SOME ASPECTS OF THE BIOLOGY OF TWO WEEDS, *Stellaria media* (L) Vill. and *Tripleurospermum maritimum* (L) Koch

by

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A B S T R A C T

Stellaria media and Tripleurospermum maritimum ssp. inodorum occur widely on agricultural land but appeared to be favoured by certain fertiliser treatments in a long term experiment.

Fertiliser experiments in the glasshouse have shown that Tripleurospermum is adversely affected by high K and that both species benefitted most with added P in early life and N later. Fertilisers did not entirely explain the distribution so some light measurements in the crop were taken and compared with the results of a light intensity and nitrogen experiment under controlled conditions. Tripleurospermum was found to be much more sensitive to low light intensities than Stellaria and as such would be unlikely to do well and probably not to set seed in the deep shadow of some of the denser, well-fertilised crops in the field.

Competition experiments in the glasshouse showed that Stellaria was a vigorous competitor greatly affecting wheat when grown in pots. Addition of fertilisers did not always improve the yield of wheat. Tripleurospermum was not a good competitor with wheat but under certain conditions did reduce the yield somewhat. The results agreed well with those of Mann and Barnes 1950.

Various angles of the effect of Stellaria are considered but it is suggested that the main competitive effect is that of germination in relation to fertilisers. There was some indication that fertilisers affected germination and this may be the most important control over the numbers of seedlings on the plots. Later competition for fertiliser, and for light becomes important.

A form of non-chemical control is suggested to reduce the amount of Tripleurospermum and Stellaria in badly infested crops.

CHAPTER 1

I N T R O D U C T I O N

Since the development of herbicides great strides have been made in the control of weeds in cultivated land. Some of the well-known weeds of arable crops are now seldom seen e.g. Papaver spp. but there still remains a large number of troublesome weeds. Many of the perennial weeds are still not successfully controlled and some of the annual weeds only partially so.

However, it has been realised gradually that continuous use of chemicals might produce strains of weeds which are resistant to herbicides. (Harper 1956) A further factor causing considerable consternation is the effects of herbicides and other chemicals upon other forms of life. The wholesale use of herbicides is now being called in question but the obvious benefits from efficient control of weeds (see Fig 3) mean that weed control must continue to be used. It is now becoming more necessary than ever before to study the biology of weeds in order that they may be more fully understood, and more efficient, cheaper methods of weed control, less harmful to other life forms may be found.

Two common weeds of agricultural land, Stellaria media (L) Vill. (common chickweed) and Tripleurospermum maritimum ssp. inodorum (L) Koch (scentless mayweed) are still only partially controlled. These two species are widespread and both occur in many different types of crops. Recently it has been suggested that they may, particularly Stellaria media, act as overwintering hosts for certain economically important viruses eg. CMV. (Tomlinson and Carter 1970, Tomlinson, Carter, Dale and Simpson 1970). This is an additional reason for the increased effort to control these two weeds efficiently. Partial control has been obtained with Ioxynil and mecoprop (pre-emergence) and dinoseb (post-emergence) (MAFF Advisory leaflet No. 528 1971). It is to this end that a study of the biology of these two weeds has been undertaken.

The Experimental Field (See field plan)

Broadbalk is one of the oldest experiments at Rothamsted and part of this field has been growing winter wheat continuously since 1843. (Rothamsted Report for 1968). The field is divided into 20 strips, each receiving a different fertiliser treatment. The treatments include combinations of N, P, K, Na and Mg, also farmyard manure (FYM) and castor meal. (See plan of field). These different treatments have been applied every year to the same plots and as a result they now have characteristic weed floras. Unfortunately, the layout of Broadbalk as an experiment is very unsatisfactory compared with today's methods for, among the plots, there is no replication or randomisation. Also, because it is a very old experimental field short-term treatments are not allowed, although observations on the discard areas of existing treatments are permitted.

The field is divided into ten strips called sections, at right-angles to the fertiliser treatments, and these sections are now used to test a three-course rotation of crops; potatoes, beans and winter wheat, compared with two wheat crops followed by fallow or continuous winter wheat. One continuous wheat section, no. 8, is not sprayed with any herbicide, but is reserved for biological studies including weeds. It is by comparing this section with others that the changes in the weed floras caused by differing agricultural practices may most easily be seen.

Section 8 of most plots is choked with weeds, certain plots more than others. The weed species on each plot vary too. The rest of the field is comparatively free of annual dicotyledonous weeds although this depends upon the time of year and what sort of season it has been.

Broadbalk supports 60 weed species, some occurring very abundantly and some only very rarely. Much work has already been

FIELD PLAN OF BROADBALK

Broadbalk drain

1	2a	2b	3	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
N_2	N_2				N_1	N_2	N_3	N_4	N_2	N_2	N_2	N_2	N_3	N_2	N_2	N_2	N_2		N_2
P				P	P	P	P	P		P	P	P	P	P	P	$\frac{1}{2}$P	$\frac{1}{2}$P		
K				K	K	K	K	K				K	K	K	K	$\frac{1}{2}$K	$\frac{1}{2}$K		K
				Na	Na	Na	Na	Na			Na			Na	Na	Na			Na
				Mg	Mg	Mg	Mg	Mg					Mg	Mg	Mg	Mg			Mg
FYM	FYM	FYM						*										CM	

Section				
9	CONTINUOUS WHEAT last fallowed 1958			
8	CONTINUOUS WHEAT last fallowed 1963 NO WEED KILLERS			
7	ROTATION	1968 P	1969 B	1970 W
6	ROTATION	F	W	W
5	ROTATION	W	F	W
4	ROTATION	W	P	B
3	ROTATION	W	W	F
2	ROTATION	B	W	P
1	CONTINUOUS WHEAT last fallowed 1966			
0	CONTINUOUS WHEAT last fallowed 1951			

1 2a 2b 3 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Broadbalk wilderness

N

W - wheat
P - potatoes
B - beans
F - fallow

* Plot 9 received N_1P,K,NaMg until 1968. The N was supplied as nitrate of soda

done on the grass weeds. It was decided, therefore, to start work on the broad-leaved weeds and two species which occur abundantly on Broadbalk were chosen (see Chapter 2) - Stellaria media (L) Vill. (common chickweed) and Tripleurospermum maritimum ssp. inodorum (L) Koch (scentless mayweed).

Although both these species are abundant on Broadbalk their density varies according to fertiliser treatments. Stellaria is more prevalent on high N plots and Tripleurospermum on well-fertilised plots with little or no K.

Hand-collected ripe seeds of both species germinate easily but a portion of Tripleurospermum seeds can survive for 7-10 years and Stellaria seeds have been shown to be viable after 70 years under grass. In their other characteristics, morphology and general habit the species are strongly contrasted.

Description of Species

1) Stellaria media, family Caryophyllaceae

Stellaria media (L) Vill.(chickweed) is a low-growing annual or overwintering herb with a fibrous root system. Occasionally a slender tap root is recognisable. The much-branched prostrate or ascending leafy stems may reach 40 cms in length and are characterised by a single line of hairs down each internode. This line of hairs makes a quarter turn at each node.

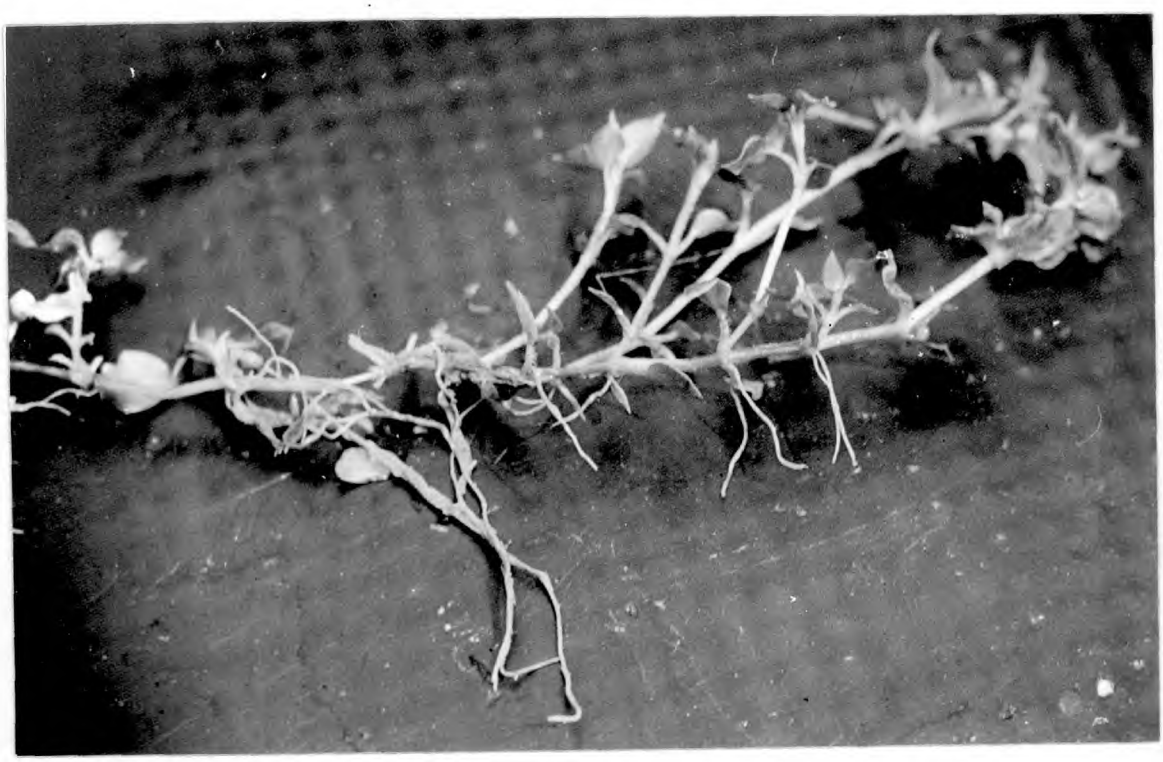
Many of these stems produce adventitious roots from nodes, which anchor the plant more firmly in the soil. This may be regarded as a form of vegetative reproduction but it is only really important when the plant is growing in particularly favourable conditions. The normal method of reproduction and dissemination is by seed and Stellaria is well adapted to do this efficiently.

The leaves are opposite, entire, simple and usually glabrous. The lower leaves are usually smaller, up to 20mm long, ovate and

Stellaria media



General view



Showing adventitious roots from nodes

long-stalked; the internodes between the upper leaves are shorter, and the leaves are more ellipitical in shape, usually sessile and larger, up,to 25mm long.

The pentamerous flowers are inconspicuous and borne in terminal cyme-like inflorescences, usually only one flower in an inflorescence being open at one time. The plant flowers throughout the year but generally flowering reaches a peak around June and July. The ovate-lanceolate sepals have narrow membraneous margins and are glandular or hairy. The petals are white and deeply bifid. There are usually 3-8 reddish anthers and three styles. The fruit is an ovoid capsule on a downwardly-curving stalk and the calyx tends to be persistent. The capsule opens by six valves to release numerous roundish or reniform reddish-brown seeds about 0.9 - 1.3mm in diameter.

This plant is homogamous and although visited by flies etc. it is automatically self-pollinated. Its chromosome number is 2n=42 and it is a therophyte.

There are several other species in this genus but this is the most tolerant of adverse conditions. Stellaria media may be a tetraploid hybrid between S.pallida (2n=22) and S.neglecta (2n=22) both of which are more restricted in their habitat and range.

As a member of the order Caryophyllaceae, Stellaria media is related to many well-known weeds :-

Silene	-	campions
Cerastium	-	mouse-ear chickweeds
Arenaria	-	sandworts
Spergularia	-	spurreys

2) Tripleurospermum maritimum, family Compositae.

Tripleurospermum maritimum (L) Koch (scentless mayweed) is divided into two sub-species and the one with which this

investigation is concerned is sub-species inodorum. This group of plants was originally included in the genus Matricaria, when T. maritimum ssp. inodorum was known as Matricaria inodora.

Tripleurospermum maritimum ssp. inodorum (L) Hyl. ex Vaarama is an annual herb with more or less erect stems from 15 - 60cms in height. The first leaves often form a rosette close to the ground. The leaves are spirally arranged, glabrous and two or three times pinnate. The primary pinnae are ovate in outline but the ultimate segments are long, slender and acute, but not fleshy. The erect stems bear small leaves and simple or corymbose inflorescences.

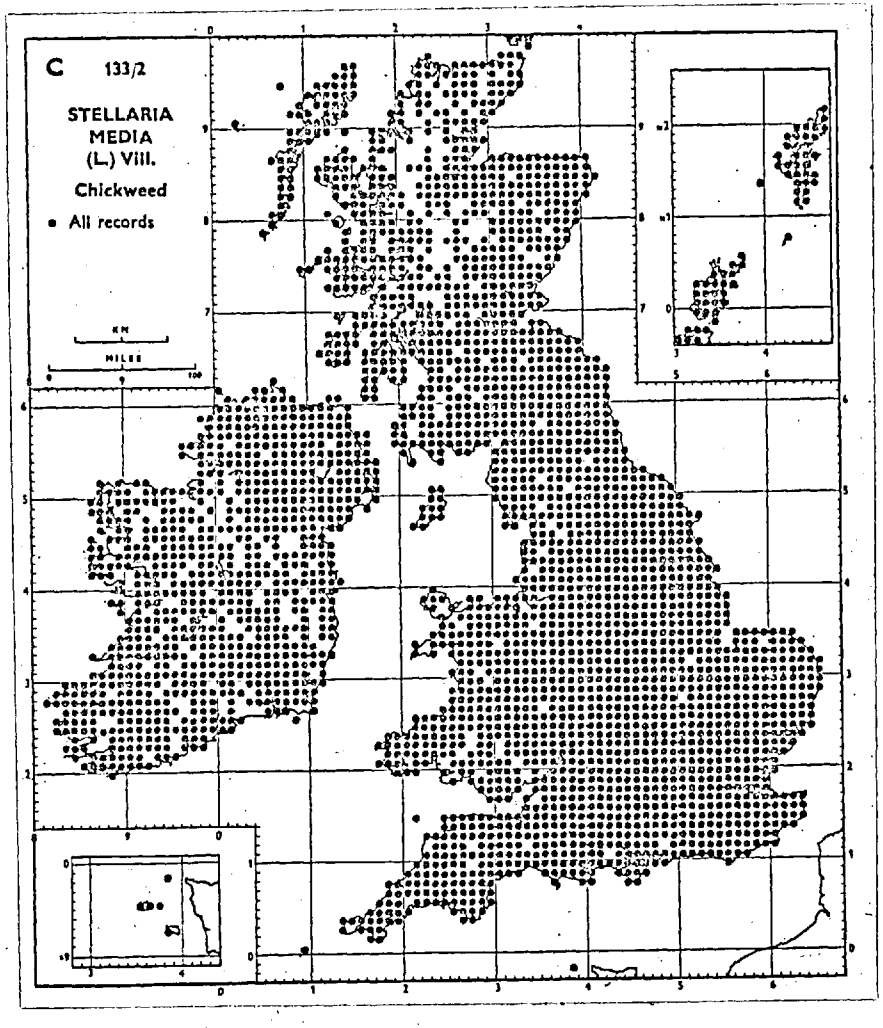
The inflorescences are conspicuous, having white ray florets and yellow centre florets. They can be seen only during the summer ie. late June to early September. The involucre is of two rows of bracts with scarious margins. The receptacle is hemi-spherical or conical and solid.

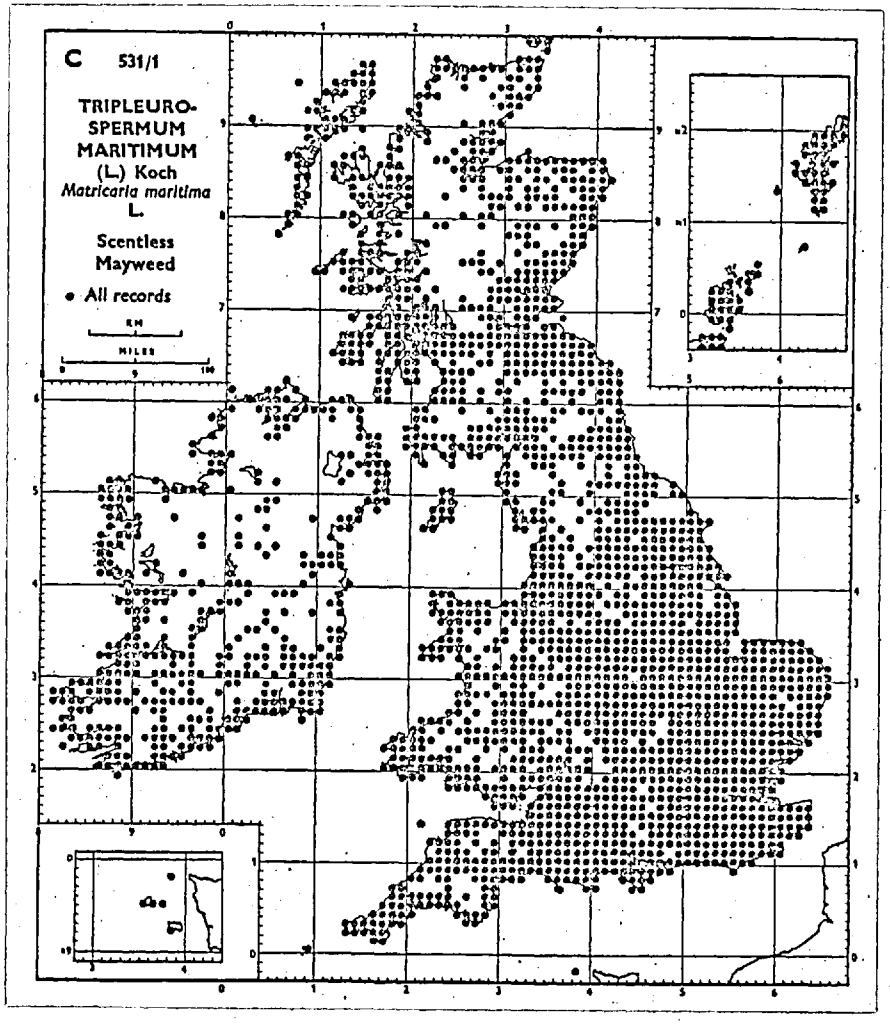
The heads are heterogamous, being composed of 12-22 ligulate white, female ray florets and numerous yellow, disc florets; which are hermaphrodite. These together form a flower-like head which may measure up to 35mm in diameter. Like all Compositae, the florets are pentamerous with epipetalous stamens usually united into a tube around the style. The ovary is inferior and one-celled.

