but even so, the early-sown crop when treated with herbicide outyielded the clean late-sown one by 878 kg/ha (Bullen 1966, 1967). In Canada, wheat sown one month late showed a yield reduction of 19% and one-month-late barley yielded 35% less (Brown 1957a).

In contrast to cereals, flax is a poor competitor, for as few as 12 wild oats/m^2 reduced yields significantly (Bowden and Friesen 1967). The reduction in yield of flaxseed, through wild oats emerging one week before the flax, was 18% greater than when they emerged one week after the crop (Bell and Nalewaja 1968c). In another instance, wild oats emerging before the crop reduced yields almost to nothing (Bowden and Friesen 1967).

DIFFERENT CROPS AND CULTIVARS

Reports on the relative abilities of spring cereals to compete with *A. fatua* all state that barley is the best competitor (Pavlychenko 1940 Molberg and Leggett 1955, Granström 1957, 1959a, Bell and Nalewaja 1967, Chancellor and Peters 1970). The other cereals do not appear to differ consistently. Two reports have indicated that wheat is much the same as cultivated oats (Brown 1955, Granström 1957). Wild oats are also equated with cultivated oats (Granström 1957). Pavlychenko (1940) found from yields of grain that wheat was a more effective competitor than rye, which was more effective than cultivated oats. On the other hand, Granström (1959a) found the order reversed.

Field beans have been found to be less effective competitors than spring barley as measured by weed growth (Lake 1971) and less effective than spring barley or wheat when measured by wild oat seed production (Chancellor and Peters 1970). Similarly, flax has been found to be less competitive than barley, wheat, oats and rye (Pavlychenko 1940) and less competitive than barley and wheat (Bell and Nalewaja 1967).

Differences between cultivars of cereals have been sought and found among cultivars of spring barley in one instance (Selman 1970a), but not in another (Chancellor and Peters 1970). Six cultivars of winter wheat varied in their competitiveness with cultivated oats, but the differences were of doubtful significance (Holmes and Pfeiffer 1962).

Winter cereals are more competitive with spring-germinating *A. fatua* than spring cereals. Winter wheat and rye are similar in their competitive ability, but are more competitive than winter barley. However, the density of the crop in the spring is more important than the species of cereal (Thurston 1962c). In contrast, winter barley was a more effective competitor with *A. ludoviciana* than wheat or rye in a pot experiment (Thurston 1956b). Winter rye has been found to be more competitive than winter wheat (Åberg and Wiberg 1957).

CROP DENSITY AND ROW WIDTH

Increasing the density of a crop is considered to be a useful way of suppressing wild oats (Godel 1938–9, Granström 1957). Thurston (1962c) has stated that *A. fatua* is best controlled by a dense autumn crop, the density being more important than the crop grown. Granström (1959a) has stated that wild oats are strongly retarded by cereals planted at more than 400 plants/m^2. In terms of sowing rate, it was reported that barley at 188 kg seed/ha greatly suppressed the number of wild oats as compared to 94 kg/ha (McCurdy 1955). Barley sown at 47 kg/ha gave a 35% reduction in the number of oat shoots, while sown at 94 kg/ha it gave a 46% oat shoot reduction, 188 kg/ha gave a 56% reduction and 376 kg/ha gave a 63% reduction of oat shoots as compared with oats (cultivated) grown alone. Furthermore, there was no interaction between nitrogen level and seed rate up to a maximum of 90 kg/ha of nitrogen (Pfeiffer and Holmes 1961). Increasing the seed rate of barley from 94 to 188 kg/ha reduced the number of seeds per head of wild oats by 52% (Bate *et al* 1970). Increasing the seed rate of barley from 94 to 188 kg/ha reduced the number of wild oats by 11% and increasing the seed rate of wheat from 78 to 156 kg/ha reduced the wild oats by 12% (Molberg and Leggett 1955b).

In Australia, low seed rates of wheat have contributed to a rapid build-up of wild oats. It was found that if the seed rate is reduced from 44 to 22 kg/ha the amount of seed produced by the wild oats is doubled (McNamara 1972). Increasing the seed rate of wheat from 180 to 250 kg/ha reduced the wild oats and increased crop yield (Catizone and Toderi 1974). Increasing the seed rate of wheat from 70 to 140 kg/ha, of barley from 63 to 126 kg/ha and oats from 47 to 94 kg/ha gave decreases in wild oats and an overall increase of 8% in yield (Tingey 1965). Peas at 200 plants/m^2 were able to check wild oats by lodging, but flax even at 1200 plants/m^2 was unable to compete (Granström 1959a).

