CHANGES IN THE WEED FLORA ON BROADBALK PERMANENT WHEAT FIELD DURING THE PERIOD 1930-55

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(*With one Figure in the Text*)

Introduction

Weeds have always been a serious problem on Broadbalk permanent wheat field at Rothamsted, as continuous autumn sowing allows no adequate interval for cleaning between successive crops. Partial fallowing of the field has been resorted to on more than one occasion, the most comprehensive scheme being carried out from 1926-29. The field was then divided into five transverse sections (the manurial treatments running lengthways), two of which were fallowed during the seasons 1926 and 1927, two during 1928 and 1929, while the fifth section was left uncropped for the whole four-year period. In 1931, a five-year cycle was started in which each of the five sections was fallowed in turn for a single season. Four of these cycles have been completed and it is now possible to assess the value of this procedure in controlling the weeds. The effect of the 1926-29 fallowing scheme and the first two of the five-year cycles on a limited number of plots have already been discussed (Brenchley & Warington 1930, 1933, 1936 and 1945). The present paper describes the results from the same plots after a further five-year cycle and also reviews the changes in the weed flora that have taken place over the whole field from 1930-55, based on visual rating. Earlier changes have been described by Warington (1924). A plan of the field with manurial and cultural treatments is given in Fig. 1.

The system of nomenclature used is that of Clapham, Tutin & Warburg (1952). In the earlier publications the classification followed was that of Bentham & Hooker, *British Flora*, 1912.

The changes involved are as follows:

Clapham, Tutin & Warburg	*Bentham & Hooker*
Alopercurus myosuroides	Alopecurus agrestis
Aphanes arvensis	Alchemilla arvensis
Arrhenatherum elatius	Arrhenatherum avenaceum
Chaenorrhinum minus	Linaria minor
Knautia arvensis	Scabiosa arvensis
Odontites verna	Bartsia odontites
Specularia hybrida	Legousia hybrida
Taraxacum officinale	Taraxacum dens-leonis
Torilis arvensis	Caucalis arvensis
Valerianella locusta	Valerianella olitoria
Veronica hederifolia	Veronica hederaefolia
Veronica persica	Veronica buxbaumii

Germination studies

Methods

Four replicate soil samples, each consisting of three borings 3 in. × 4 in. × 6 in. deep (7·5 × 10 × 15 cm.), were taken immediately after harvest before the stubble

was ploughed, from both cropped and fallowed sections of a number of differently manured plots. From 1925-30 seven plots had been sampled, but it was only possible to continue with three of these in the next ten years or in 1945. The same three plots have been sampled again in 1955 and two additional plots (5 and 9) included, the latter being selected on account of their high content of *Vicia sativa*