Pollination is by insects and results in a single achene per floret. Most hermaphrodite florets are protandrous and so favour cross-pollination but self-pollination is possible at a later time. The achenes are 2.3mm long and half as broad. They have three broad ribs on the inner face and two dark brown oil glands on the top of the outer face.

The chromosome number is 2n=18 or 36 but the genetics of the group is very complex. Kay (1969) chose to separate the two sub-species into distinct species on the basis of their morphology and ecology. Tripleurospermum inodorum he found could be diploid or

DISTRIBUTION OF *STELLARIA MEDIA* and *TRIPLEUROSPERMUM MARITIMUM* IN THE BRITISH ISLES





tetraploid, but the tetraploid is not normally found in this country, occurring widely in Mediterranean districts. The group has been classed as therophytic but has been included with the hemicryptophytes because plants may sometimes over-winter in a mild season.

As a member of the Compositae and the tribe Anthemideae, it has many relatives which are also weeds :-

Anthemis	-	chamomiles
Achillea	-	yarrow
Matricaria	-	scented mayweeds
Chrysanthemum	-	corn marigold and ox-eye daisy
Artemisia	-	mugwort

Both Stellaria and Tripleurospermum are polymorphic, due, at least, in part, to their genetic plasticity, which produces differences in size, habit, hairiness, length of petals etc.

These species are both native to the British Isles and abundant here as weeds of arable and waste land on all soils. (see distribution map) Stellaria is a cosmopolitan species whereas Tripleurospermum is restricted to N and central Europe, Scandinavia and W. Asia.

The success of both these species as weeds was shown when surveys were made of the most common dicotyledonous weeds of East Anglia. Stellaria is second on the list and Tripleurospermum comes well within the first twelve. (Fryer and Chancellor 1970)

Now let us examine the reasons for the success of these species as arable weeds. The requirements for a successful weed:-

1) Ability to germinate easily under most conditions at any time of year.
2) Rapid growth rate to enable seedlings to become established quickly.

3) Good fast-growing root systems to enable efficient use of soil nutrients.
4) Efficient means of reproduction either by seed or asexual methods if the plant is perennial or just by seed if annual.
5) Efficient means of dispersal.
6) Plasticity - ie. the ability to adapt morphologically or genetically to its environment.

If a plant is efficient in several of these ways then it will make a very successful weed. However, if any one of these is prevented or reduced then the efficiency of the weed may be impaired and some sort of control may be said to be acting.

Stellaria and Tripleurospermum, as has been shown, display several of the above chacteristics. Experiments have shown that they both germinate easily in the field all the year round although both show a peak in germination during winter amd spring. Requirements for germination of Tripleurospermum are more specific eg. light is essential.

These two weeds produce seeds in large quantities, but their dispersal is less efficient. Tripleurospermum has a shorter flowering period than Stellaria. Stellaria is normally self-pollinated whereas Tripleurospermum is usually cross-pollinated but can be selfed. Both plants produce small seeds which may be blown with the wind or carried on mud etc. Plasticity is a characteristic of both these plants.

CHAPTER 2

PRELIMINARY EXPERIMENTS

Before planning experiments with growing plants it is first necessary to see which suitable species will germinate under readily obtainable and reproduceable laboratory conditions. Four weed species normally abundant on Broadbalk were selected for preliminary experiments to test the ability of the seeds to germinate under certain conditions. The four species selected show consistent and contrasting features thought to be brought about by fertilisers. The species chosen were :-

Atriplex patula L.	on high K plots
Medicago lupulina L.	on low N plots
Stellaria media (L) Vill.	on high N plots
Tripleurospermum maritimum (L) Koch	on low K plots

GERMINATION EXPERIMENTS

1) In incubators

Fifty hand-collected seeds of each species, Atriplex patula, Medicago lupulina, Stellaria media and Tripleurospermum maritimum were placed on filter paper in green glass germinators. The filter paper was kept damp by a 'wick' which dipped into the water below. The germinators were placed under the following conditions :-

a) constant dark at 2°C
b) constant dark at 20°C
c) 8 hours light at 30°C, 16 hours dark at 20°C
d) 8 hours light at 30°C, 16 hours dark at 15°C

Each treatment had two replicates.

Results

Tripleurospermum seeds did not germinate at all in the dark. They grew well in both light regimes but better in treatment (d) with a lower 'night' temperature. Unlike Tripleurospermum,

Stellaria, was unaffected by the 5°C difference in night temperature between treatments (c) and (d), and also showed some germination in all regimes. Medicago showed very little germination and no seeds germinated in treatment (d). A 20 minute treatment in concentrated sulphuric acid produced only three seedlings in 20°C dark.

Atriplex seeds proved very difficult to germinate due to their persistent calyx which rapidly becomes infected with bacteria and fungi once moistened. Even after removal of the calyx and treatment with concentrated sulphuric acid no seedlings were produced in any treatment.

TABLE 1

Number of seeds out of 50 which germinated during 3½ weeks in incubators.

	Treatment			
Mean no. of seeds	a	b	c	d
Tripleurospermum maritimum	none	none	21	49
Stellaria media	13	7	30	30
Medicago lupulina	3	2	1	none
Atriplex patula	none	none	none	none

From the results Tripleurospermum appears to require light and a fairly low 'night' temperature . Any Tripleurospermum seeds buried even to only a very shallow depth will be unlikely to germinate but will remain dormant until they are exposed to light again.

Haskell 1949 suggested that light and high temperature inhibited germination but Stellaria seeds germinated in both light and dark, though better in the light. It is likely therefore, that buried Stellaria seeds would still manage to germinate and reach the surface provided they were not buried deeper than 4cms (Chancellor 1964).

The germination of Stellaria seeds in treatment (d) was not as good as that of Tripleurospermum. This may be caused by the lower night temperature but it seems more likely, since the numbers in treatments (c) and (d) are alike, that some sort of innate dormancy is acting on these seeds. Alternatively, the percentage viability of the sample of Stellaria media used may have been lower than that of Tripleurospermum. (See experiment 2)

The germination of Medicago was poor but best at the lowest temperatures (Brenchley and Warington 1930). This suggests that the seeds require vernalisation (a cold moist temperature treatment) before germination takes place. The seed coat may play an important part in this species' germination since it is very hard and thick. After treatment with concentrated sulphuric acid, the same number of seeds germinated as after cold treatment. Light did not improve germination.

Atriplex seeds proved impossible to germinate under any of these experimental conditions. Atriplex is a winter-spring germinator (Brenchley and Warington 1930) and so, like Medicago probably requires vernalisation. However, its persistent calyx must somehow be removed first. In the field this is probably carried out by fungi and bacteria prior to the winter period.

2) Germination in soil under glasshouse conditions.

Two hundred hand-collected seeds of each species Atriplex patula, Medicago lupulina, Stellaria media and Tripleurospermum maritimum, each from the same batch as the previous experiment, were sown in sterilised soil in shallow pans in October. They were kept in a cool glasshouse and watered regularly. The seeds were covered with a thin layer of soil except for Tripleurospermum which were left uncovered since the previous experiment indicated a sensitivity to light. Two replicates of each species were used.

After four weeks 98% of the Tripleurospermum seeds had germinated and 95% of the Stellaria seeds. Germination of Stellaria was more rapid than that of Tripleurospermum despite the extra layer of soil. Since these seeds were from the same batches as those of the previous experiment, the germination of Stellaria in treatments (c) and (d) is explained by its lower percentage germination than Tripleurospermum.

Only two seedlings were produced by Medicago and none by Atriplex. However, in February, 17 weeks after sowing, the Medicago showed a sudden burst of germination whereas Atriplex had still produced no seedlings at all. (Table 2)

TABLE 2

Number of seeds out of 200 which germinated in pans.

Species	No. of seeds germinated (Mean of two pans.)			
	1st week	4th week	17th week	% viability
Stellaria media	19	190	-	95
Tripleurospermum maritimum	14	198	-	98
Medicago lupulina	1	2	98	49
Atriplex patula	none	none	none	-

These results showed that of the four species Stellaria media and Tripleurospermum maritimum would be easiest to germinate at any time of the year without special treatments. The other two species require further work on their germination requirements which is not the object of this study of weed biology.

SEED WEIGHTS.

Samples from various batches of hand-collected seeds of Stellaria media and Tripleurospermum maritimum were counted and a known number weighed to determine the average weight of one seed. Similar samples of wheat were also counted and weighed to determine grain weight as a comparison. Seeds had been stored in glass jars in the laboratory and were air dry.

As the seeds were counted, attempts were made to include only mature seeds. In some samples this proved difficult but in general the darker coloured seeds are more mature. In Tripleurospermum particular care was taken to choose seeds without the remains of the long stigma still attached. Samples were taken from seeds collected in fields on the Rothamsted farm and collected from fertiliser experiments in the glasshouse. Spring wheat samples also came from Rothamsted farm.

Results

Tripleurospermum maritimum

TABLE 3

Weight of 250 seeds (gm)	Weight of one seed (mg)
0.063	0.252
0.109	0.436
0.076	0.304
0.073	0.292
0.076	0.304

Mean weight of one seed = 0.304 mg.

Stellaria media

Weight of 500 seeds (gm)	Weight of one seed (mg)
0.186	0.372
0.191	0.382
0.178	0.356
0.181	0.362
0.192	0.384

Mean weight of one seed = 0.371 mg.

Spring wheat (Kolibri)

Weight of 100 seeds (gm)	Weight of one seed (mg.)
4.964	49.6
5.011	50.1
5.029	50.3
5.031	50.3
5.000	50.0

Mean weight of one seed = 50.1 mg.

These results show that on average Stellaria media seeds are slightly heavier than those of Tripleurospermum (0.05 mg) whereas spring wheat seeds are some 160 times heavier than either of the two weed seeds. This should give an enormous advantage to the wheat at germination because the seeds contain a larger embryo and much greater food reserves and can, therefore, overcome unfavourable conditions at, and just after, germination.

SEED NUMBERS

Seeds of single flower heads of Tripleurospermum plants were counted. Seeds were taken from heads of twelve different plants in the fertiliser experiment. The numbers of flower heads both in flower and due to flower were also counted on twelve different plants.

Twenty unopened capsules of Stellaria plants were saved and the seeds in each were counted. The number of flowers, flower buds and capsules on a branch were counted on twelve different plants and the number of branches per plant.

Results

TABLE 4

Tripleurospermum maritimum

Average no. of capsules per plant = 24.3
Average no. of seeds per head = 463.0
Average no. of seeds per plant = 11250

Stellaria media

Average no. of branches per plant	=	42.5
Average no. of capsules per branch	=	31.5
Average no. of capsules per plant	=	1338.7
Average no. of seeds per capsule	=	9.6
Average no. of seeds per plant	=	12850

These figures are probably slightly exaggerated compared with the numbers of seeds produced inthe field since all samples were taken from plants grown in the glasshouse. Although, care was taken to collect samples and measure plants given very different fertiliser treatments, all the plants had been grown in conditions better than most would ever encounter in the field since they were all watered regularly and suffered very little competition.

EXAMINATION OF PAST RECORDS

1) Weed Records

Complete weed surveys are made twice a year, in spring and in the stubble, on Broadbalk. These surveys are done visually, and each species is assigned a score for abundance. These scores have been tested (Thurston 1969) and are almost linearly related to the logarithm of the number of weeds present per unit area.

TABLE 5

Visual score	Plants/$\frac{1}{3}m^2$	Log	Assigned no.	Description
PPP	195.8	2.29	9	complete cover
PP+	70.9	1.85	8	
PP	43.0	1.63	7	very plentiful
P+	12.5	1.10	6	
P	3.1	0.49	5	plentiful
√+			4	
√			3	distributed
0+			2	
0			1	occasional

By assigning values to these visual scores it is possible to obtain comparisons of weed abundance between plots, between years, between seasons and between sprayed and unsprayed sections.

Table 6 shows that Stellaria was particular prevalent, during the period 1959-1969 on plots 7 (N_2,P,K,Na,Mg), 8 (N_3P,K,Na,Mg), 12 (N_2,P,Na), 13 (N_2,P,K), and 14 (N_3,P,K,Mg) but grew very sparsely, if at all, on plots 3 (no fertiliser), 5 (P,K,Na,Mg), 6 (N_1,P,K,Na,Mg), 17 and 18 (N_2,$\frac{1}{2}$P, $\frac{1}{2}$K,Na,Mg). This suggests that Stellaria is favoured by N given as ammonium salts and occurs only sparsely, if at all, on very low or no N plots. It seems to be indifferent to mineral fertilisers. Stellaria is most obvious in stubble and is often associated with lodging of the crop, which also tends to increase with added N. (Table 6)

Tripleurospermum appears to be favoured by plots 6 (N_1,P,K,Na,Mg) 15 (N_2,P,K,Na,Mg) and 19 (castor meal) but also does well on plots 2B (FYM), 7 (N_2,P,K,Na,Mg), 8 (N_3,P,K,Na,Mg), 9 (N_4,P,K,Na,Mg) 11 (N_2,P), 12 (N_2,P,Na), 13 (N_2,P,K) and 14 (N_3,P,K,Mg) (Table 6) but its abundance varies greatly with the season. There were no plots at any time during the 11 years on which Tripleurospermum was not recorded. It, however, grows better on plots given farmyard manure (FYM) or ammonium sulphate. It responds to N but seems to be more abundant at low levels of K unless other minerals are given. Tripleurospermum is often favoured in the crop after fallow. First cereal crops after fallow are sometimes badly infected with wheat bulb fly (Leptohylemyia coarctata Fall) which causes gaps in the crop. Tripleurospermum tends to fill these gaps forming large, bushy plants.

TABLE 6

Estimates of weed abundance on Broadbalk

Plot average over 11 years (1959-1969)

Plot	Stellaria media			Tripleurospermum maritimum		
	Sprayed	Unsprayed	U-S/U %	Sprayed	Unsprayed	U-S/U %
2B FYM	2.7	0.7	neg.	7.5	8.2	85
3 no fertiliser	0.15	0.2	25	7.1	5.6	neg.
5 (PKNaMg)	0.6	0	neg.	6.6	6.6	none
6 (N_1PKNaMg)	0.5	0.2	neg.	4.4	8.9	50
7 (N_2PKNaMg)	1.1	4.1	73	3.9	8.6	55
8 (N_3PKNaMg)	1.8	7.8	77	3.6	8.2	56
9 (N_4PKNaMg)	1.2	0.5	neg.	4.2	8.0	47
10 (N_2)	0.35	1.4	75	2.8	6.9	59
11 (N_2P)	0.9	3.3	73	4.4	8.3	47
12 (N_2PNa)	1.7	4.1	58	4.5	8.5	47
13 (N_2PK)	1.9	5.1	63	3.2	8.3	61
14 (N_3PKMg)	0.6	5.7	89	3.3	8.5	61
15 (N_2PKNaMg)	0.25	1.4	82	5.4	8.9	39
16 (N_2PKNaMg)	0.9	2.1	57	3.2	7.5	57
17 ($N_2\frac{1}{2}$PKNaMg)	0.45	0.3	neg.	3.4	6.6	48
18 ($N_2\frac{1}{2}$PKNaMg)	0.05	0	neg.	2.7	5.0	46
19 castor meal	0.3	1.6	81	5.6	9.3	40

TABLE 7

Estimates of weed abundance on Broadbalk

Yearly average over all plots for the whole year

(see also fig. 1 & 2 for Spring & stubble figures)

Year	Stellaria media			Tripleurospermum maritimum		
	Sprayed	Unsprayed	U-S/U %	Sprayed	Unsprayed	U-S/U %
1959	0.1	2.0	45	4.4	11.6	62
1960	1.9	5.3	64	2.6	6.8	61
1961	1.5	2.9	48	8.9	10.7	16
1962	2.0	2.0	none	4.3	8.9	51
1963	0.3	F	-	6.4	F	-
1964	0.5	1.5	66	4.8	7.3	34
1965	1.7	2.3	26	6.6	7.0	5
1966	0.4	1.6	75	4.1	9.7	57
1967	0.6	1.4	57	3.9	7.1	45
1968	0.2	1.9	89	2.0	6.7	70
1969	0.05	0.7	92	1.3	2.7	51

Table 7 shows the relative abundance of the two weed species over an 11 year period. Stellaria was particularly abundant in 1960, 1961 and 1965 (fig 1) whereas Tripleurospermum was abundant in 1959, 1961 and 1966. (fig 2) By subtracting the yearly averages for sprayed from unsprayed sections and calculating the percentage of the unsprayed section, it can be seen that sometimes the herbicidal spray was effective and sometimes produced little or no control of the weeds e.g. Stellaria - no control in 1962, a little in 1965 (Table 8)

Tripleurospermum - very little control in 1965

2) Herbicide records

Comparing table 7 with the list of herbicides in table 8, Stellaria was well controlled by Ioxynil and mecoprop in 1966 and 1968 and by Terbutryne in 1969 but Tripleurospermum was not well controlled by any herbicide. The best was Ioxynil and mecoprop in 1968 which reduced the numbers by 70%.