The width between crop rows does not appear to have any great influence on wild oat infestations. Rows of wheat sown at 12 or 21 cm spacing did not differ in their effect upon wild oats (Catizone and Toderi 1974) and barley in 6 and 22 cm row spacings also showed no difference in effect (Hoepfner 1969). In winter wheat at 15 and 41 cm spacing, there were 20-25% fewer wild oats at harvest in the wider spacing. This was probably due to early cultivations between the wide rows and to the greater inter-specific competition within the rows, for as the seed rate had been kept constant, there were more plants per metre of row. However the wide rows yielded 20% less than the narrow rows, although the wide rows had fewer wild oats in them (Tingey 1965). In spring barley, 10 cm rows had 24% less wild oat seed produced both within and between the rows than 20 cm rows (Bate *et al* 1970). In another instance, there were fewer wild oat plants in barley in 12 cm row spacing than in an 18 cm one (Selman 1970a).

WILD OAT DENSITY

Wild oat density is undoubtedly important because it affects overall plant density, which in turn affects the time of onset of competition (Harper 1961) and its intensity. However, the competition offered is influenced by other variables, such as the relative times of emergence of crop and weed, crop density, fertiliser levels etc., and wild oat density is not necessarily the most important factor involved in determining crop yield losses. Similar wild oat densities do not always give similar crop yield reductions in different areas of the world, and it is therefore difficult to find a constant relationship between wild oat density and crop yield reduction. However, in general, the greater the weed density the greater the crop yield reduction. Wild oats have been shown to be relatively insensitive to intra-specific density stress (Haizel and Harper 1973).

In wheat, low densities of wild oats can cause yield reductions. Four plants/m^2 reduced yields by 3% (Selman 1969, McNamara 1972), 11 plants/m^2 by 140 kg/ha (Cuthbertson 1967) and 12 plants/m^2 have given significant yield reductions in summer fallow and stubbleland (Bowden and Friesen 1967). At intermediate densities of wild oats (up to 100/m^2) rather larger reductions have been recorded. In Canada, in summer fallow receiving fertiliser (56 kg/ha of 11-48-0) the mean yield reduction in wheat yields over 3 years was 16% from 48 wild oats/m^2 and without fertiliser 23%. On the other hand, the same density of wild oats on stubbleland with fertiliser

(112 kg/ha of 16-20-0) gave a mean yield reduction over two years of 31%; but without fertiliser there was no significant reduction and even at 84 plants/m^2 the reduction was significant in only one of the two years (Bowden and Friesen 1967). In eastern England, the average yield reduction of wheat from 40 wild oats/m^2 was about 40% (Selman 1969). In America, 84 wild oats/m^2 have reduced yields by 22% (Bell and Nalewaja 1968b).

At higher densities in wheat (above 100 plants/m^2) reductions due to wild oats are not much higher. In an Australian wheat crop yielding about 2800 kg/ha, 120 wild oats/m^2 reduced the yield by 30% and 240/m^2 reduced it by 45%. In a crop yielding 1950 kg/ha, the reductions by these densities were 14% and 29% and in a crop yielding 1100 kg/ha, 6% and 19% respectively (Paterson 1969). In England, a mean density of 157 stems/m^2 (at harvest) reduced the yield of wheat by 33% (Chancellor and Peters 1974), and in America 192 plants/m^2 caused a 39% loss of yield (Bell and Nalewaja 1968b). Above 480 plants/m^2 it is thought that further yield reductions are unlikely (Paterson 1969), although this may only relate to Australian conditions.