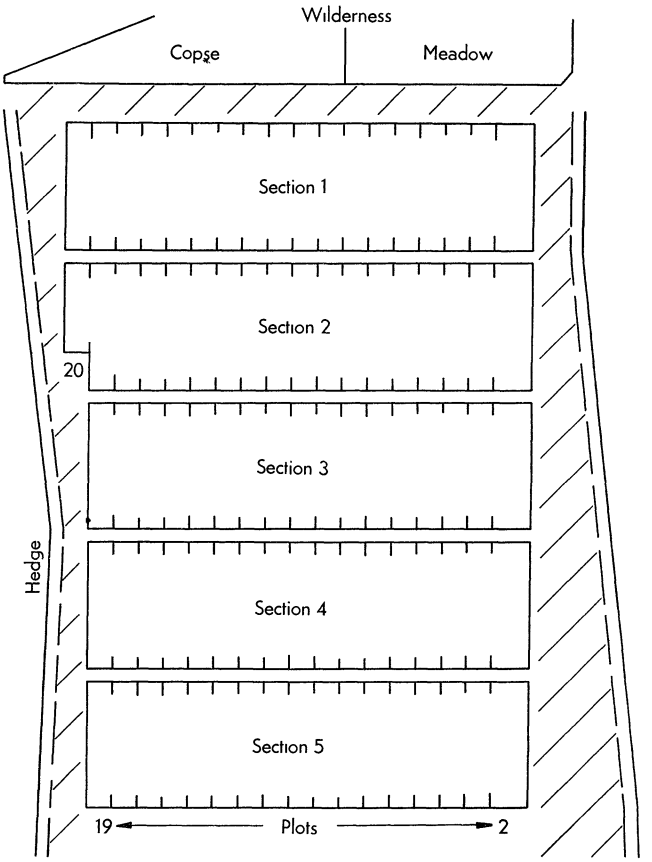

Fig. 1. Fallow. Sections 1, 2 and 3 in 1926 and 1927. Sections 3, 4 and 5 in 1928 and 1929. All sections cropped in 1930. Order of fallow cycle started in 1931: Section 1, 2, 5, 4, 3, 1, 2. . . .

Plot		Manurial Treatment	
2		Farmyard manure	
3		Unmanured	
5		P, K, Na, Mg	—
6		P, K, Na, Mg	N_1 }
7		P, K, Na, Mg	N_2 } as $(NH_4)_2SO_4$
8		P, K, Na, Mg	N_3 }
9		P, K, Na, Mg	N_1 as $NaNO_3$
10		— — — —	N_2 }
11		P — — —	N_2 }
12		P — Na —	N_2 } as $(NH_4)_2SO_4$
13		P, K, — —	N_2 }
14		P — — Mg	N_2 }
15		P, K, Na, Mg	N_2 (autumn) }
16		P, K, Na, Mg	N_2 as $NaNO_3$
17	alternate years	P, K, Na, Mg	—
18		— — — —	N_2 as $(NH_4)_2SO_4$
19		Rape cake or castor meal	
20		— K, Na, Mg	N_2 as $(NH_4)_2SO_4$

N_1, N_3, N_3 denote level of nitrogen. N_1 = 2 cwt. $(NH_4)_2SO_4$ per acre. (251 kg./ha.).

and *Ranunculus arvensis* respectively, weeds for which further information is desired. Data from these last samples are not yet available. The plots comprise those receiving complete and deficient fertilizers, and in consequence show different types of weed association. The soil after being reduced in bulk by washing on sieves (Brenchley & Warington 1930) was set out in shallow pans and kept watered in a glasshouse for three years. All seeds that germinated were identified, counted and removed at six weekly intervals and the soil then thoroughly cultivated. Any periodicity in germination could thus be detected and, though seeds of different ages were necessarily present, information was obtained regarding the length of dormancy of the different species. Only annual species could be studied by this method.

Results

Both the intensive fallow of 1926-29 and the first two five-year fallow cycles had successfully reduced the total weed seed population compared with that present in

Table 1. *Broadbalk wheat field. Weed seeds germinating per* 15 *sq. ft.* (1·4 *sq. m.*) (*depth* 6 *in.*) (15 *cm.*). *Plots* 2, 7 *and* 18 *taken together*

	Years Sampled			
	1930	1931-35	1936-40	1945
Name of Weed		Mean	Mean	
Group I. Decreased				
Capsella bursa-pastoris	660	321	250	164
Myosotis arvensis	620	300	296	145
Papaver rhoeas	16 245	9069	4358	4247
Veronica arvensis	7170	2917	1474	702
Group II. Increased				
Medicago lupulina	199	719	1081	1588
Specularia hybrida	694	513	1088	2308
Group III. Little change				
Alopecurus myosuroides	5354	7071	8380	6951
Aphanes arvensis	9303	8549	6898	5076
Arenaria serpyllifolia*	1114	485	446	595
Stellaria media	673	719	1243	218
Veronica hederifolia	543	680	605	759
Total (including species with less than 500 germinations)	44 125	32 103	26 770	23 593

* Included in this group as figure for 1925 (viz. 297) was so much below that for 1930 and most species have continued the trend shown from 1925.