TABLE 8

Herbicides used over the period 1959 to 1969

Year	Herbicide used
1959	MCPA and TBA
1960	Mecoprop
1961	MCPA and TBA
1962	MCPA and TBA
1963	Mecoprop and 2, 4-D
1964	Dicamba MCPA
1965	Dicamba MCPA
1966	Ioxynil and mecoprop
1967	Ioxynil and mecoprop
1968	Ioxynil and mecoprop
1969	Terbutryne

Fallowing does tend to lessen the numbers of both weeds but these are soon replenished after a year or more.

FIGURE 1

YEARLY WEED ABUNDANCE ON BROADBALK

(Average over all plots)

STELLARIA MEDIA

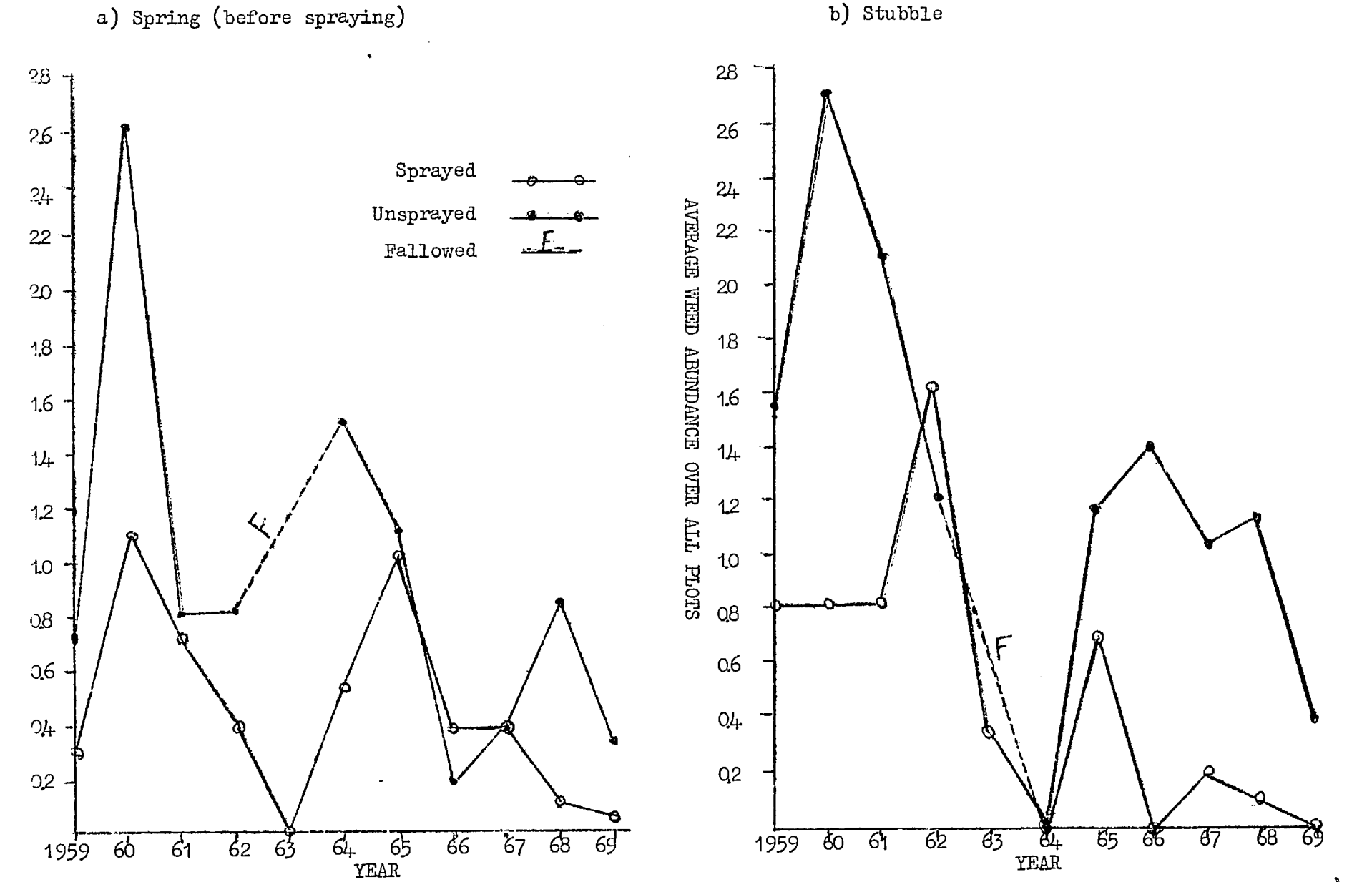


FIGURE 2

YEARLY WEED ABUNDANCE ON BROADWALK

(Average over all plots)

TRIPLEUROSPERMUM MARITIMUM

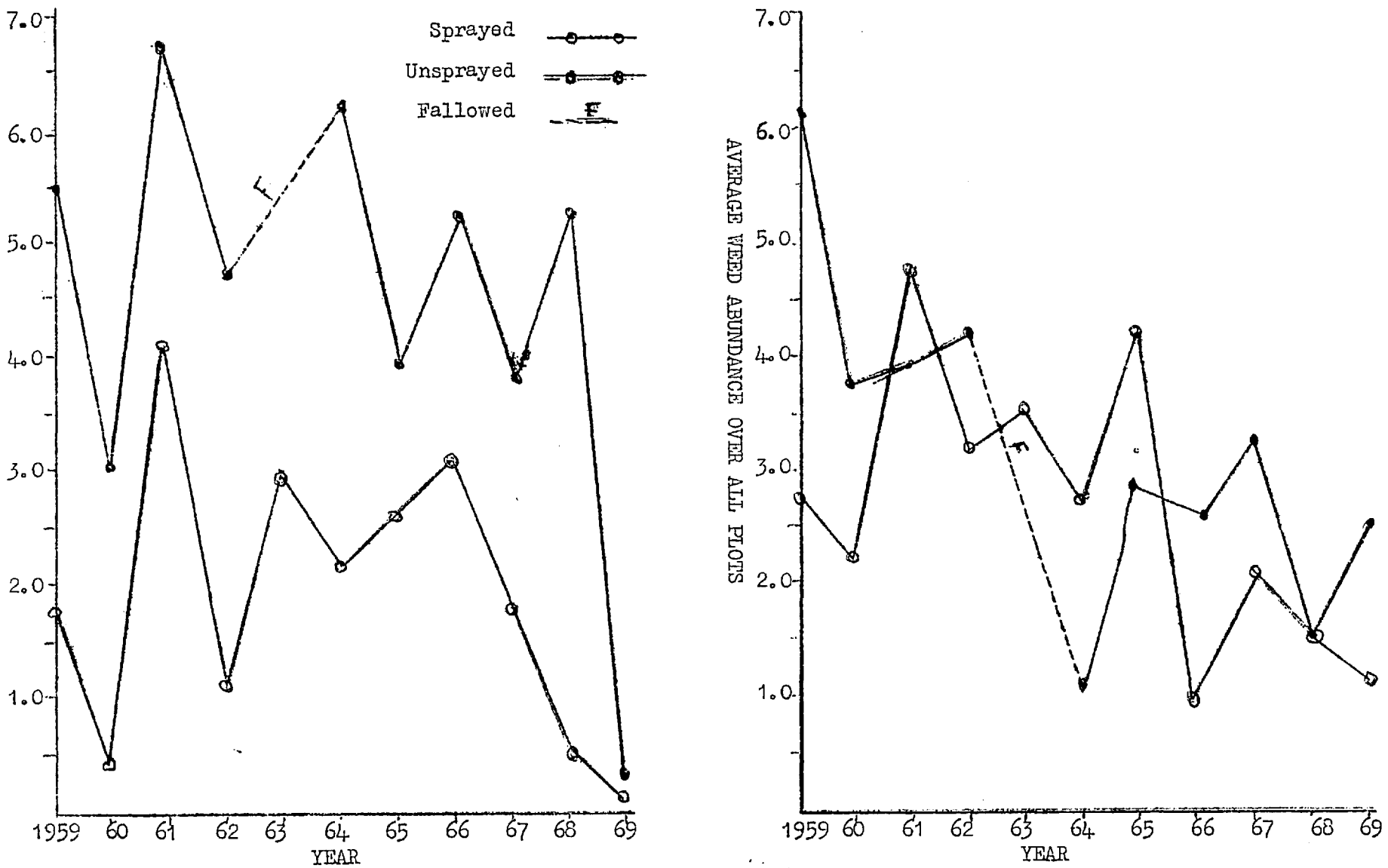


FIGURE 3

GRAIN YIELD ON BROADBALK 1970

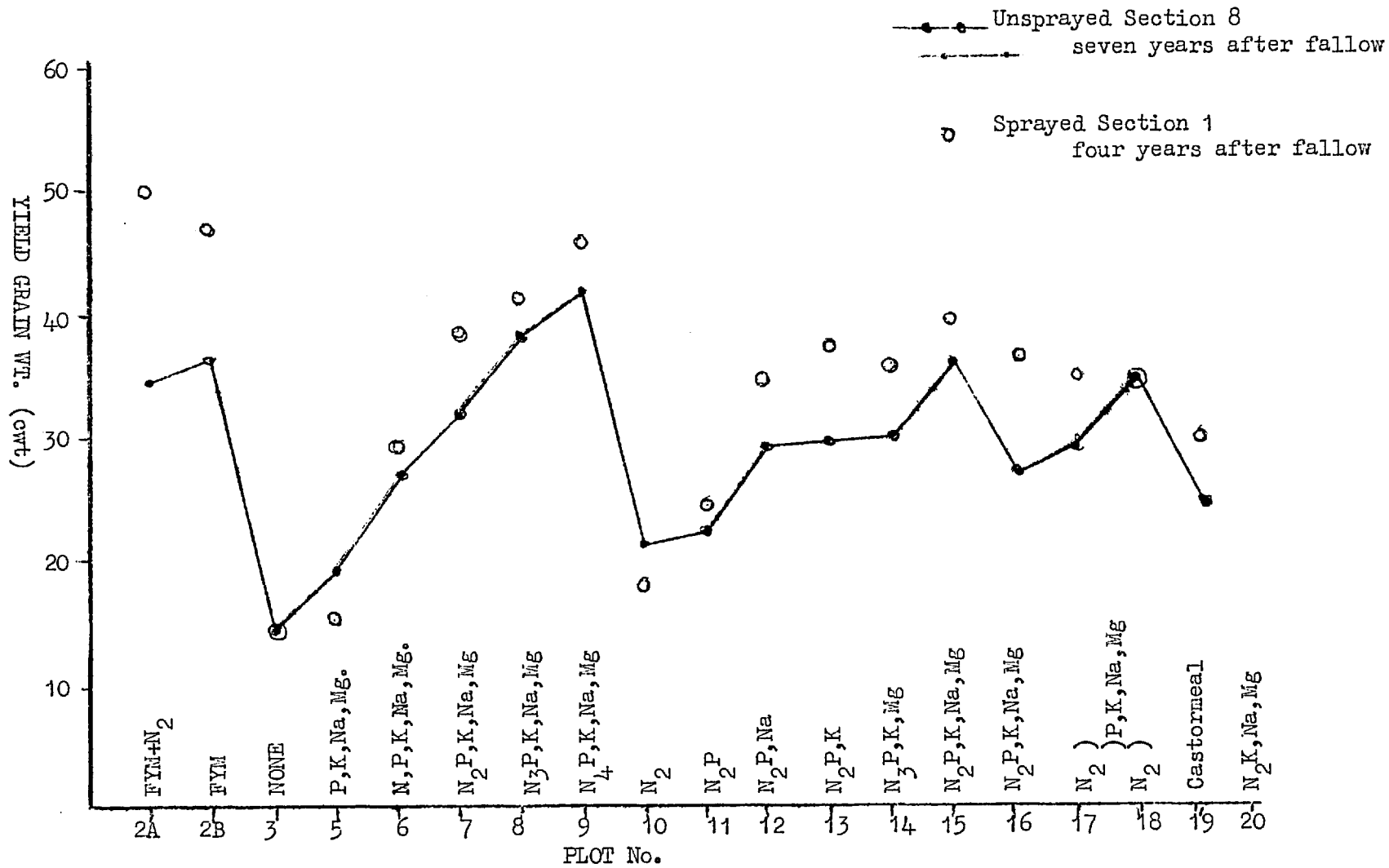
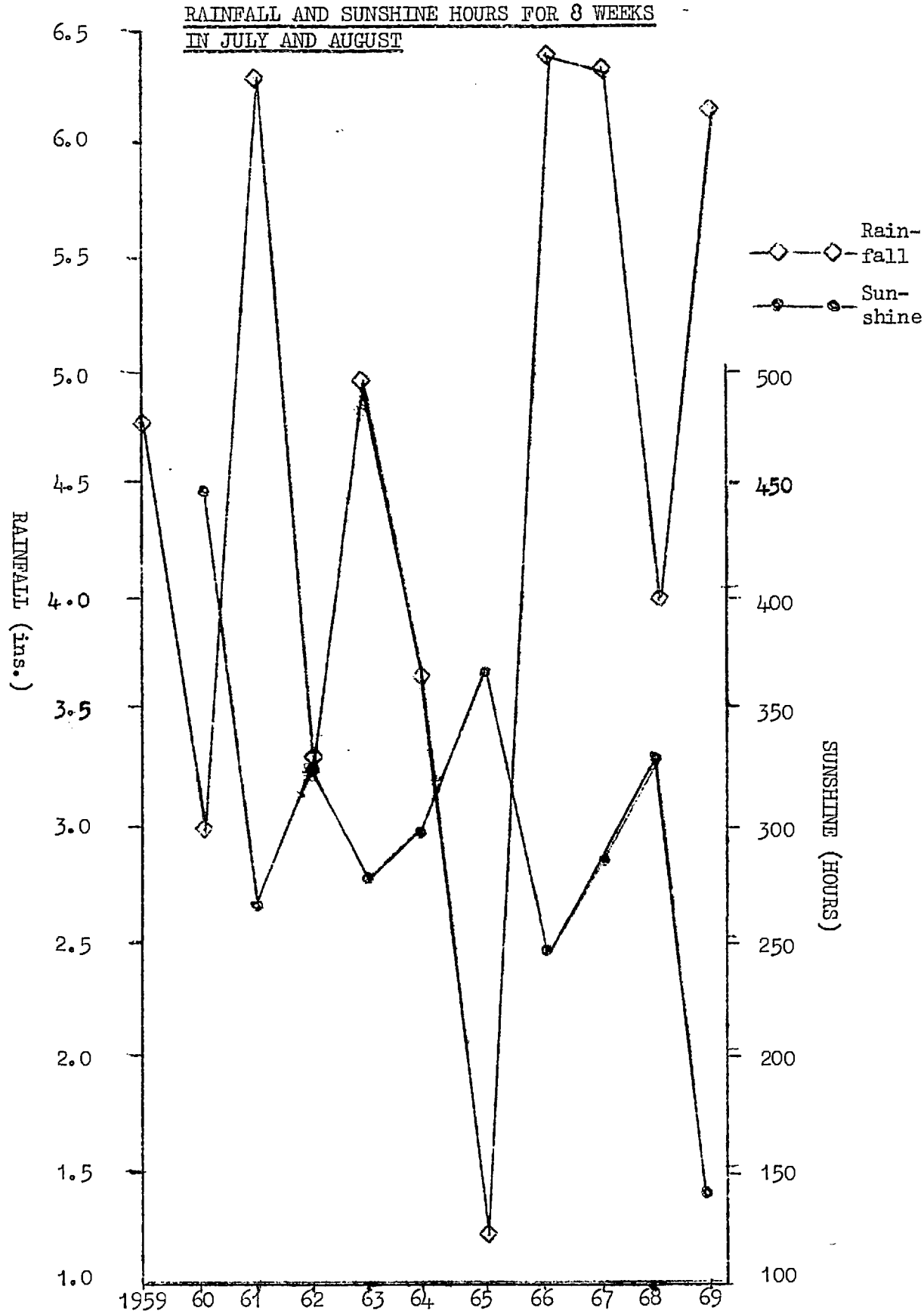


FIGURE 4

RAINFALL AND SUNSHINE HOURS FOR 8 WEEKS IN JULY AND AUGUST



3) Farm records

Comparison of table 7 with table 9 (yearly sowing date for wheat) shows that Stellaria may do better in a year when the drilling is late. e.g. 1960 and 1965.

TABLE 9

Times of Drilling winter wheat on Broadbalk

Year	Date of drilling
1959	October 19th
1960	January 18 - 19th
1961	November 3rd
1962	October 30th
1963	October 30th
1964	October 26th
1965	January 7th
1966	November 3 - 4th

4) Weather records

A knowledge of the life-cycle of these two species may suggest some other factors which may influence their abundance. If the weather is very wet during seed ripening season, then the heads of Tripleurospermum tend to go rotten and less seed is shed. Conversely, the drier and sunnier the season the more Tripleurospermum seedlings could be expected next year. (Table 10)(fig 4) (Thurston 1969)

Warm, dry summers do not affect the seed set of Stellaria so much since these plants flower over a much longer period of time. However, very dry summers tend to decrease the number of plants since they have a high transpiration rate and thin cell walls. Stellaria, therefore, tends to flourish in wetter seasons (Sinha 1967)

Tripleurospermum seeds germinate all the year round but the bulk of the germination occurs in the spring and autumn. Agricultural operations eg. rolling, harrowing etc. in spring may damage the autumn germinators. However, if April is wet then the new spring seedlings get a good start and flourish. If frosts occur

late, seedlings benefit most when May is wet. Should a combination of all these favourable factors occur in the same year then the year's 'crop' of weeds should be luxuriant! (and crop yield reduced (fig 3))

TABLE 10

Rainfall and sunshine hours for 8 weeks in July and August

(Also Figure 4)

Year	Rainfall (in)	Sunshine (hours)
1959	4.74	-
1960	3.01	441.1
1961	6.26	269.4
1962	3.22	322.5
1963	4.99	274.1
1964	3.62	296.8
1965	1.17	359.9
1966	6.46	242.8
1967	6.42	285.8
1968	3.91	320.6
1969	6.14	137.2
Mean	4.54	295.0

Examination of weather records for the past 11 years and attempts to correlate aspects of the weather with abundance of these weeds, have not been successful.