Barley appears to be similar to wheat in the levels of yield reduction imposed by wild oats, despite the fact that barley is generally considered to be a better competitor with them than wheat (see p. 106). Low densities of wild oats have given equivalent yield reductions in barley to those occurring in wheat. Four wild oat plants/m^2 have given an average of about 3% reduction in yield (Selman 1969) and 15 plants/m^2 (at harvest) gave 15% reduction in one year, but in the following year it required 74 wild oat plants/m^2, that is 5 times the density, to achieve the same reduction (Hoepfner 1969). At intermediate wild oat densities, 48 plants/m^2 have reduced yields by 17% (De Gournay 1964) and by 40% (Selman 1969), while 84 plants/m^2 have reduced yields by only 7% (Bell and Nalewaja 1968b). At higher wild oat densities, 175/m^2 caused a loss of 1882 kg/ha (Selman 1970), 192/m^2 a reduction of 26% (Bell and Nalewaja 1968b) 218 stems/m^2 (at harvest) caused a loss of 26% and 306/m^2 a loss of 32% (Chancellor and Peters 1974). Chancellor and Peters also found that there were no significant yield reductions at less than 150 stems of wild oats/m^2 (at harvest).

Flax is much less competitive with wild oats than cereals. Bowden and Friesen (1967) found on summerfallow land that 48 wild oat plants/m^2 caused over three years a mean yield loss of 41% and 12/m^2 caused significant yield reductions in two of the three years. On stubble land over 2 years both 12 and 48 plants/m^2 caused significant yield reductions of 32% and 60% respectively. The highest density of 228 wild oats/m^2 caused a mean yield reduction of 70% on summerfallow and 77% on stubbleland. Bell and Nalewaja (1968a) investigated the same wild oat densities in three out of five experiments and included two levels of fertility. When fertiliser was applied, 12 wild oats/m^2 reduced yields on average by 23% and 48/m^2 reduced them by 57%. Without fertiliser, 12/m^2 reduced yields on average by 24% and 48/m^2 by 53%. At the highest wild oat density of 192/m^2 yields were reduced by 86% when fertiliser was applied and by 83% without fertiliser.

The effect of wild oats on peas is similar to that on flax, 10 plants/m^2

caused a 31% yield reduction and 79/m^2 a 67% reduction (Gargouri and Seeley 1972a).

FERTILISER

Ever since Blackman and Templeman (1938) showed that crop losses from dicotyledonous weeds could be offset by fertiliser, competition studies have frequently included fertiliser levels as a factor.

In barley, research in the 1950s in Canada showed that wild oats could be reduced by heavy seed rates and that the use of fertiliser enhanced the effect. In one instance, a combination of early drilling, a heavy seed rate and fertiliser gave a 65% reduction in the number of wild oat stems (Sexsmith 1955). In another, there was a progressive decrease of wild oats when fertiliser was used with an increased seed rate. At 94 kg seed/ha without fertiliser the wild oat density was 58/m^2 and at 188 kg seed/ha the density was 31/m^2. With the addition of 56 kg/ha of 11-48-0 fertiliser to the lower seed rate, the wild oat density was reduced to 28/m^2 and applied to the higher seed rate it was reduced to 22/m^2 (McCurdy 1958). On the other hand, the same fertiliser application to barley resulted in a 16% increase in wild oats (Molberg and Leggett 1955). In Sweden, the addition of nitrogen improved the competitive ability of barley against wild oats (Granström 1957). Besides these reports of changes in the relative competitiveness of crop and weed through the use of fertiliser, there are others reporting that fertiliser did not alter the competitive balance between barley and wild oats (Thurston 1956a, 1959, Brown 1957b, Bell and Nalewaja 1966, 1967, 1968b, McBeath *et al* 1970) or between barley and cultivated oats (Pfeiffer and Holmes 1961) or between barley and *A. ludoviciana* (Thurston 1959a).

In pot experiments, the deleterious effects of wild oats on barley were partly overcome at high nutrient levels when the wild oats were removed at the onset of tillering, but not at low ones (Koch 1967).

Wheat, which is generally considered to be a weaker competitor than barley (p. 106), appears similar to barley in the effects of fertiliser on its competitive ability with wild oats. In Canada, two instances showed a reduction of wild oats as a result of adding fertiliser. In the first, the addition of 56 kg/ha of 11-48-0 fertiliser reduced the density of wild oat stems by 75% (Sexsmith 1955) and, in the other instance, the same fertiliser application reduced the wild oats by 28% (Molberg and Leggett 1955). There is one report that fertiliser had a similar effect on crop and wild oats (both *A. fatua* and *A. ludoviciana*) (Thurston 1959a). Finally, there are three reports of fertiliser favouring wild oats in wheat (Granström 1959, Bell and Nalewaja 1967, Catizone and Toderi 1974); in the last the crop yield was increasingly reduced by increasing the nitrogenous fertiliser. Flax is a poor competitor with wild oats and the addition of fertiliser appeared to benefit the weed alone (Granström 1959, Bell and Nalewaja 1967). Peas were similar (Granström 1957, Gargouri and Seeley 1972b).