1925 (Brenchley & Warington 1945; Table 12). As interest in the present paper now centres on the effect of continuing these cycles, 1930 instead of 1925 is taken as the basis for comparison, for this was the first year the whole field was back under crop after the initial 4-year scheme. In order to reduce the effect of seasonal fluctuations, the mean germinations from each 5-year cycle (1931-35; 1936-40) have been taken instead of the figure for each successive fifth year.* Since 1935 was an exceptionally wet and weedy season, whereas 1940 was dry and clean, this method of presentation probably gives the truer picture. It also eliminates the variation between sections, for from the nature of the scheme the same section was without crop every fifth year. Taking all species together there has been a steady decrease in viable weed seeds, the numbers germinating in 1945 being only 53 per cent of those in 1930. The individual species, however, vary in their response to fallow and fall into three main groups showing (1) decrease; (2) increase or (3) little or fluctuating changes. Most of them continue the trend they exhibited previously.

* No mean is available for the 1941-45 period as samples were not taken annually after 1940.

Group 1. *Decreased*

Papaver rhoeas is still the most important weed in this group. Owing to its long dormancy, reduction has been slow, and there are still enough viable seeds present for it to remain a potential danger, as field observations confirm. *Veronica arvensis* and *Capsella bursa-pastoris* (both previously allotted to Group 3) have also shown a reduction since 1930, while *Polygonum aviculare*, at one time an important weed, has failed to return in any quantity. Other species that have maintained their reduction or have been still further reduced are *Aethusa cynapium*, *Atriplex patula*, *Euphorbia exigua*, *Galium aparine*, *Myosotis arvensis*, *Senecio vulgaris*, *Torilis arvensis* and *Veronica persica*.

Group 2. *Increased*

Medicago lupulina is the only species that has shown a large and consistent increase since 1930. It occurs chiefly on the nitrogen deficient plots, only one of which (18) was sampled. Though the figures are thus derived from a limited area, the increase is fully corroborated by field observations on this and other plots short of nitrogen. *Specularia hybrida*, previously placed in Group 3, should also come into this group, for despite fluctuations its numbers have increased nearly $3\frac{1}{2}$ times during the period under review, and it is noticeably more prevalent on the field than formerly.

Group 3. *Little changed or fluctuating*

Alopecurus myosuroides, one of the most serious weeds, continues to behave as before. It is quickly reduced by a year's fallow, but up to 1945 has shown little change in quantity at the end of each five-year cycle as it readily re-establishes itself under crop. *Aphanes arvensis*, *Veronica hederifolia* and *Odontites verna*, on the other hand, have maintained a level position without being much affected by fallow. The figures for *Aphanes arvensis* are amazingly high, though such a small species probably offers little competition to the crop. *Stellaria media* and *Arenaria serpyllifolia* both show wide fluctuations but seasonal conditions are probably the chief factor in determining their prevalence, for they increased between 1925 and 1930 when fallowing was intensive. *Stellaria media* germinations, for instance, reached a maximum in 1935, a wet year, but fell sharply in 1940 which had a dry summer. The germination figures for *Matricaria inodora* are too small for any definite conclusions to be drawn, and though the evidence available up to 1945 indicates that there has been little change in its frequency (116 in 1945 compared with 130 in 1930 per 15 sq. ft. [1·4 sq. m.]), more recent observations on the field suggest that this species may have to be transferred to Group 2. Data regarding *Avena* spp. are also indefinite, as only in one year were an appreciable number of germinations recorded, but the behaviour of this weed is more fully discussed under the Field Records section.

Field records

Methods

Visual ratings of the prevalence of both annual and perennial weeds growing on all plots were made at least twice each season from 1930-55. This data thus continues for ten years longer than that from the soil samples. No attempt was made

to estimate small differences in weed population and three categories only were recognized:

(1) Plentiful, up to infestation status.
(2) Present, distributed or in patches.
(3) Occasional.

A rating intermediate between (1) and (2) was sometimes necessary if a normally unimportant species such as *Lithospermum arvense* occurred more frequently than usual, in case this might be the first indication of its becoming troublesome. For all the major species conclusions are based on changes in the first and intermediate categories only. Error due to differences in the rating standards used on different occasions or by different individuals is thus at a minimum, for no difficulty is experienced in assigning a species to the 'plentiful' group.