Aspects examined included rainfall and sunshine hours at certain critical periods, times of frost and maximum and minimum soil temperatures. The reason for this apparent lack of correlation is probably that there are so many factors acting, that it is not possible to single out any one of them.

CHAPTER 3

FERTILISER EXPERIMENTS

Experiment 1

A preliminary experiment on Tripleurospermum maritimum and Stellaria media

This experiment was designed to test whether the addition of mineral fertilisers to previously unmanured Rothamsted soil would produce measureable effects on weeds growing in pots and if so, to determine the levels of fertiliser required.

Experimental Procedure

5" plastic pots with saucers were filled with 1.3Kg Rothamsted soil, clay with flints, low in nutrients and screened to remove stones over $\frac{1}{2}$" in diameter, and mixed with 20% sand.

Three levels of each of N, P and K were tested factorially giving 27 treatments in all, with two replicates of each combination. The amounts were as follows expressed in ppm of the fertiliser in the dry soil :-

	Amount of fertiliser in ppm in the soil		
Fertiliser	0	1	2
N	0	25	75
P	0	50	150
K	0	100	200

Solutions of ammonium nitrate and potassium chloride were made and applied in 20cc aliquots to the dry soil, to give quantities as follows :-

N_1, 25ppm N, 0.089 gm NH_4NO_3 per pot

N_2, 75ppm N, 0.267 gm NH_4NO_3 per pot

K_1, 100ppm K, 0.336 gm KCl per pot

K_2, 200ppm K, 0.672 gm KCl per pot

Some difficulty was encountered over the phosphate to be used since many phosphates are practically insoluble and if not, the combined base is too toxic. It was finally decided that a calcium phosphate, in a finely divided solid form should be used.

P_1, 50ppm P, 0.36 gm $CaHPO_4 . 2H_2O$ per pot

P_2, 150ppm P, 1.08 gm $CaHPO_4 . 2H_2O$ per pot

Where the treatment did not include N or K solutions, equivalent quantities of distilled water were used.

The weighed amount of dry soil was mixed with the appropriate fertilisers for each potand placed in the pot, which was then transferred to a cool glasshouse and watered to bring the soil to a moisture content suitable for planting.

Two 5-day old seedlings of similar size were planted in each pot. The pots were randomised and kept, watered, in a cool glasshouse. At harvests, 14 and 21 weeks after planting, dry weights were recorded and leaf areas measured on an EEL leaf area meter. Only dry weights of tops of plants were recorded after overnight drying at 98°C. Root dry weights were not recorded due to the difficulty of extraction from Rothamsted soil.

Results

This experiment was set up in November (14/11/69) and continued over the winter until March (17/3/70). Daylight hours were therefore, short and temperatures and light intensities low. Consequently growth was very slow at the beginning but as spring advanced, growth became more rapid. Many of the Stellaria plants were flowering by the end of the experiment but none of the Tripleurospermum had begun to flower, probably due to the low light intensity and short days.

At the first harvest 14 weeks from planting all plants were small but Tripleurospermum markedly so. Table 8 shows that the growth of Stellaria up to the first harvest was very much better than that of

Tripleurospermum. The increase in dry weight and leaf area of Stellaria in the seven weeks between the first and second harvest was 6.5 and 2.5 times respectively. In Tripleurospermum dry weight increased 20 times and leaf area 11 times over the same period.

TABLE 11

Mean dry weights and leaf areas of Stellaria media and Tripleurospermum maritimum

	Mean dry wt (gm)				Mean leaf area (cm^2)			
Species	1st H	SE	2nd H	SE	1st H	SE	2nd H	SE
Stellaria media	268.1	61.8	1797.7	513.8	108.3	19.4	283.7	78.4
Tripleurospermum maritimum	26.6	10.3	531.2	202.8	13.0	3.7	141.9	39.9

NOTE SE = standard error which refers only to that species and that harvest for which it is quoted.

Fig. 5 and 6 and Table 12 show the effects of N, P and K on the two species at different harvests.

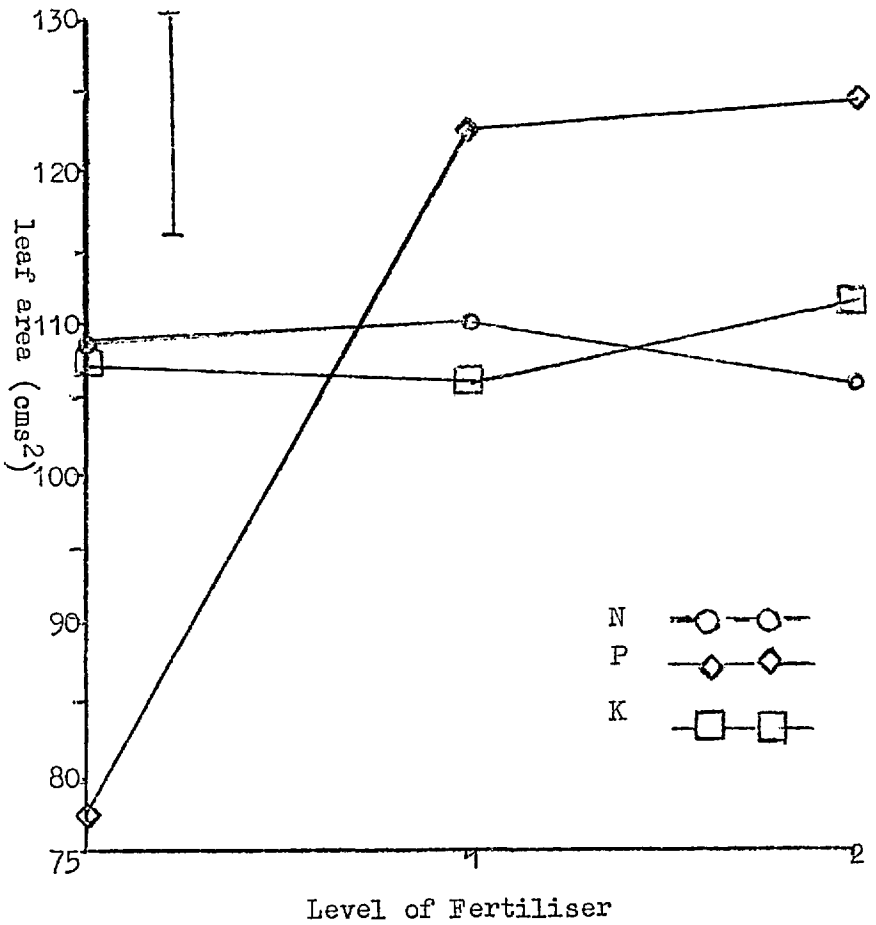
Leaf area of Tripleurospermum shows a significant increase of 147% with P_1 at the first harvest but this increase is smaller at the second harvest, 108%. Leaf area slso significantly increases by 34% with added N_1 at the second harvest but shows no effect in the first. K_2 decreases the leaf area by 20% at the second harvest.

Changes in dry weight measurements were affected by the same fertiliser treatments as those of leaf area. Usually, however, the percentage changes in dry weight were larger than those in leaf areas. eg. Addition of P_1 gave, in the first harvest, an increase of 147% in leaf area and 164% in dry weight. In the second harvest leaf area increased 108% with P_1 and dry weight 224%. However, the decrease in leaf area with K_2 (20%) was larger than the 14% decrease in dry weight. Tripleurospermum was not affected by interactions of fertilisers.

FIGURE 5 EXPERIMENT 1

Effect of N, P and K on Leaf Area of Stellaria Media

A) 1st HARVEST



B) 2nd HARVEST

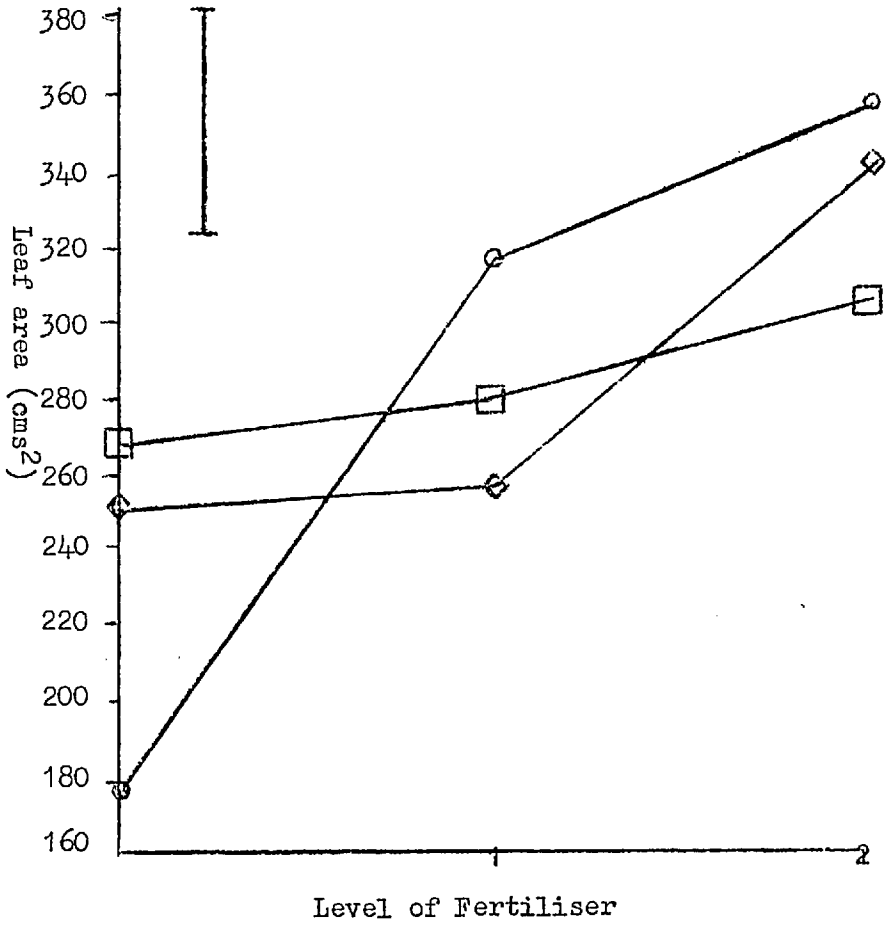
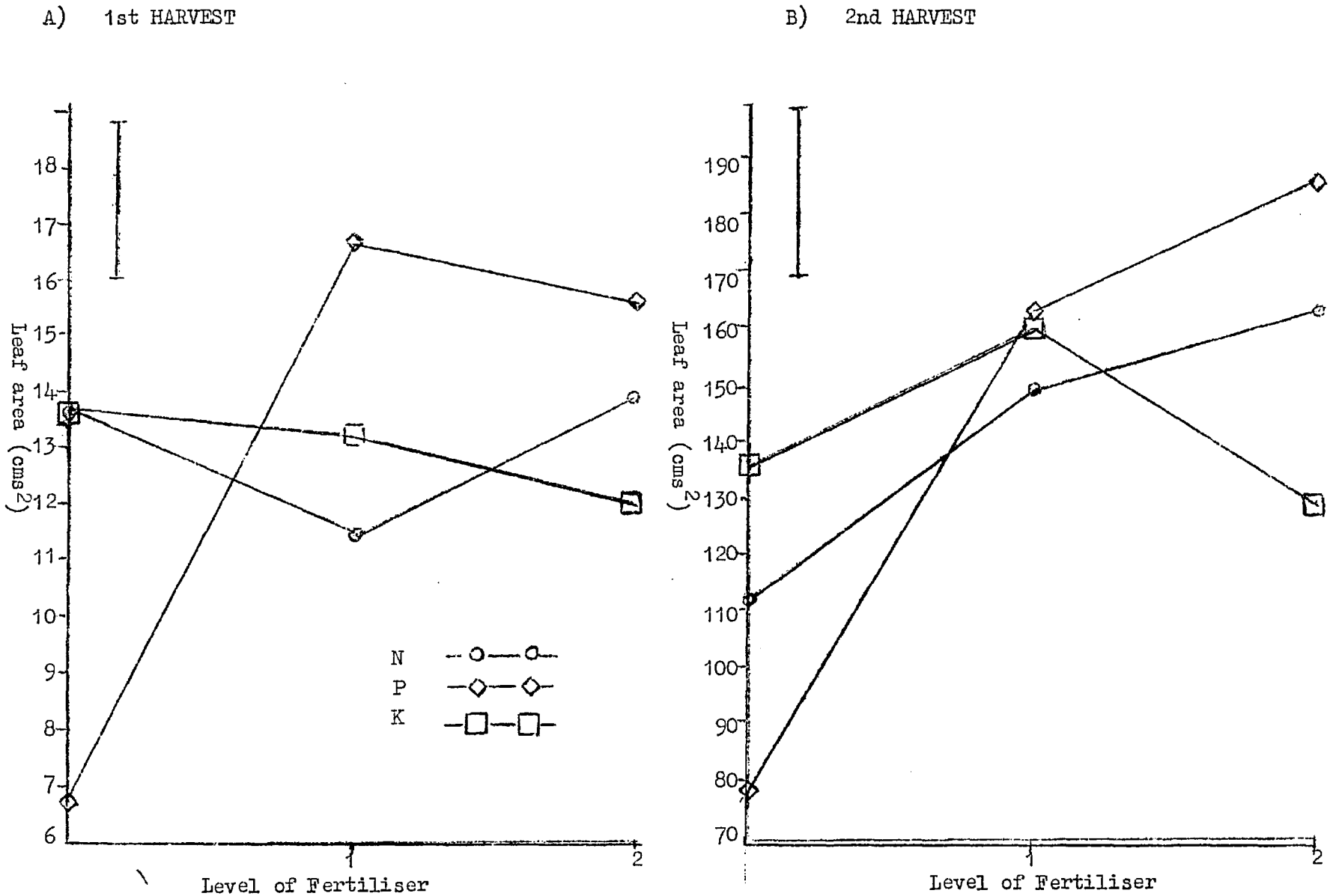


FIGURE 6 EXPERIMENT 1

Effect of N, P and K on Leaf Area of Tripleurospermum maritimum



Both P_1 and P_2 increased the leaf area of Stellaria at the first harvest but only P_2 caused a significant increase, 35%, at the second harvest. In contrast, added N had no effect at the first harvest but doubled the dry weight and increased the leaf area by 76% by the second harvest; N_2 gave only a further 13% increase, Stellaria is not affected by K or by the interaction of fertiliser.

TABLE 12

Effects of added N, P and K on dry weight of Stellaria media and Tripleurospermum maritimum

Harvest		1st harvest				2nd harvest			
Level of fertiliser		0	1	2	LSD	0	1	2	LSD
Stellaria media									
Dry weight (mg)	N	265.6	269.9	269.3	43.7	1158	2058	2176	363.3
	P	185.6	310.3	308.6	43.7	1360	1787	2245	363.3
	K	267.5	263.2	273.8	43.7	1733	1767	1891	363.3
Tripleurospermum maritimum									
Dry weight (mg)	N	26.9	24.5	28.3	7.3	385	576	631	143.4
	P	13.5	35.7	30.5	7.3	190	617	786	143.4
	K	27.1	29.8	22.8	7.3	473	602	518	143.4

NOTE LSD = least significant difference for that harvest, that species.
SE = standard errors are the same as those quoted for the previous table and refer to that species, that harvest.

It was not possible to compare the harvests statistically due to the nature and design of the experiment.
The figures quoted are the means of all the treatments in the experiment which included that particular level of fertiliser.

Increases in the total dry weights of Stellaria plants were produced by the same levels of fertiliser as those which increased leaf area. In some cases the percentage increases were very similar eg. addition of N_1 at harvest two gave an increase in leaf area of 76% and an increase in dry weight of 77%.