Wild oats have taken up the same amount of nitrogen from the soil as winter oats (Thurston 1959a) to twice as much (Bowden 1971a). They have taken up as much nitrogen as winter wheat (Thurston 1959) to rather less than wheat from nutrient solutions (Koch and Köcher 1968) and they have taken up rather less nitrogen than barley (Koch and Köcher 1968), the same amount as barley (Sinyagin 1966) to rather more than barley (Thurston 1959a). The nitrogen content of nutrient solutions has affected the root/shoot ratio of *A. fatua* (Koch and Köcher 1968).

Wild oats, compared with cultivated oats, utilise twice as much phosphorus (as P_2O_5) (Bowden 1971g); but rather less than winter wheat and barley (Koch and Köcher 1968) or utilise little at all (Sinyagin 1966). Phosphorus had no effect on growth or seed production of wild oats (Sexsmith and Russell 1963). Wild oats have assimilated less potassium than barley (Sinyagin 1966) and have responded like cultivated oats to manganese deficiency (Thurston 1951). Applications of nitrogenous fertiliser have resulted in increased germination of *A. ludoviciana* (Watkins 1971) (see also Chapter 3, p. 79).

OTHER FACTORS IN COMPETITION

Soil moisture can be an important factor in competition. This is especially so in dry farming conditions in Canada when competition can be intensified by limited moisture (Pavlychenko and Harrington 1935-6). In Australia too, soil moisture is quite frequently a limiting factor and loss of yield and reduced quality often occurs as a result of competition for moisture (McNamara 1972). In Utah, various irrigation treatments on spring cereals had no effect on the number of wild oats present in the crop and in only one experiment were yields of spring oats found to be directly proportional to the level of irrigation received (Tingey 1965).

Light too can be an important factor in competition. Studies have been made on the structure of leaf canopies of pure and mixed stands of barley, *Sinapis alba* and *A. fatua* grown in pots (Haizel 1972a). He found that differences between species in the time of maturation had a marked effect upon the canopies of mixed stands. In addition, none of the various mixtures yielded more (in weight of above ground parts) than the highest yielding species in pure stand (Haizel 1972b). In low-growing crops such as flax, competition for light with *A. fatua* can be very important (Bowden 1971).

Soil pH can also be a factor of importance in competition between wild oats and barley, for *A. fatua* is more tolerant of acidity and grows better than barley on acid soils (Thurston 1962c).

Roots and their growth are frequently unknown factors in competition, but studies by Pavlychenko (1937, 1940 etc) in Canada have shown that wild oats and cereals differ considerably in root development. He found that wild oats had three or fewer seminal roots, while cultivated oats had three or four, wheat four or five, rye five or six and barley six to thirteen. Wild oats can possibly be suppressed by a cereal at an early stage; but not later on, for wild oats produce crown roots prolifically.

The small number of seminal roots is reflected in the development of seedlings. Koch and Rademacher (1966) found that, in each of two years, wild oats emerged shortly before the barley crop, but were subsequently slower in development. It was not until after tillering, when the crown roots were presumably well-grown , that their rates of development became equalised. This catching-up can also be attributed to their higher (than cereals) net assimilation rate, although this disparity did not persist (Thurston 1959a).

Reports have been made of allelopathic interactions between wild oats and other plants, especially rye. Osvald (1950) found references in old Swedish literature to rye killing wild oats, but his tests were negative apart from a 10% reduction in germination. However, exudates from red fescue lowered *A. fatua* germination by 10-20% and strongly retarded the subsequent growth of those that did germinate. Börner (1960) grew wild oats and rye in flasks of nutrient solution interconnected by tubing and found that circulating the solution resulted in *A. fatua* increasing in weight by 6% and rye decreasing by 5%. Thurston (1962b) found no inhibitory effect on wild oats from rye. Tinnin and Muller (1971) reported that dead stems of *A. fatua* on the soil surface affected the germination of associated annual plants.