By summing the occasions on which the plentiful rating was reached on the different sections, an estimate of the distribution of a given species and the effect of fallow upon it could be obtained. The method, however, had its limitations, as the number of records made each year was not always the same, and undue emphasis might be given to a weed if an extra record was taken in a year when it was already prevalent. Further, the method was only applicable to the most important weeds. In spite of this, it seems that the results give a very fair estimate of the principle changes in weed flora over the long period under review.

Results. (*a*) *Annuals*

In 1930, when the whole field was under crop for the first time since 1925, differences in weed distribution due to the previous fallows were still manifest. Sections 1 and 2 which had already been back under crop for two years, were once more heavily infested with *Alopecurus myosuroides*, though *Papaver rhoeas*, which had previously been equally prevalent, was not an important weed. On the three other sections there was much less *Alopecurus myosuroides* than at the top of the field but about the same amount of *Papaver rhoeas*. As these local differences gradually evened out, it became easier to assess the effect of the fallow once in five years on both these and other species, such as *Matricaria inodora*, *Ranunculus arvensis*, *Vicia sativa* and *Avena* spp., all of which have reached infestation level after 1930. In many instances, however, seasonal and cultural conditions, and in a few cases manurial treatment or position in the field, have proved more important than fallow in determining the prevalence of a given weed, while in others the reason for their fluctuations remains obscure. As in the germination experiments the weeds fall into three main groups according to their behaviour.

Group 1. *Decreased*

Papaver rhoeas

For many years after the intensive fallow *Papaver rhoeas* was a relatively unimportant weed, though judging from the numerous seedlings visible each spring it has remained a potential colonizer. In 1936, 1950 and 1953 it reappeared in considerable quantity taking advantage of a patchy crop attacked by wheat bulb fly. Adequate competition would thus seem to be a vital factor in preventing the establishment of this weed. On the first two occasions the return was temporary, but since 1953 *Papaver rhoeas* has reached a plentiful rating on a number

of plots, particularly on section 5. It remains to be seen whether this is the start of a permanent re-infestation.

Scandix pecten-veneris

This weed has clearly decreased in importance particularly since 1937, though little immediate effect of fallow on it is evident. Occurrence in any quantity is local and though temporarily plentiful on sections 4 and 5 (1942-44), it is principally found at the top of the field on sections 1 and 2. *Scandix pecten-veneris* is apparently influenced by climatic and cultural conditions, and was unusually prevalent in 1935 and 1937, both wet summers with no spring cultivations, and also in the wet seasons of 1946 and 1950. It was scarce in 1947, however, when rainfall was equally high and spring cultivation was again missed.

Torilis arvensis

Torilis arvensis occurs in quantity on a few plots only. Reduction has been slow, probably on account of the long dormancy of its seed, but it is certainly less prominent than formerly, especially since 1937. The section following fallow is usually freer of the weed than the others, but seasonal conditions seem the chief factor determining its prevalence.

Galium aparine and *G. tricorne*

Galium aparine has only been plentiful with any regularity on section 5 of the plot receiving minerals and triple nitrogen as sulphate of ammonia (8), while *G. tricorne*, though widely distributed, has rarely reached the plentiful rating and never on this plot. There seems little doubt that both species now occur less frequently than before fallowing was introduced, though the immediate effect of fallow is not obvious.

Polygonum aviculare

Though generally much less important than formerly, it is doubtful whether the reduction in this weed is due to fallow or even permanent, for its appearance is erratic and the seed has a long dormancy. After several seasons of comparative unimportance, including 1935, a generally weedy year, it was very prevalent in 1936 and to a less extent in 1938, though negligible in the intervening year. It germinates almost entirely in the spring and its behaviour is probably much influenced by cultivation operations at that time of year. The evidence, however, is not altogether consistent. In 1936 additional, and in 1938 normal cultivations were carried out, whereas in 1945 and 1947 also years when *Polygonum aviculare* was plentiful, there was no spring cultivation at all, while a lack of cultivation in 1937 was associated with a drop and not an increase in the weed. There is some indication of an increase in *Polygonum aviculare* on the section following fallow in contrast to the results from the germination experiments. This might be due to the tilth being more favourable for germination or to a reduction in crop competition, the latter factor being particularly likely in 1936 when wheat bulb fly attacked the crop. *Veronica arvensis, V. persica, Myosotis arvensis* and *Capsella bursa-pastoris*, though unimportant species also appear to be on the decrease.