EFFECT OF FERTILISERS N, P & K ON *STELLARIA MEDIA*

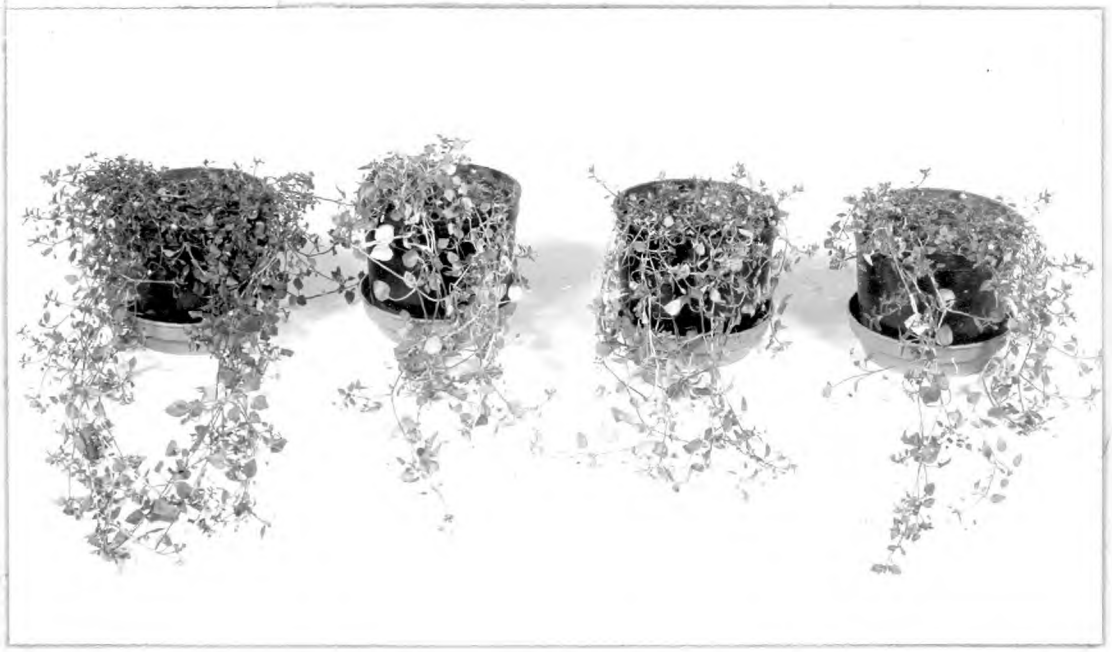
First experiment 26/1/70

1st harvest



Control K_1 P_1 N_1

2nd harvest



Control N_2 P_2 K_2

The growth of both these species increased with added P and N but increases in Stellaria were greater, probably because of its better growth rate under these conditions. The results show that both species required P and not N in early life. In Stellaria this P requirement did not last long and as the plants grew their requirements for N increased. Tripleurospermum reacted similarly but the P and N requirements were not so large. In addition the leaf area of Tripleurospermum was adversely affected by K_2 buf the dry weight was significantly increased by K_1. Stellaria was unaffected by K.

Experiment 2

A factorial fertiliser experiment with Tripleurospermum maritimum, Stellaria media and spring wheat.

The preliminary fertiliser experiment (Experiment 1) produced some interesting results in that both Tripleurospermum maritimum and Stellaria media require P and not N in early life and it is only later that N is required.

The effects of N, P and K were easily measured but it was thought that the potential of plants given phosphate was not fully rea;ised, so in this experiment the levels of P were raised from 50ppm and 150ppm to 100ppm and 200ppm. The small size of the pots had also restricted the plants, so this experiment used larger ones. Thus, bigger pots, more harvests, more plants and adjusted levels of fertilisers were used. Separate pots of spring wheat were also included to compare the responses of wheat and the two weeds to different levels of fertiliser.

Experimental Procedure

7" plastic pots with saucers were filled with 5Kg of the same soil used in the previous experiment. The amounts of fertiliser required for the larger quantities of soil were calculated and applied to the dry soil as before. Table 13.

TABLE 13

Amounts of fertiliser used

Fertiliser	Concentration(ppm)	Amount of chemical/pot(gm)	chemical used
N_1	25	0.3430	NH_4NO_3
N_2	75	1.0300	NH_4NO_3
P_1	100	2.244	$Ca(H_2PO_4)_2H_2O$
P_2	200	4.488	$Ca(H_2PO_4)_2H_2O$
K_1	100	1.295	KC1
K_2	200	2.589	KC1

Two levels each of added N, P and K were used in a completely factorial experiment, giving 27 different treatments, with two replicates of each for each species.

Ammonium nitrate and potassium chloride were applied as solutions in 40cc aliquots. When the treatments did not include N or K solutions the equivalent quantities of distilled water were added. P was applied as solid calcium tetrahydrogen diorthophosphate (N_1 is approximately equal to 62 lb N/acre)

At the same time that fertiliser was applied, 50cc of Ethirimol solution (PP149) were added to the wheat pots and 50cc of distilled water to the weed pots. Ethirimol is a systemic control for mildew in cereals and was applied here simply as a preventive measure.

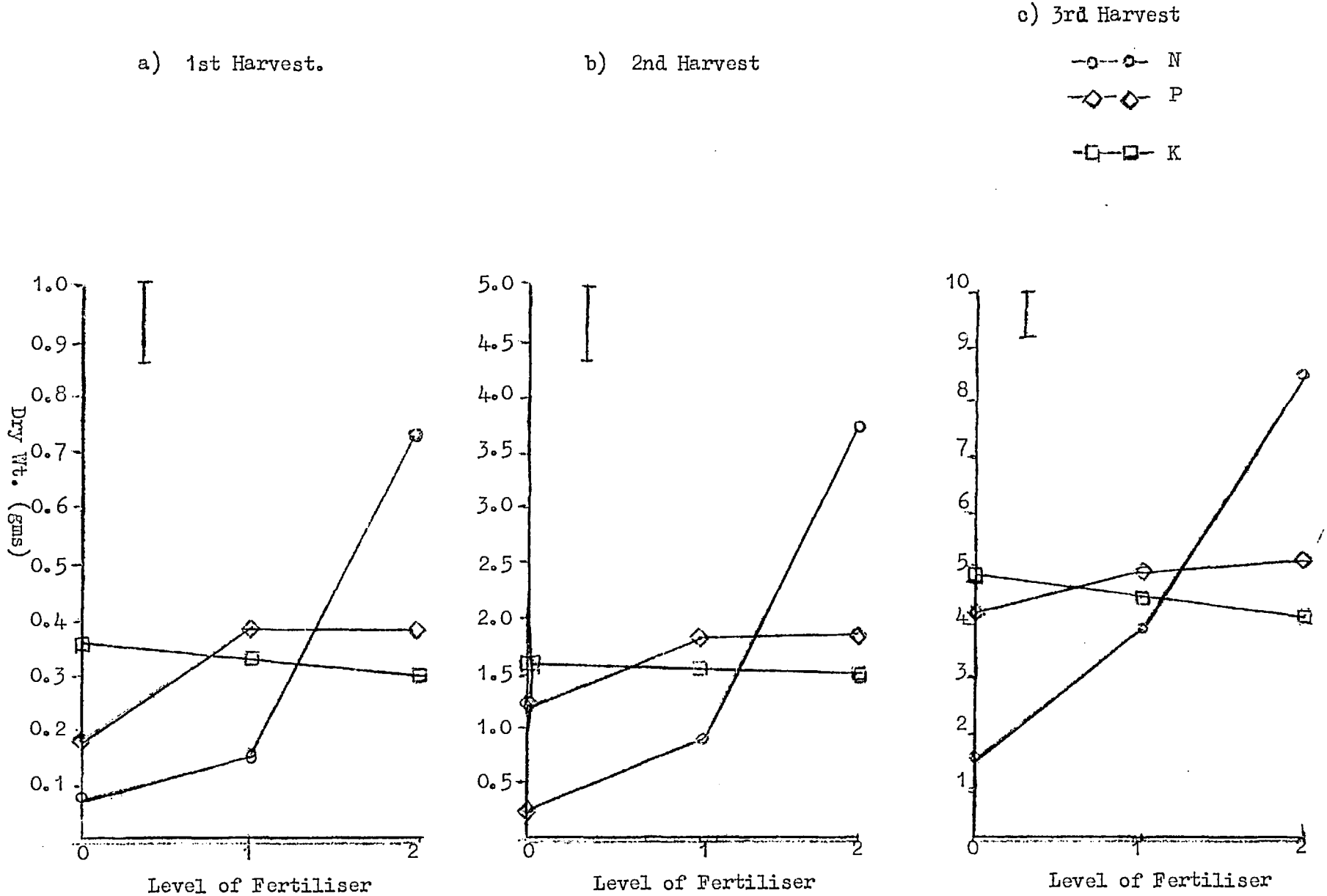
On 2/3/70 seeds were sown directly into the pots and when the seedlings were large enough to handle easily, they were thinned to 4 plants per pot. At sowing, the spring wheat (Kolibri from Rothamsted farm 1969) and Stellaria seeds were covered with a thin layer of soil (untreated). The Tripleurospermum seeds were left on the surface, in accordance with earlier results.

The pots were randomised in two blocks, each containing 1 replicate of each treatment and kept, watered in a cool glasshouse. When the weather was fine, the trucks on which the plants were kept, were pushed outside into wire-netting cages to protect the plants.

Harvests were taken 9 weeks, 13 weeks and 22 weeks after sowing except Stellaria whose 3rd harvest was 17 weeks after sowing (on 29/6/70) since the plants were dying. For the first two harvests one plant was taken at random from each pot and for the third harvest (3/8/70 except Stellaria) the remaining two plants in each pot were used. Dry weights of leaves and stems and leaf areas were measured as before.

FIGURE 7 EXPERIMENT 2

Effect of N, P, K, on total top Dry Weight of Wheat



Results

Growing conditions for these plants were particularly favourable, since they were protected from the bad weather and were able to benefit from the good, and many Stellaria plants were flowering only $8\frac{1}{2}$ weeks after sowing. Many Tripleurospermum plants had flower buds three weeks later and some wheat plants were in flower a week after i.e. at the beginning of June.

The Stellaria grew rapidly some plants having a main stem length up to 23cm and side stems up to 19cm only $8\frac{1}{2}$ weeks after sowing. Growth of wheat was rapid too, some plants having five leaves and beginning to tiller only six weeks after sowing. $2\frac{1}{2}$ weeks later some plants had as many as six tillers and were up to 56cm in height. Tripleurospermum was very slow to begin growth; the largest plants after six weeks were only 60mm in height, with eight leaves. By $8\frac{1}{2}$ weeks from sowing the number and size of leaves had increased considerably and most plants were now producing side shoots.

The last experiment had shown that much time was required to pick off and lay out the Stellaria leaves for leaf area measurement. It was, therefore, decided to use a random shoot from each plant and then use a leaf area calculated from the water content of the representative shoot and that of the whole plant. The total leaf areas of Stellaria were estimated in the usual way on the EEL leaf area meter when the plants were small at the first harvest but for the second and third harvests leaf areas were calculated from sub-samples and water contents. (Hughes, Cockshull & Heath 1970)

Total top dry weight per plant

Wheat (Fig. 7)

At the first harvest, addition of P produced no increase in dry weight unless N_2 was given and the increase with respect to N was not obvious unless P was given, then the increase with N_2 was significantly bigger than from N_0 or N_1. (Table 14a) K_2 decreased the dry weight at N_2 and prevented the increase in dry weight with both levels of P (Table 14 b & c)

TABLE 14a

Effect of N, P on the total top dry weight of wheat at first harvest

Fertiliser	N_0	N_1	N_2	Mean	
P_0	0.065	0.175	0.348	0.196	
P_1	0.063	0.163	0.963	0.396	SE of treatments = 0.066
P_2	0.084	0.170	0.925	0.393	
Mean	0.070	0.169	0.745	0.328	SE of means = 0.038

TABLE 14b

Effect of N. K on the total top dry weight of wheat at first harvest

Fertiliser	N_0	N_1	N_2	Mean	
K_0	0.078	0.148	0.830	0.352	
K_1	0.073	0.152	0.794	0.340	SE of treatments = 0.066
K_2	0.084	0.209	0.612	0.294	
Mean	0.070	0.169	0.745	0.328	SE of means = 0.038

TABLE 14c

Effect of P. K on the total top dry weight of wheat at the first harvest

Fertiliser	P_0	P_1	P_2	Mean	
K_0	0.217	0.423	0.415	0.352	
K_1	0.164	0.384	0.471	0.340	SE of treatments = 0.066
K_2	0.206	0.382	0.292	0.244	
Mean	0.196	0.396	0.393	0.328	SE of means = 0.038

At the second harvest N acted independently of P (Table 14d) but increases in dry weight with P_1 were only effective with N_2 and without K (Table 14e).

TABLE 14d

Effect of N, P on the total top dry weight of wheat at the second harvest

Fertiliser	N_0	N_1	N_2	Mean	
P_0	0.148	0.883	2.748	1.260	
P_1	0.530	0.872	4.130	1.844	SE of treatments = 0.366
P_2	0.210	0.918	4.325	1.818	
Mean	0.296	0.891	3.734	1.641	SE of means = 0.212

TABLE 14e

Effect of P, K on the total top dry weight of wheat at the second harvest

Fertiliser	P_0	P_1	P_2	Mean	
K_0	1.100	2.538	1.435	1.691	
K_1	1.417	1.587	1.942	1.648	SE of treatments = 0.366
K_2	1.263	1.407	2.077	1.582	
Mean	1.260	1.844	1.818	1.641	SE of means = 0.212

At the third harvest, N increased the dry weight whatever the level of P but only significantly affected dry weight when N was high. (Table 14f) K_2 and N with no P was 32% lower than when P was given. K produced no significant effects on dry weight at this harvest.

TABLE 14f

Effect on N, P on the dry weight of wheat at the third harvest

Fertiliser	N_0	N_1	N_2	Mean	
P_0	1.378	3.127	7.537	4.014	
P_1	1.754	4.106	8.614	4.825	SE of treatments = 0.407
P_2	1.822	4.320	8.961	5.304	
Mean	1.651	3.851	8.371	4.624	SE of means = 0.235

Dry weight of leaves and stems

In the first harvest the dry weight of both leaves and stems was increased with addition of P but not if K_2 was given. High N gave a significant increase in leaf dry weight at all levels of P and K but this increase in stem dry weight was not evident if P was not applied.

In the second harvest leaf dry weight was increased only with N but stem dry weight increased with high P and N. The dry weight of ears in harvest 3 responded similarly.

Leaf Areas (Table 17)

Leaf areas reacted similarly to total dry weights at the first harvest, in response to fertiliser treatments.

Addition of P increased the leaf area at N_2 with or without K except when K_2 was given, when the increase was prevented. N_2 increased the leaf area except at K_2 when a decrease in leaf area was obvious.

In the second harvest, in contrast to total dry weight, only N produced an increase in leaf area, P having no effect.

Stellaria media

Total shoot dry weight per plant (Figure 8)

In the first harvest addition of P_1 gave a significant increase of 46% but this was not augmented by increasing the amount to P_2 (Table 15a). The increase was irrespective of N or K. N_2 and K_2 produced a decrease in dry weight.

TABLE 15a

Effect of N, P on the total shoot dry weight of Stellaria media in the first harvest.

Fertiliser	N_0	N_1	N_2	Mean	
P_0	0.393	0.303	0.459	0.385	
P_1	0.761	1.237	0.889	0.962	SE of treatments = 0.131
P_2	1.167	1.189	0.899	1.502	
Mean	0.740	0.910	0.749	0.800	SE of means = 0.076

In harvest two the only significant effect was the increase in dry weight with N_2 irrespective of K or P. (Table 15b)

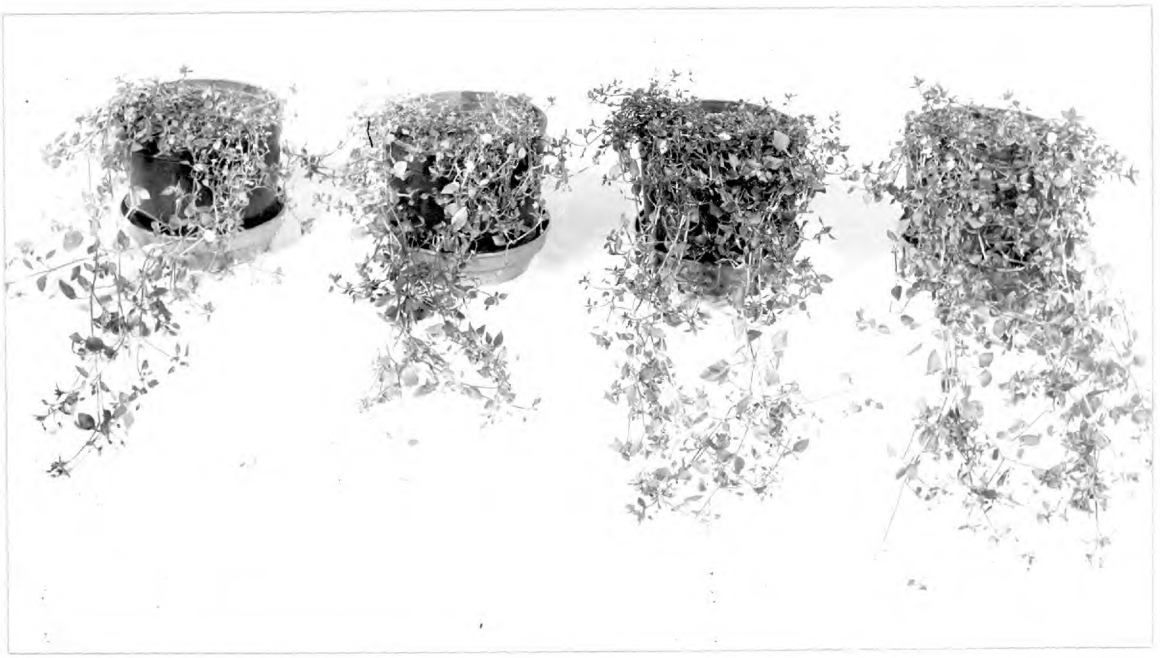
TABLE 15b

Effect of N, P on the total shoot dry weight of Stellaria media in second harvest

Fertiliser	N_0	N_1	N_2	Mean	
P_0	2.603	4.338	6.300	4.414	
P_1	2.720	4.857	5.782	4.453	SE of treatments = 0.975
P_2	2.028	3.638	8.065	4.577	
Mean	2.451	4.278	6.716	4.481	SE of means = 0.563

EFFECT OF NITROGEN ON *STELLARIA MEDIA*

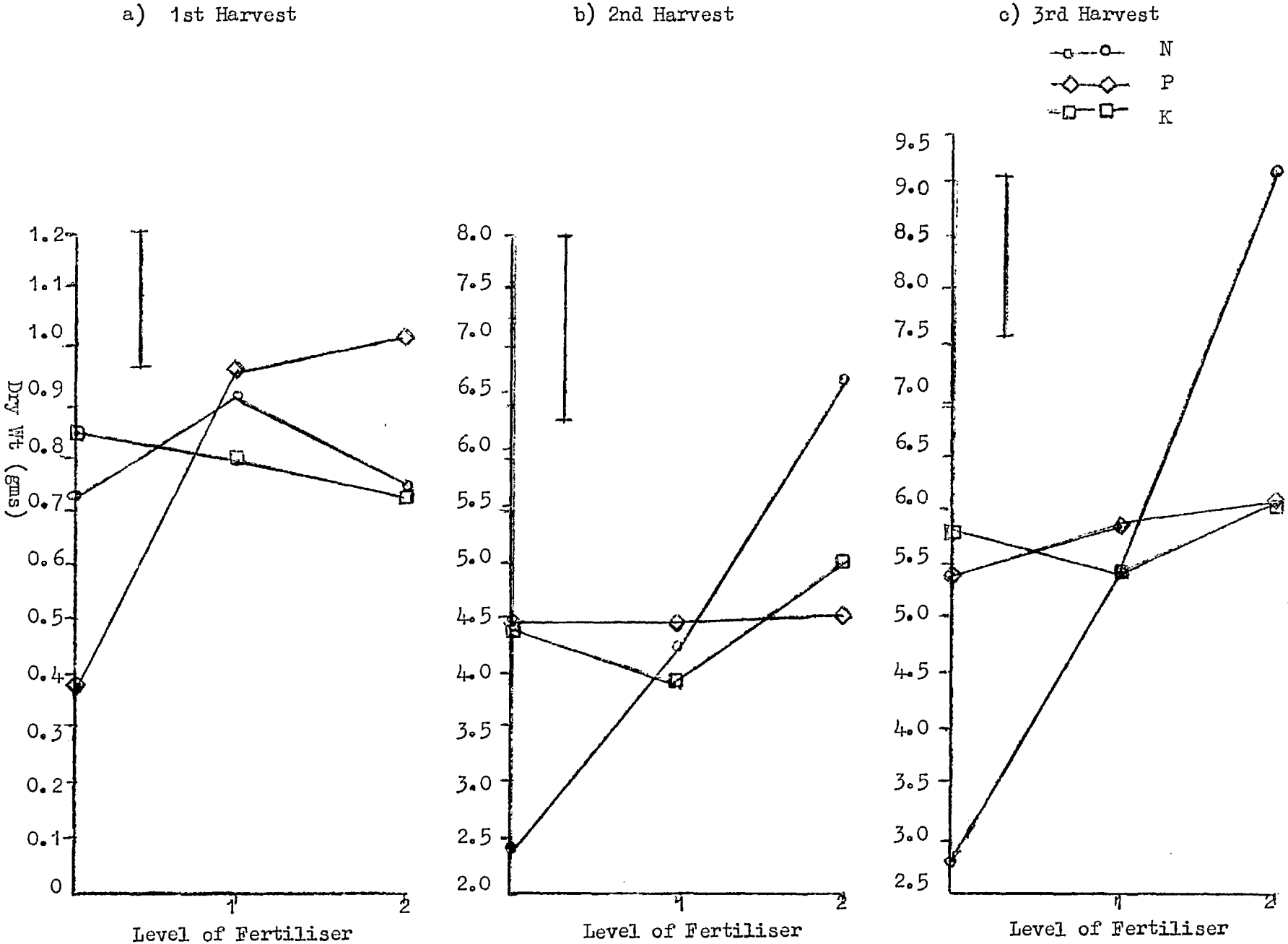
1st harvest 26/1/70



Control	N_1	N_2	N_2P_2

FIGURE 8 EXPERIMENT 2

Effect of N, P, K on total shoot dry weight of Stellaria media.



In harvest three both levels of N produced an increase in dry weight if neither P nor K were given. If K or P_1 was added only N_2 produced an increase. Addition of P_2 gave an increase with N_1 only, (Table 15c and d)

TABLE 15c

Effect of N, P on the total shoot dry weight of Stellaria media in the Third Harvest

Fertiliser	N_0	N_1	N_2	Mean	
P_0	2.611	4.867	8.820	5.432	
P_1	2.920	4.712	9.798	5.810	SE of treatments = 0.858
P_2	2.917	6.778	8.519	6.071	
Mean	2.816	5.452	9.046	5.771	SE of means = 0.495

TABLE 15d

Effect of N, K on the total shoot dry weight of Stellaria media in the Third Harvest

Fertiliser	N_0	N_1	N_2	Mean	
K_0	2.744	5.865	8.843	5.818	
K_1	2.613	5.011	8.733	5.452	SE of treatments = 0.858
K_2	3.090	5.481	9.562	6.774	
Mean	2.816	5.452	9.046	5.771	SE of means = 0.495

Leaf and stem dry weights

In the first harvest leaf and stem dry weights responded in the same way as total dry weights. Both increased with addition of P but decreased when K_2 and N_2 were applied.

In the second harvest also the responses were similar. Leaf and stem dry weights increased with addition of N_2 but in leaves this increase was only evident if P or K were given.

The leaf dry weight in the third harvest increased with N_2 if P was applied but the increase in stem dry weight with N was improved by K.

Leaf areas (Table 17)

Leaf area in the first harvest was increased by addition of P but N_2 and K_2 tended to decrease it.

In harvest two, N_2 increased the leaf area but at K_2 both N_1 and N_2 produced an increase.

In the third harvest leaf area increased with N_2 if P or K were given. P tended to increase the leaf area if N_2 or K were provided.

Tripleurospermum maritimum

Total shoot dry weight per plant (Figure 9)

P produced a significant increase in dry weight in the first harvest, irrespective of N or K. P_1 produced the increase and P_2 gave no further effect. (Table 16a)

Table 16a

Effect on N, P on the total shoot dry weight of Tripleurospermum maritimum in the first harvest.

Fertiliser	N_0	N_1	N_2	Mean
P_0	0.059	0.067	0.081	0.069
P_1	0.331	0.288	0.391	0.337 SE of treatments = 0.048
P_2	0.405	0.335	0.453	0.397
Mean	0.265	0.230	0.308	0.268 SE of means = 0.028

When N_1 was given as well as K_2, the dry weight was significantly decreased by 77% but recovered when N_2 was given. (Table 16b)

Table 16b

Effect of N, K_2 on the total shoot dry weight of Tripleurospermum maritimum in the first harvest.

Fertiliser	N_0	N_1	N_2	Mean
K_2	0.335	0.189	0.301	0.275 SE of treatments = 0.048

EFFECT OF FERTILISERS N, P & K ON *TRIPLEUROSPERMUM MARITIMUM*

2nd experiment 17/7/70



Control N_1 N_2



K_2P_2 $K_2P_2N_1$ $K_2P_2N_2$

FURTHER FERTILISER EFFECTS ON *TRIPLEUROSPERMUM MARITIMUM*

2nd experiment 17/7/70



Control K_1 P_1 N_1



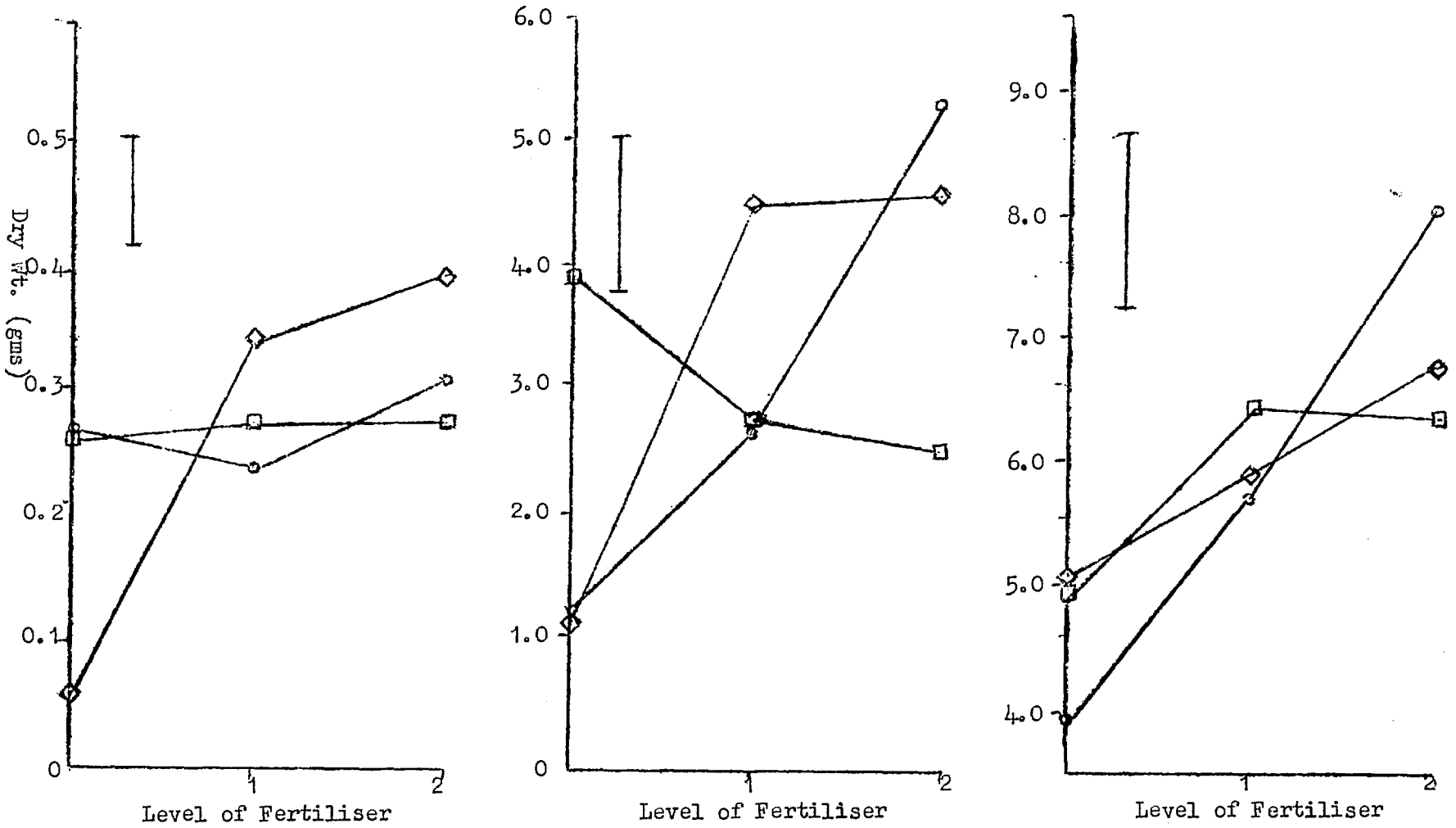
Control K_2 P_2 K_2P_2

FIGURE 9 EXPERIMENT 2

Effect of N P K on total shoot dry weight of Tripleurospermum maritimum

a) 1st Harvest b) 2nd Harvest c) 3rd Harvest

N
P
K



In the second harvest both levels of P increased the dry weight except at K_2. Addition of K significantly decreased the dry weight at P_2 or when N was given. (Tables 16c and d).

N and P interacted, giving increases in dry weight only when both were applied. (Table 16e)

TABLE 16c

Effect of P, K on the total shoot dry weight of Tripleurospermum maritimum in the second harvest.

Fertiliser	P_0	P_1	P_2	Mean	
K_0	1.212	4.622	5.703	3.846	
K_1	1.023	3.373	4.092	2.829	SE of treatments = 0.690
K_2	1.133	4.142	2.455	2.577	
Mean	1.123	4.046	4.083	3.084	SE of means = 0.398

TABLE 16d

Effect of N, K on the total shoot dry weight of Tripleurospermum maritimum in the second harvest.

Fertiliser	N_0	N_1	N_2	Mean	
K_0	1.798	3.728	6.010	3.846	
K_1	0.832	2.288	5.368	2.829	SE of treatments = 0.690
K_2	1.177	2.127	4.427	2.577	
Mean	1.269	2.714	5.268	3.084	SE of means = 0.398

TABLE 16e

Effect of N, P on the total shoot dry weight of Tripleurospermum maritimum in the second harvest.

Fertiliser	N_0	N_1	N_2	Mean	
P_0	0.817	0.992	1.560	1.123	
P_1	1.382	3.355	7.400	4.046	SE of treatments = 0.690
P_2	1.608	3.797	6.845	4.083	
Mean	1.269	2.714	5.268	3.084	SE of means = 0.398

In the third harvest, increase in K augmented the increase in dry weight with N. (Table 16f). Addition of K when P was given also increased the dry weight in contrast to the effects of K in the second harvest. (Table 16g)

Increase in dry weight with P_2 was only evident if N was given but the greater the amount of P supplied the greater was the increase in dry weight with N. (Table 16h)

TABLE 16f

Effect of K, N on the total shoot dry weight of Tripleurospermum maritimum in the third harvest.

Fertiliser	N_0	N_1	N_2	Mean
K_0	3.752	4.571	6.393	4.905
K_1	4.538	6.195	8.768	6.494 SE of treatments = 0.731
K_2	3.497	6.434	9.149	6.360
Mean	3.929	5.733	8.097	5.920 SE of means = 0.422

TABLE 16g

Effect of K, P on the total shoot dry weight of Tripleurospermum maritimum in the third harvest.

Fertiliser	P_0	P_1	P_2	Mean
K_0	4.739	5.124	4.852	4.905
K_1	5.678	6.055	7.748	6.494 SE of treatments = 0.731
K_2	4.802	6.728	7.550	6.360
Mean	5.073	5.969	6.717	5.920 SE of means = 0.422

TABLE 16h

Effect of N, P on the total shoot dry weight of Tripleurospermum maritimum in the third harvest.

Fertiliser	N_0	N_1	N_2	Mean
P_0	2.929	5.258	7.032	5.073
P_1	4.508	5.475	7.924	5.969 SE of treatments = 0.731
P_2	4.348	6.468	9.334	6.717
Mean	3.929	5.733	8.097	5.920 SE of means = 0.422

Leaf and stem dry weights

In the first harvest adding P increased leaf dry weights but the plants were so small that no stems had been formed. When no P was given, K_2 decreased the leaf dry weight.

Leaf dry weight increased with addition of P_2 and N_2 at the second harvest. Stem dry weight was decreased by K_2 at P_2, but normally adding P increased it, particularly if N was provided. N_2 increased stem dry weight when P was also given.

Leaf areas (Table 17)

In the first harvest addition of P gave an increase in leaf area. K_2 plus N_2 decreased leaf area but K alone or N alone increased it.

N_2 increased leaf area in the second harvest as did P_2.

Growth of wheat was greatly improved by N throughout the experiment particularly if P was also provided, but P only improved growth if N was given.

Early growth of Stellaria was greatly improved by P, but this effect was later replaced by an increase in growth with N.

Growth of Tripleurospermum was improved by P at the first harvest and by P and N at the second and third harvest. K_2 with N increased the dry weight in the third harvest but decreased it in the first and second harvest. K_2 with N_2 also decreased the dry weight of young wheat and Stellaria plants but had no other effects.

TABLE 17

Effect of N, P and K upon the leaf areas of spring wheat Stellaria media and Tripleurospermum maritimum

Mean of 3 levels of 2 other fertiliser (cm^2)
Level of fertiliser

Species	harvest	Fert	0	1	2	LSD
Wheat	1	N	45.5	65.5	173.2	19.4
	2	N	40.8	83.1	189.6	26.2
	1	P	70.5	106.0	107.6	19.4
	2	P	108.4	103.8	101.2	26.2
	1	K	97.8	96.7	89.7	19.4
	2	K	107.7	106.3	99.4	26.2
Stellaria	1	N	146.6	166.8	150.6	32.1
	2	N	230.4	562.5	1136.4	363.6
	3	N	218.4	415.8	750.6	208.4
	1	P	97.7	175.1	191.2	32.1
	2	P	592.1	598.2	739.0	363.6
	3	P	295.7	536.8	552.3	208.4
	1	K	165.8	159.7	138.6	32.1
	2	K	605.9	625.8	697.6	363.6
	3	K	424.6	450.7	509.5	208.4
Tripleuro-spermum	1	N	69.7	67.4	79.3	13.1
	2	N	181.7	267.8	529.4	111.6
	1	P	37.1	83.1	96.2	13.1
	2	P	196.1	378.3	404.4	111.6
	1	K	70.6	72.9	72.9	13.1
	2	K	357.2	320.6	301.1	111.6

EXPERIMENT 3

Effect of varying the time of application of fertiliser.

For winter cereals it is common agricultural practice to apply nitrogen fertilisers in either the winter or spring or both. The responses of the two weed species to N indicated that they did not require N in early life and might, therefore, benefit by late application of N fertilisers. The initial response to P suggested that, if it were practical, application of P fertilisers in the spring might curtail the growth of these two weeds somewhat. However, P is very slow-acting and unlikely to do the crop much good if applied in spring.

It was decided to carry out a small experiment in the glasshouse to test the effect of different times of application of N and P fertilisers.