Group 2. Increased

Matricaria inodora

From 1930-46 *Matricaria inodora* was of little importance except on one plot on the outside of the field (19), though it was temporarily noticeable on three other plots (2, 15 and 18) in 1937. Ten years later, it suddenly became an outstanding weed on every plot, particularly on sections 4 and 5. Contributory factors to this infestation were probably the omission of a spring cultivation and the heavy rainfall between March and July of that year. For the next two years it returned to its former unimportant position, being chiefly confined to sections 4 and 5 of the original plot (19). Spring cultivations had been carried out in both these seasons and there was considerably less rainfall during the summer than in 1947. In 1950, however, it reappeared in force, this time particularly associated with the section fallowed the previous year, where wheat bulb fly had caused a patchy crop. Since then it has remained an important weed on many plots (especially 11-15) particularly at the bottom of the field on sections 4 and 5. Increasing soil acidity may have encouraged its establishment this time, as the weed is particularly prevalent on that portion of section 5 which did not receive a dressing of lime in 1954, and it is known to be an acid-loving species (Mann 1939). Reduction in competition with other weeds may also partly account for this local dominance, as *Papaver rhoeas* is less prevalent here than on the limed portion. That *Matricaria inodora* is shy of competition is evident from its tendency to concentrate on the outside of the plots or on bare patches.

Vicia sativa

As would be expected this species flourishes chiefly on nitrogen deficient plots. It first appeared in any quantity in 1932 on section 5 of the plot receiving minerals only (5), though prior to 1930 it had also been plentiful on section 1 of this plot. After some spread during 1933 and 1934, it increased enormously in 1935 and 1937, the infestation being slightly less serious in the intervening year. The omission of spring cultivation and the high rainfall in both these years may have encouraged the weed, though in 1936 when cultivation was particularly thorough, *Vicia sativa* was already important even before wet weather set in. The dry year of 1938, however, brought about a marked decrease in the weed and it remained restricted again in any quantity to a single plot (5) till 1945. The next large increase occurred in 1948 for no apparent reason, and infestation level was once more reached on a number of plots in 1955.* Though the intensive fallow of 1926-29 had reduced the weed, a single year's fallow is clearly useless as a means of control. Climatic and possibly cultural conditions appear to be the chief factors determining its prevalence and given a few dry years, *Vicia sativa* might well return to its former unimportant position.

Avena ludoviciana and *A. fatua*

Avena was a troublesome weed over much of the field prior to the intensive fallow of 1926-29 and hand-pulling had been used to eradicate it from 1921-24. By 1931 it had re-established itself on an outside plot (20) and by the end of the first five-year cycle (1935) was also important on plots on the other side and in the

* A dry summer, but heavy rainfall occurred in May.

centre of the field (2 and 10). A temporary drop in the density of the weed occurred in 1940 and 1941, though it continued to spread. Hand-pulling was started again in 1943 and carried out annually till 1955 when eradication was almost complete, though about 8 years elapsed before any appreciable reduction in the weed was obtained. Since 1944, Thurston (1951) has made a special study of the occurrence of *Avena* spp. on Broadbalk, and has shown *A. ludoviciana* to be the dominant and *A. fatua* the less frequent species. She found (Thurston 1953) that the seeds of both species have a long dormancy, which would account for the lack of success with a short fallow as a means of control.

Medicago lupulina

This weed is prolific on the nitrogen deficient plots, but in some seasons may also become important in the presence of complete manures, though never on the plot where a triple sulphate of ammonia dressing is given (8). Even one year's omission of nitrogen encourages it, as can be seen on the pair of plots which receive minerals and nitrogen in alternate years. Fallow reduces the weed, but the level of infestation is so high that one fallow in five years cannot control it. Quantity appears to be largely determined by season, though the fluctuations are not always predictable. For instance, there was a marked reduction in the weed in 1938 and 1943, but it was very prevalent in 1934, another dry summer. The seed can have a long dormancy, but given wet conditions it may germinate freely on the stubble or even before shedding. Autumn cultivation would then offer an excellent opportunity of getting rid of the weed.

Ranunculus arvensis

Neither in 1930, nor for at least ten years previously, had this been an important weed and its spread since fallowing was introduced shows it cannot be controlled by this means. Infestation started in 1932 on section 1 of an outside plot (20). From here it spread in 1937 to plots in the centre and the other side of the field including the lower sections 4 and 5. After becoming restricted again in any quantity to a central and outside plot (9 and 20), a further spread began in 1942 and a high degree of infestation was reached over most of the field by 1947, and with the exception of 1948, this position has been maintained up to the present (1956). The years of spread are notable for the omission of spring cultivations and wet summers, but there have been years with equally high rainfall (1951) when *Ranunculus arvensis* was less prolific, and dry springs (1950) when the amount of this weed was considerable. The only plots on which *Ranunculus arvensis* has never reached the plentiful rating are the unmanured (3), minerals only (5), and nitrogen applied in the autumn (15).

Specularia hybrida

Specularia hybrida is an insignificant weed which has increased since 1930 and particularly since 1946, indicating its independence of fallowing operations. Fluctuations in the quantity recorded are probably influenced by the time of year the rating is made, for the plant is only readily seen during its short flowering period. The large numbers of *Specularia hybrida* seedlings germinating from the soil samples, however, corroborate both its numerical importance and its tendency to increase.

Group 3. *Fluctuating or Unchanged*

Alopecurus myosuroides

Field observations entirely confirm the results of the germination experiments. *Alopecurus myosuroides* is strikingly reduced by a single year's fallow though it returns rapidly when the land is put back under crop. This accounts for the changes in position of the worst infested sections. Success with fallow as a control measure depends largely on the short dormancy of the seed, but the increased competition offered by the improved crop the following year probably also plays a part. That the competition factor alone does not determine the prevalence of the weed, however, is shown on the nitrogen starved plots where both weed and crop are equally sparse.

Aphanes arvensis

Aphanes arvensis is a widespread but insignificant weed, which probably offers little competition to the crop, yet has reached the plentiful rating on several occasions, chiefly on a plot where nitrogen is at a low level and competition light (6). Germination results from the soil samples confirm the numerical importance of this species. As the weed was plentiful directly after the intensive fallow of 1926-29, it is not surprising that a fallow every fifth year fails to reduce it. The long dormancy of the seed and the rapidity with which the plant reaches the seed-forming stage probably account for its persistence. Seasonal and cultural conditions affect it to some extent, for it was particularly plentiful in 1935, 1937 and 1946, the first two of which had no spring cultivation and all of which were wet.

Arenaria serpyllifolia

This inconspicuous weed is very seasonal, but it may occur in considerable quantity. It is chiefly to be found in the centre of the field on plots 9-14.

Lithospermum arvense

Like *Ranunculus arvensis*, *Lithospermum arvense* has only become a prominent weed since 1930, but unlike it, is now of little significance. The reasons for its appearance and disappearance are obscure, but they are clearly independent of fallowing operations. At first *Lithospermum arvense* occurred in localized patches, but from 1937-43 it increased rapidly in both quantity and distribution. Though temporarily less prevalent in 1945, it continued to be an important weed till 1952, since when it has failed to reach the plentiful rating anywhere.

Stellaria media

The amount of *Stellaria media* varies widely from year to year. It was plentiful in 1930 and thus, as expected, is not reduced by a single year's fallow in spite of the short dormancy of its seed. 1937, 1939 and 1942 were particularly favourable years for it, and although it is usually associated with wet seasons, this is not always the case. *Stellaria media* is chiefly found on the plots receiving minerals and adequate nitrogen (7 and 8).

Odontites verna

Like *Polygonum aviculare*, *Odontites verna* is one of the few species germinating almost entirely in the spring, and cultivation at this time of year seems to be the

chief factor determining its prevalence. Its appearance in any quantity is erratic and fallow is of little importance in its control as might be expected from its rise in importance since 1930.