Experimental procedure

5" plastic pots with saucers were filled with 1.3Kg of soil as used for experiment one. Each pot received 0.671Kg (200ppm)KCl (in 20cc distilled water) as a basal application of K. The pots were then fertilised as follows with two replicates of each treatment for each species :-

	At start	8 weeks later
1)	N	
2)	N and P	
3)	N and $\frac{1}{2}$P	$\frac{1}{2}$P
4)	N	P
5)	P	
6)	P and N	
7)	P and $\frac{1}{2}$N	$\frac{1}{2}$N
8)	P	N

P was applied as before in solid form and N in 20cc distilled water as follows :-

P (200ppm)	1.167g	$Ca(H_2PO_4)_2H_2O$	per pot
½P (100ppm)	0.583g	$Ca(H_2PO_4)_2H_2O$	per pot
N (75ppm)	0.268g	NH_4NO_3	per pot
½N (37ppm)	0.134g	NH_4NO_3	per pot

Two seedlings 14 days old were transplanted into each pot and the pots kept watered in a cool glasshouse. Eight weeks after transplantation the later fertilisers were added. It was not possible to mix these with the soil as previously but they were applied as evenly as possible to the soil surface and then watered in.

Eight weeks after late fertiliser application the plants were harvested and dry weights recorded on 28/1/71.

Results (Table 18)

Analysis of the dry weights showed that Stellaria had a tendency to benefit by addition of N and P. Addition of N with no P had a detrimental effect on Stellaria giving a dry weight 51% smaller than the mean of all the other treatments. If P was applied later the plants recovered.

Tripleurospermum tended to be adversely affected by early application of N but dry weight was only significantly smaller when P was applied late or not at all.

Late application of P to crops would tend to help in the control of Tripleurospermum maritimum in the field as the plants would remain small and set little seed. It would have virtually no effect upon Stellaria. Unfortunately late application of P to winter cereals would probably retard their growth somewhat. It would therefore be better to wait until spring, cultivate, so removing many of the

weed seedlings, and then sow and fertilise spring wheat or barley. The Tripleurospermum seedlings not destroyed by cultivation would have been deprived of a good supply of P and so would remain small, producing little or no seed.

TABLE 18

Effect of different times of fertiliser application on the dry weight of Stellaria and Tripleurospermum

	Stellaria	Tripleurospermum
No N	4.115	1.120
N early	4.720	0.915
½N and ½N	4.295	1.315
N late	4.715	1.095
No P	1.945	0.330
P early	4.635	0.850
½P and ½P	4.730	0.950
P late	4.155	0.420
LSD	1.906	0.490

CHAPTER 4

LIGHT EXPERIMENTS

Experiment 4

Effect of light and temperature on the growth of Tripleurospermum maritimum

During the first fertiliser experiment in the glasshouse, which took place during the winter, the Tripleurospermum plants grew very slowly. It was decided that additional light and a higher temperature might improve their growth.

Hence, two pots each containing three Tripleurospermum seedlings planted in the Rothamsted soil as used before were placed in

1) a cool glasshouse under lights giving increased light intensity and longer days.
2) a warm glasshouse under lights giving increased light intensity and longer days.

By the 19th December, five weeks after planting the seedlings in the pots, both sets of plants showed a markedly improved growth rate compared with those plants involved with the fertiliser experiment, which had no extra light and were kept in a cool glasshouse. Both sets of plants in the improved light conditions showed strong healthy growth, the plants becoming very bushy. At the lower temperature the plants were larger; whereas at the higher temperature the leaves, although just as numerous, were smaller, thicker and greener. The plants were all producing side shoots.

By January, there was a noticeable difference between the sets of pots grown under different light and temperature conditions (see photographs). All were producing side shoots in profusion.

By March 9th differences were even more obvious. The plants in the fertiliser experiment were growing more quickly and gradually

EFFECT OF LIGHT AND TEMPERATURE ON *TRIPLEUROSPERMUM MARITIMUM*

21/1/70



Increased light and temperature | Increased light | Control

16/3/70



Increased light and temperature | Increased light | Control

coming to resemble those grown under increased light at the same temperature. These plants seemed to have grown little, merely becoming more leafy and bushy but showing no tendency to bolt. Those grown under increased light at a higher temperature had bolted and were showing well-developed flower buds. The stems were not long (10-20cm) but each plant had two or more stems with flower buds. The shortness of the stems is probably due to the crowded conditions in the pots (three plants in a 5" plastic pot with no added fertiliser) and consequent competition for fertiliser.

This experiment shows that Tripleurospermum in winter requires additional light (either increased light intensity or increased day length, or both) for good growth and increased temperature for flowering. Controlled environment studies of the effects of light intensity differences on the growth of Tripleurospermum and Stellaria media are discussed later. (Experiment 6)

Experiment 5

Light measurement on Broadbalk

The results of the last experiment indicate that light may be an important factor in the distribution of Tripleurospermum on Broadbalk. It became important, therefore, to try to investigate the light penetrating the crop on Broadbalk.

Measurement of light penetrating the crop.

Since Broadbalk is a classical experiment permission must be obtained to carry out experiments on it. Permission to place tube solarimeters on Broadbalk was obtained but actual plots were not to be used, the headlands only between the plots being allowed.

These tube solarimeters were used to record the light intensity above and in the crop at levels at which different weeds have their photosynthetic tissue.

Two pairs of tube solarimeters were used. Each tube was 0.9m long since this gives a good reading of radiation in a crop. One tube of each pair was black, the other black and white in alternating sections. The black and white tubes give a reading of the total radiation and the black ones of only the infra-red radiation. By comparing these two tubes an estimate of the total visible radiation i.e. that normally available for photosynthesis, can be obtained.

One pair of solarimeters was mounted on a metal base, attached to an adjustable stand so that the tubes were kept horizontal. This pair was used to record the light above the crop at about 1m above the ground. The results from the other pair of tubes in the crop are expressed as a percentage of the unobstructed light falling on the first pair of tubes.

The second pair of tubes, after co-ordinating their reading with the first, were set at the required level above the ground (on stands where necessary) at right angles to the crop rows, with the tubes about 30cm apart. Care was taken when placing these tubes to disturb the crop as little as possible and to avoid trampling. (Szeicz, Monteith and Dos Santos 1964)

The spectrum of light of interest in this experiment is obviously that of visible light in the region 0.4 - 0.75 Solarimeters normally give a reading for total radiation but by using the black tubes which absorb all the visible light, the amount of infra-red radiation can be estimated. Therefore, by comparing the tubes of one pair with the other pair the percentage of 'visible' light penetrating the crop can be calculated.

The tubes should be placed approximately at right angles to the sun so that the correct reading is obtained. Most of the light measurements were, therefore, made during late morning or early afternoon when the sun was shining along the crop rows. However, some measurements taken at 5 p.m. were compared with some taken at midday on the same day. (TABLE 19) Those in the evening were all found to be approximately 10% lower than those taken at midday because the sun was no longer shining along the crop rows and consequently the tubes were shaded much more by the crop. Moreover, the tubes were no longer at right angles to the sun and previous experiments (Szeicz et **al.** 1964) have shown that readings from these solarimeters were not as accurate when the sun was shining along the tubes.

TABLE 19

Percentage transmission of light to different levels in the crop at different times of the day on 10/6/70

Plot	Height above ground (cm)	Time of day	
		midday	5 p.m.
2B (FYM)	0	14.5	5.0
	25	28.8	13.4
	50	37.1	27.2
3 (none)	0	71.9	62.5
	25	90.3	79.3

Weather conditions greatly affected the accuracy of the readings and cloudless, windless days were best. If the weather is windy, the crop moves, casting intermittent shadows, which cause fluctuations in the readings. If it is very windy with changing cloud cover, then differences between replicate readings on the same plot may be large. (TABLE 20)

TABLE 20

Plot 2B (FYM) 25/6/70. percentage light transmission to different levels in the crop under very windy and cloudy conditions

Height above ground (cm)	% transmission
0	14.9
0	22.3
0	20.0
25	22.1
25	31.5
25	68.9
50	14.3
50	80.0
50	52.2

NOTE On that day further measurement was abandoned until the afternoon when the wind had dropped somewhat.

In 1970 only the sprayed and almost weed-free headlands between sections 1 and 2 were used for light measurements. This indicated the effects of the crop upon the light available to the weeds. Only seven plots (2B, 3, 5, 6, 7, 8, 9,) were studied in 1970 giving a comparison of FYM, no fertiliser, P,KNa & Mg only and P,K,Na,Mg plus four different amounts of N (see field plan of Broadbalk).

Measurements were made on 27th May, 10th and 25th June and 30th July. On 25th June the morning readings were abandoned because of wind and further measurements were taken during the afternoon when the wind had dropped. Two sets of readings were taken on each plot except on 27th May. Sometimes the replicate readings agreed very well, e.g. on 25th June 1970

Plot 5 (P,K,Na,Mg) ground level 50.2% and 51.8%

Plot 6 (N_1,P,K,Na,Mg) 50cm height 83.9% and 84.5%

TABLE 21

Crop heights and percentage light transmitted at three different heights above ground in the crop of 4 dates in 1970

Plot	Date	Time of Day	Average % light transmission at 0cm	25cm	50cm	Av. crop height
2B FYM	27/5	am	11.7	-	-	77
	10/6	am	14.5	28.8	37.1	92
	25/6	pm	23.1	31.1	52.6	95
	30/7	am	20.7	30.6	44.4	86
3 none	27/5	am	82.4	-	-	38
	10/6	am	71.9	90.3	-	49
	25/6	pm	59.3	78.7	95.8	65
	30/7	am	47.5	74.6	88.3	62
5 mins only	27/5	am	73.9	-	-	49
	10/6	am	44.1	82.8	-	57
	25/6	pm	51.0	57.8	81.6	70
	30/7	am	53.3	86.2	95.6	66
6 N_1 mins	27/5	am	68.8	-	-	52
	10/6	am	39.4	69.3	95.6	68
	25/6	pm	40.5	52.0	84.2	75
	30/7	am	45.4	74.0	81.2	69
7 N_2 mins	27/5	am	46.1	-	-	59
	10/6	am	41.9	64.3	98.1	77
	25/6	pm	27.3	40.1	53.9	82
	30/7	am	32.5	55.3	71.2	78
8 N_3 mins	27/5	am	37.6	-	-	64
	10/6	am	24.8	23.9	60.5	80
	25/6	pm	21.4	31.7	57.2	87
	30/7	am	32.2	42.4	56.0	80
9 N_4 mins	27/5	am	44.8	-	-	60
	10/6	am	42.9	45.1	86.6	68
	30/7	am	60.2	82.8	78.4	76

NOTE: Readings on 27/5 were not replicated.

But others differed considerably, probably due to patchy crops or alterations in cloud cover, e.g. on 25/6/70

Plot 2B (FYM	50cm height	70.8% and 34.4%
Plot 8 (N_3,P,K,Na,Mg)	25cm height	15.2% and 84.5%

The average of the replicate readings is quoted in Table 21. On each date ten random measurements of crop height were made on each plot. The mean crop heights are also quoted in Table 21.

Table 21 shows that plots 2B(FYM) had the least amount of light penetrating to the crop at any time and plot 3 (no fertiliser) had the most.

On 27th May less than 50% of full daylight was reaching the ground in crops on plots 2B(FYM), 7 (N_2P,K,Na,Mg), 8 (N_3P,K,Na,Mg) and 9 (N_4P,K,Na,Mg). Plots 2B and 8 admitted the least light and were the tallest crops. Although plot 9 has N_4P,K,Na,Mg the crop was neither so tall or so thick as plot 8 (N_3P,K,Na,Mg). This is because until 1967 plot 9 only received N_1 in the form of nitrate of soda which spoilt the tilth.

Light at ground level on plots 2B(FYM), 7(N_2P,K,Na,Mg) and 9(N_4P,K,Na,Mg) on June 10th was practically unchanged since May 27th. The total amount of light transmitted to the ground on plots 3 (no fertiliser), 5 (P,K,Na,Mg), 6 (N_1P,K,Na,Mg) and 8(N_3P,K,Na,Mg) was much lower than previously. On plot 6 the amount of light reaching the ground was 29.4% lower than on May 27th.

50cm was well above the height of the crop on plot 3 (no fertiliser) on June 10th and effectively above the crop on plots 5, 6 and 7 because the leaves curl over downwards so that they do not provide effective shade to their full potential height as measured.

On plots 2B(FYM), 8 (N_3P,K,Na,Mg) and 9 (N_4P,K,Na,Mg) less than 50% of full daylight was penetrating to 25cm above ground and on plot 2B (FYM) only 37% daylight was transmitted to 50cm above ground.

By June 25th slightly more light was reaching the lower levels on plot 2B because the lower leaves were beginning to die, most of the flag leaves had turned over and the ear was the tallest part of the plant.

Other plots showed a decrease in transmission except at ground level on plots 5 (P,K,Na,Mg) and 6 (N_1P,K,Na,Mg) where transmission increased probably due to the lower leaves dying. Plot 3, with the shortest crop plants was still intercepting only 4% of light at 50cm height.

Many plots showed increases in transmission of light by July 30th because of leaf death. On plot 3 (no fertiliser), however, the light transmitted to ground level fell by 12%. This was probably due to a dense growth of Equisetum arvense which had invaded this plot and grew to a height of 30 to 40cms.

Plots 2B(FYM), 6 (N_1P,K,Na,Mg) and 9 (N_4P,K,Na,Mg) showed a decrease in transmission at 50cm height. This may be caused by the ears, which were ripening and beginning to bend.

The mean crop heights increased between the first three dates on all plots but decreased in height on the last date due to the flag leaf and ear turning over. Plot 2B(FYM) grew tallest, 95cm before the flag leaf turned over. Plot 7 (N_2P,K,Na,Mg) and 8 (N_3P,K,Na,Mg) were next tallest but the crop on plot 9 (N_4P,K,Na,Mg), although expected to grow taller than plot 8, was only 76cm high. Again this was probably attributable to the short time that N_4P,K,Na,Mg has been given. Plot 3 (no fertiliser) had by far the smallest crop plants which grew to only 65cm.

In 1971, bad weather made readings impractical until 23rd June when the ears had shot and some were beginning to flower. Despite the bad weather, the crop was slightly taller than on June 25th the year before and more plants were in ear.

Light measurements were this time taken on the unsprayed headland between Sections 8 and 9 (see field plan of Broadbalk) on the ground, at 25cm and 50cms above the ground in the crop.

TABLE 22

Crop heights and percentage light transmitted at three different levels in the unsprayed crop on 23rd June 1971

Plot	Time of Day	Average % light transmission at			Average crop height	
		0cm	25cm	50cm	sprayed	unsprayed
2B FYM	am	3.3	4.7	11.2	107.7	108.8
3 none	am	44.5	51.6	86.4	55.9	77.4
5 PKNaMg	am	30.7	37.3	50.7	68.2	87.3
6 N_1PKNaMg	am	12.3	21.5	32.4	88.9	96.9
7 N_2PKNaMg	am	8.5	15.3	35.1	100.6	99.8
8 N_3PKNaMg	pm	9.3	21.2	22.3	104.9	98.4
9 N_4PKNaMg	pm	5.1	17.1	24.5	107.1	104.5
10 N_2	pm	13.4	38.5	47.2	84.5	70.4
11 N_2P	pm	23.5	46.8	72.0	89.0	83.4
12 N_2PNa	pm	18.2	36.2	53.2	93.5	92.4

All plots showed lower light intensities than those measured on weed-free plots at a similar time last year. (Tables 21 & 22) However, the wheat was further advanced this year and may have affected these readings.

In 1970 the lowest reading was on the ground on plot 8 (N_3PKNaMg) when the light penetrating was 21.4%. In 1971, at a similar time on weedy plots, the lowest was on the ground on plot 2B(FYM), where only 3.3% of total visible light penetrated. Much light on plot 2B(FYM) was intercepted by tall bushy *Vicia sativa* plants (up to 124cm in height) and also some *Papaver* ssp, and blackgrass (*Alopecurus myosuroides*). Plot 3 (none), as usual, was very little affected by weeds (except leguminous ones e.g. *Medicago lupulina*) but plots 5 (PKNaMg) and 6 (N_1PKNaMg) suffered from tall bushy *Vicia* and

blackgrass. Alopecurus was also dense on plots 7 (N_2PKNaMg), 8 (N_3PKNaMg) and 9 (N_4PKNaMg) but less so on 10 (N_2), 11 (N_2P) and 12 (N_2P Na).

Even at a much later date in 1970 (30th July) the light penetrating to the ground on plot 2B(FYM) was only 20.7%, while at an earlier date (27th May) less light penetrated (11.7%). Never over the measured period did the light reaching the ground of relatively weed-free sections fall below 10%. However, on the unsprayed section in 1971, 4 plots had less than 10% of full daylight on the ground. Plot 7 (N_2PKNaMg) had 8.5%. plot 8 (N_3PKNaMg) 9.3%, plot 9 (N_4PKNaMg) 5.1% at ground level while plot 2B(FYM) had only 3.3% on the ground, 4.7% at 25cm and 11.7% at 50cms from the ground equal to the lowest amount of light recorded in 1970 on the ground.

Light measurements on plots 10 (N_2), 11 (N_2P) and 12 (N_2PNa) were also included in 1971. Of these three plots 11 (N_2P) intercepted least light, 23.5% reaching the ground. Plots 10 (N_2) and 12 (N_2PNa) were similar but plot 12 (N_2PNa) intercepted slightly less light than plot 10 (N_2).

Light measurements on weedy plots were much as expected except perhaps rather lower than predicted. One interesting point which emerged was that plot 7 (N_2PKNaMg) appeared to intercept more light than the better fertilised plot 8 (N_3PKNaMg). This seemed rather strange, but it is likely that one of the positions for sampling on plot 8 happened to be in a patch particularly thick with weeds or partially lodged. The replicate readings for plot 8 (N_3mins) were as follows and certainly suggest that this is indeed the explanation.