At first *Odontites verna* was largely restricted to plots on the outskirts of the field, but a marked increase in quantity and distribution occurred in 1932. No further increase took place till 1937 when it became prolific on a number of plots. The unusually early date of the spring cultivation in 1932 and the lack of any cultivation at all in 1937 may have resulted in an exceptionally high seeding survival these years. Apart from 1939, it returned to a position of little importance till 1945 (another year without a spring cultivation) when it became abundant on three plots (3, 17 and 18). Quantities of seed were obvious on the soil surface in the late summer of that year, but the anticipated infestation did not occur until two years later when the plentiful rating was reached on almost every plot – again when spring cultivation had been omitted. Since 1947, the weed has been of local importance only. Much seed shedding was noticed in 1955, and it remains to be seen if, and when, a fresh invasion will occur. *Odontites verna* has also shown this capacity for delaying its peak germination for a year under glasshouse conditions (Brenchley & Warington 1936; and unpublished), and the seed is known to have a very long dormancy.

Veronica hederifolia

Though occurring in considerable quantity on most plots, particularly those receiving organic manure (2 and 19), this weed is short lived and offers little competition to the crop. One year's fallow does not reduce and may even increase it, possibly owing to the speed with which it can produce a fresh seed.

Grass spp.

Grasses other than *Alopecurus myosuroides* are of local importance only. They are mostly incursors from the hedge-row and species such as *Agrostis stolonifera* and *Poa trivialis* are frequently abundant at the base of plot 19. Other species that occur occasionally on this plot are *Holcus lanatus*, *Lolium perenne* and *Arrhenatherum elatius*. Of more interest is the large patch of *Poa annua* that has occurred on the lowest section of a central plot (14) since 1951, and which may well be associated with soil acidity.

Minor species of little or local importance only

A number of less important weed species occur on Broadbalk, some of which show an interesting distribution.

Lathyrus pratensis is associated with nitrogen deficiency and reaches the plentiful status on the unmanured plot (3). It is also found on the plots receiving mineral only, or minerals and nitrogen alternately (5 and 17) but appearance elsewhere is rare. Though less prevalent on the section following fallow, the weed maintains its level and presumably its seed has a long dormancy. *Knautia arvensis* and *Valerianella locusta* have a similar distribution.

Anagallis arvensis and *Chaenorrhinum minus* occur chiefly on the plot receiving sulphate of ammonia only (10), but *Euphorbia exigua*, though most frequent here, is also associated with the unmanured (3) and the group of plots (17-20) where crop competition is generally light. The distribution of *Aethusa cynapium* follows

that of *Euphorbia exigua* very closely but it occurs as well on a plot receiving complete manure (16) where competition must be high. *Atriplex patula* is also chiefly to be found on plot 10, but in this case the plots where it is next most frequent are those close to it, viz. 11 and 12.

Myosotis arvensis shows a distribution difficult to explain for it thrives on plots which include adequate and deficient manuring (2, 6, 15, 17, 18 and 19). The same applies to *Veronica arvensis* and *V. persica.*

Galeopsis tetrahit and *Heracleum spondylium* are regular intruders from the hedge row, the former species being almost entirely confined to plot 19 where it may be plentiful, and the latter, though less frequent and not restricted to any plot, occurs chiefly on section 1 near the Wilderness 'Meadow'. Other local intruders are: *Achillea millefolium, Stellaria graminea, Plantago lanceolata* and *Ranunculus ficaria. Viola arvensis* and *Cerastium vulgatum* have a wide distribution but are most frequent on the plot receiving castor-meal (19). Species of general occurrence, but showing no special association with any part of the field are: *Capsella bursa-pastoris, Senecio vulgaris, Taraxacum officinale* and *Plantago major. Polygonum convolvulus* is well distributed but tends to be most frequent on plots 14 and 16-19, while *Fumaria officinalis* and *Sinapis arvensis,* though occurring regularly, are too scarce for any manurial preference to be detectable. Species that have appeared on isolated occasions only are: *Agrostemma githago, Allium vineale, Chenopodium album, Epilobium montanum, Lamium purpureum, Lapsana communis* and *Thlaspi arvense.*

(*b*) *Perennials*

By 1930 the intensive fallow had much reduced the perennial weeds and virtually eliminated *Sonchus arvensis.* The chief species present now, in order of importance, are *Cirsium arvense, Convolvulus arvensis, Tussilago farfara* and *Equisetum arvense. Rumex* spp. are of rare occurrence only. Though distributed over most of the field, *Cirsium arvense* remained quite unimportant from 1931-39, but in 1943, 1948 and 1950 it reached the plentiful rating on several plots. It was scarce, however, in some of the intervening years, e.g. 1946, but in that year the most infested section was under fallow. Marked increases occurred again in 1953 and 1954, and by 1955 it was prolific on at least some sections of most plots. Fallow once in five years thus does not seem able to effect permanent control of the weed, though much may depend on the seasonal conditions and thoroughness of the cultivation during the fallow period. Manuring appears to play a minor part in its distribution, but the unmanured plot (3) and that receiving minerals alone (5) are noticeably free of the weed. *Convolvulus arvensis,* on the other hand, flourishes on these nitrogen deficient plots, particularly on sections 1 and 2. Seasonal fluctuations are large, dry conditions encouraging the weed. This and the lack of uniformity in distribution make the effect of a single year's fallow difficult to trace.

The distribution and degree of prevalence of *Tussilago farfara* follow that of *Convolvulus arvensis* very closely, though it is less restricted to sections 1 and 2 at the top of the field. Fluctuations in quantity are small, but it is favoured by dry seasons. *Equisetum arvense* rarely reaches the 'plentiful' rating and then chiefly on the sections 4 and 5 of plots with unbalanced manuring [nitrogen deficient (5, 15) or nitrogen alone (10)]. A one-year fallow has little affect on the prevalence of either this species or *Tussilago farfara.*

Discussion and Summary

In any attempt to assess the changes in weed flora over a number of years many factors have to be taken into account. Distribution is by no means uniform over the field and moreover may change, particularly where a sectional fallow scheme is in operation. The basis of comparison before and after fallow is thus not always the same and only by taking the average effect over a long period can such differences be eliminated. Patchiness in the stand of wheat, due to bulb fly attack or other causes, may also encourage local weed colonization which may or may not become permanent. A change in timing of the visual records from one year to another or an unusually early or late season can inadvertently alter the rating allotted to a species, for the peak period of a short lived, insignificant weed such as *Specularia hybrida* may easily be missed, and the lack of a record in early July result in the loss of a true estimate of the prevalence of *Avena* spp. In the majority of cases, however, seasonal and cultural conditions seem more important than fallow in determining the quantity of weed that occurs in any one year, both the balance between the weeds and between the weeds and crop being affected by them. A general picture of the changes that have occurred since 1930 may be summed up as follows: The reduction in annual species achieved by the intensive fallow of 1926-29 has on the whole been maintained, that of *Papaver rhoeas* being the outstanding example, though since 1953 there have been signs of the return of this weed. *Alopecurus myosuroides*, another principal weed, on the other hand, has only been temporarily checked by the once in five year fallow and has quickly re-established itself, though less noticeably so since 1953. This reduction in some species has been accompanied by a large increase in others e.g. *Ranunculus arvensis*, *Vicia sativa* and *Avena* spp., the latter having been gradually eliminated by hand pulling.

Germination results from soil samples agree remarkably well with field rating records, but comparison is limited to the species prevalent on the plots selected for sampling, which unfortunately have not so far included those with much *Ranunculus arvensis* or *Vicia sativa*. Further, no germination data are available for the period 1946-54 when considerable changes in weed flora took place.

Perennials were unimportant in 1930. Of the species then present *Sonchus arvensis* has failed to return, but *Cirsium arvense* has once more become a serious weed, chiefly since 1943. *Convolvulus arvensis* is also re-established but *Tussilago farfara* and *Equisetum* remain relatively unimportant and of local occurrence only.

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