Plot 8 (N_3mins)	on the ground	4.8% and 13.8% light available
	at 25cm	14.1% and 28.3% light available
	at 50cm	13.6% and 31.1% light available

Crop heights in weedy and sprayed plots proved interesting. Plots 2B(FYM), 3 (no fertiliser), 5(PKNaMg) and 6 (N_1PKNaMg) had crop heights on sprayed sections greater than on weedy sections but the crop was shorter on sprayed parts of plots 7(N_2PKNaMg), 8(N_3PKNaMg), 9(N_4PKNaMg), 10(N_2), 11(N_2P) and 12 (N_2PNa).

The sprayed and unsprayed crop heights were taken in different years but seasonal effect should be the same all over the field. The explanation may be that sprayed crop heights were taken on headlands between sections 0 and 1 at the top of the field but weedy crop heights were measured near the bottom of the field. It is possible, however, that the dense growth of weeds on well fertilised plots encouraged the crop to grow taller in competition for light. If this is so then plot 2B(FYM) is the exception since this is as well fertilised as those plots receiving much chemical fertiliser.

Experiment 6

The effects of light intensity and nitrogen on Tripleurospermum maritimum and Stellaria media when grown in controlled environment

Earlier results have shown that the growth of both Tripleurospermum maritimum and Stellaria media is greatly improved with nitrogen. This does not account solely for the distribution of these weeds on Broadbalk. Tripleurospermum seeds are light sensitive and it seems also that the plants will not flower unless given sufficient light. Stellaria appears to be very little affected by either light intensity or daylength. It was decided to test the separate and combined effects of light intensity and nitrogen upon the two species, by using two Saxcil cabinets in which temperature, day length and light intensity could be controlled.

Materials and methods

The two Saxcil growth cabinets were set to give as near as possible identical temperatures, humidities and daylengths but different light intensities.

TABLE 23

Temperatures in the cabinets in °C

	Dry bulb		Wet bulb	
	Day	Night	Day	Night
Cabinet 8	14.3	10.3	11.5	9.2
Cabinet 9	14.2	10.1	11.3	9.0

Humidity

Relative himidity was set as 70% by day, 90% by night i.e. wet bulb depressions of 3°C and 1°C respectively.

Daylength

Both cabinets were lit between 09.00 and 23.00 hours i.e. 14 hour day with flourescent and tungsten filament lamps.

Light intensity

Cabinet 8 half standard light intensity with half the tungsten lights, 1200 lumens per sq. ft. i.e. 'low light'

Cabinet 9 full standard light intensity with all the tungsten lights 2500 lumens per sq.ft. i.e. 'high light'

The conditions in the cabinets were, as far as possible, chosen to simulaye an 'average' set of conditions during the period mid-March to the end of June.

The low light intensity, 1200 lumens per sq.ft. in cabinet 8 was close to the average for mid-March. The light intensity in cabinet 9 2500 lumens per sq.ft. was similar to the average for mid-April. It was hoped to use a higher intensity similar to that of midsummer but was not possible in these cabinets. Standard light intensity is approximately equal to 20% of full daylight at midday in midsummer but 16 hours standard light intensity = approximately to one full day in mid-summer.

The conditions imposed meant that plants in the high light intensity were receiving 148.68 cals/cm^2/day and those in 'low' light 71.32 cals/cm^2/day from visible light.

Experimental layout

5" plastic pots with saucers were filled with 1.3kg of Rothamsted soil as before. Each pot received an application of P and K and in addition half the pots received N (150ppm).
In each cabinet there were

2spp × 2 levels of N × 4 harvests × 4 replicates = 64 pots

Treatments

P and K. 0.58gm K_2HPO_4, dipotassium hydrogen orthophosphate dissolved in 20cc distilled water was added to each pot before planting.

Nitrogen 2.66gm NH_4NO_3, ammonium nitrate dissolved in 20cc distilled water was added to each of 64 pots before planting. The other 64 pots received 20cc distilled water.

Seeds, hand-collected on 5/8/70 from plants growing in a bean experiment on Rothamsted farm, were sown in boxes of Rothamsted soil. Stellaria seed was sown and covered with soil on 22/9/70 and Tripleurospermum sown but not covered, a day later. These seedlings were transplanted to the pots, two to a pot, sprayed with pyrethrins, placed in the cabinets after randomisation and kept watered every day.

During the experiment regular checks were kept on the temperature, humidity and light intensity in the cabinets with minor adjustments being made as necessary. The lights had to be turned off for two short periods in order to replace some flourescent tubes, but both cabinets were treated the same.

Towards the end of the experiment, union disputes caused power cuts of up to two hours but during power failure the cabinet doors were kept shut to minimise the changes in temperature and humidity.

Dry weights of each plant were recorded at four harvests taken during the experiment. For the first three harvests leaf colour was recorded using the Royal Horticultural Society's colour chart. For the fourth and last harvest leaf areas were measured, directly for Tripleurospermum and by subsampling and calculation for Stellaria (as before)

Results

Stellaria media

Dry Weight (Table 25b)

In the first harvest, the only significant effect was produced on plants without N, when those in high light were 88% bigger than those in low light.

The second harvest gave a 20% mean significant increase in dry weight with plants in high light. This increase was not significant in either plants given N or plants not given N but was only evident in the mean. There was a 19.6% increase in dry weight with addition

of N but this was only just significant (P = 0.05).

In harvest three, the dry weights of plants given N were significantly bigger than those not given N. The mean percentage increase being 127%. Variation in light intensity had no effect.

Addition of N again produced significant increases in the dry weight throughout harvest 4. The significant increase with N in high light was 199% and in low light 86%, but there was no significant light effect.

Leaf area (only measured in harvest four)(Table 26)

Addition of N produced a significant mean increase of 137% in leaf area. Light intensity and N interacted giving the greatest values for leaf area at high N and low light (see Table 24)

TABLE 24

Effect of N and light intensity on the leaf area of Stellaria media

(cm^2)

Fertiliser	N_0	N_1	Mean	
High light	122.7	347.1	234.9	
Low light	234.8	492.9	363.8	SE = 60.59
Mean	178.7	420.0	299.4	SE = 42.85

Stellaria media, therefore, had a slightly larger leaf area in low light than in high but when given N the leaf area in low light increased greatly.

Light intensity appeared to affect dry weight only when the plants were small and received no N. When the plants had plenty of N the effects of light intensity were nullified to some extent. The response to N was not evident early in the plant's life but the increase in dry weight became very marked at the third and fourth harvest. By the end of the experiment all but two plants had flowers or buds.

Tripleurospermum maritimum

Dry Weight (Table 25a)

In harvest one there were no significant differences between high and low light, or levels of N. Plants given N in high light were, however, 141% signigicantly bigger than plants receiving no N in low light.

In the second harvest high light significantly increased dry weight by 84% independently of N. Addition of N gave no effect.

At the third harvest, no - N plants were unaffected by light intensity, but in N-treated plants high light intensity resulted in a 28% increase.

TABLE 25a

Effect of light intensity and nitrogen on Tripleurospermum

	Dry weight in gm				
harvest	HL	HL & N	LL	LL & N	LSD
1	0.0053	0.0094	0.0039	0.0051	0.0059
2	0.776	0.794	0.361	0.492	0.149
3	1.608	3.545	1.211	2.758	0.24
4	1.759	3.570	1.898	4.145	0.76

TABLE 25b

Effect of light intensity and nitrogen on Stellaria

	Dry weight in gm				
harvest	HL	HL & N	LL	LL & N	LSD
1	0.0360	0.0222	0.0192	0.0257	0.014
2	1.446	1.692	1.173	1.440	0.36
3	2.839	6.232	2.551	5.994	1.022
4	3.198	7.001	3.778	7.029	1.84

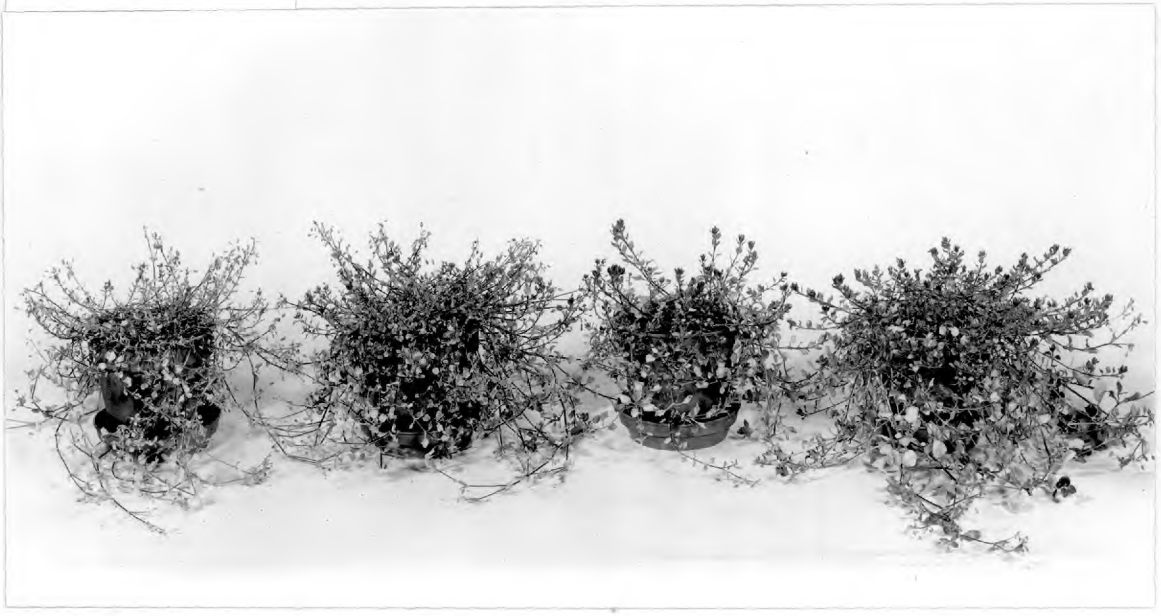
TABLE 26

Effect of light intensity and nitrogen on the leaf area of Tripleurospermum and Stellaria at the fourth harvest

	Leaf area (cm^2)				
Species	HL	HL & N	LL	LL & N	LSD
Tripleuros-permum	105.8	166.8	113.8	188.6	37.05
Stellaria	122.7	347.1	234.8	492.9	181.1

EFFECT OF LIGHT INTENSITY AND NITROGEN

Stellaria media



High light **High light & N** **Low light** **Low light & N**

Tripleurospermum maritimum



High light **High light & N** **Low light** **Low light & N**

In harvest four there was no effect of light intensity on dry weight but N produced a significant increase of 111%.

Leaf area (harvest four only) (Table 26)

The only significant effect was a leaf area increase of 62% from added N. Probably, as indicated in the dry weights, the high light requirement of these plants was disappearing by the fourth harvest and so no effect was seen upon leaf area at this stage.

Summary on dry weights and leaf areas

With dry weights, the increase with high light was only evident at high N when the plants were small. By the second harvest, the increase in dry weight with high light was very marked but independent of N. In the third harvest the two variates light intensity and nitrogen interacted to give the largest results at high N in high light. In the last harvest there was no response to light but only to N. There appears to be a critical period in the life of Tripleurospermum when high light intensity gives the most benefit to plant growth. This period may commence at seedling emergence or slightly later but appears to end when the plant is about ten weeks old. It is possible that this period is also critical for the formation of flowers since at the end of the experiment four plants in high light had flowering stems and buds but only one in the low light treatment.

Leaf colour

At the first three harvests leaf colours were compared with the Royal Horticultural Society's colour chart. In general the Stellaria leaves were a more yellow green (about shade 144) whereas Tripleurospermum leaves were more grey-green (about shade 137-38). As the experiment progressed comparison of colours became increasingly difficult since many of the Stellaria leaves turned yellow and many Tripleurospermum leaves turned reddish-brown particularly those not given N. In both cases, plants in high light tended to have paler or more discoloured leaves whereas those receiving high N tended to be greener and to stay greener longer.

Experiment 7

The effects of changes of light intensity upon Stellaria media and Tripleurospermum maritimum

As the Saxcil cabinets gradually became emptied a further experiment was set up to test the effect of changes of light intensity upon Tripleurospermum maritimum and Stellaria media.

Experimental procedure

5" pots were filled with Rothamsted soil as used before and each one was planted with two seedlings on 21/10/70, sprayed with pyrethrins and placed in the cabinets according to the following treatments for each species.

a) 2 pots - high light throughout
b) 2 pots - low light throughout
c) 2 pots - high light four weeks, low light four weeks
d) 2 pots - low light four weeks, high light four weeks

The two cabinets were running under exactly the same conditions as described in the previous experiment.

On 5/11/70 the plants in both cabinets were not growing well so that it was decided to add fertiliser. Accordingly 0.665gm NH_4NO_3 and 0.580gm K_2HPO_4 were carefully added to each pot and watered in. On 25/11/70 those pots whose treatment included a change in light intensity were moved and on 21/12/70 all pots were harvested, dry weights and leaf areas being measured.

Results

After analysis it was found that changes in light intensity and the two different light intensities in the experiment had produced no effect whatever on the dry weight or leaf area of Stellaria media.

The dry weight of Tripleurospermum maritimum was greatly affected by light intensity. The plants in continuous high light were 199% larger than those which had a change in light intensity

EFFECT OF CHANGES OF LIGHT INTENSITY

Stellaria media



High light **High light & low light** **Low light & high light** **Low light**

Tripleurospermum maritimum



High light **High light & low light** **Low light & high light** **Low light**

and 77% bigger than those given low light throughout. In the mean high light gave dry weight per plant a definite advantage.

High light throughout the experiment also increased the leaf area of Tripleurospermum. High light plants were 14% larger than low light, 83% and 74% bigger than the low light/ high light and the high/low light treatment respectively.

Since in both leaf area and dry weight high light treatment was best, it was expected that the combination treatments including high light would give better results than those plants in low light throughout. This was not so and, therefore, the change from one light intensity to another must in some way check the plant's growth.

The results of this experiment show clearly that Tripleurospermum is adversly affected by low light intensities when Stellaria media is not. This therefore goes further in explaining the distribution of these two species on Broadbalk.

Experiment 8

The effect of different types of shading on weeds.

Previous experiments have shown that reduced light intensity may affect the growth of weeds in pots. An experiment was therefore set up to test the effects of different types of shading.

Experimental procedure

Cylinders (7" diameter, 18" height) were made of clear cellulose acetate. These were painted with opaque black paint in the following patterns:-

1) completely black
2) vertical stripes 2cm wide, 2cm apart i.e. cutting off half the incident lateral light
3) horizontal stripes 2cm wide, 2cm apart i.e. cutting off half the incident lateral light
4) a combination of 2 and 3 giving a checked effect i.e. cutting off three quarters of the incident lateral light.
5) unpainted i.e. totally clear.

Six 5" pots with saucers were filled with the same soil as that used before and two weed seedlings were planted in each pot. One cylinder was placed round each pot, except one for which no cylinder was provided, for comparison. The pots with and without cylinders were then placed in a cool glasshouse and watered regularly. The cylinders were removed periodically and cleaned to remove the mud splashed up during watering.

Unfortunately it was not possible to replicate this experiment or to grow the two weed species Stellaria media and Tripleurospermum maritimum at the same time; the two sets of results are thus not comparable. The Tripleurospermum seedlings were planted on 15/10/70 and harvested on 28.1.71 whereas Stellaria seedlings were given a shorter growing period at a more favourable time, 11/2/71 to 22/4/71.

The cellulose acetate somewhat alters the quality of the light transmitted, permitting more light of the red than of other regions of the spectrum to pass through. However, the top of the cylinders was open to normal sunshine and the plants received this as they would do in a dense crop.

Results (Table 27)

It is evident from the results that Stellaria made much better growth in a shorter time than Tripleurospermum but this is most probably only due to the better growth season that the Stellaria plants were grown in.

The two plants growing in the black cylinder were very small indeed with Stellaria and, in Tripleurospermum, failed to survive. Obviously then the light reaching these plants was very low and below the critical level for Tripleurospermum.

With Tripleurospermum, the clear cylinder produced a beneficial effect (not significant) over the control with no cylinder. This was probably a sheltering effect, slightly raising the temperature and keeping the air more moist. The clear cylinder plants had dry weights significantly bigger than those of the cylinders with vertical or horizontal stripes or both. Shading decreased growth of Tripleurospermum but differences between the types of shading were insignificant and the depth of shading produced no significant effect until it reached the critical level when death resulted.

With Stellaria the beneficial effect of the cylinders was not observed. The open pots and clear cylinder plants were not significantly different but both were significantly different from all those cylinders with any type of shading. There was no significant difference between types of shading but, as would be expected, the 'check' cylinder reduced the dry weights somewhat as in Tripleurospermum. These, however, were only indications and in this experiment cannot be taken as 'results' since the experiment was not replicated.

TABLE 27

Effects of different types of shading on the two weed species

	Tripleurospermum maritimum		Stellaria media	
	Dry wt/plant	Dry wt/pot	Dry wt/plant	Dry wt/pot
No cylinder	0.059 0.048	0.107	0.590 0.385	0.975
Clear cylinder	0.150 0.143	0.293	0.541 0.308	0.849
Vertically Striped cylinder	0.034 0.023	0.057	0.070 0.050	0.120
Horizontally striped cylinder	0.029 0.018	0.047	0.081 0.105	0.186
Checked cylinder	0.012 0.008	0.020	0.068 0.030	0.098
Black cylinder	dead dead	-	0.005 0.010	0.015
Growing time	14 weeks		10 weeks	
Standard error	0.025		0.125	

One important result if these are regarded as valid is that Stellaria appeared to be sensitive to reduction in light. The plants in the experiment were very small when harvested and it may be that Stellaria is sensitive to light only when the plants are very small as indicated in the first cabinet experiment.

CHAPTER 5

Experiment 9

Field sampling to show the relationship between crop and weeds.

Fertiliser experiments have shown that different treatments of N, P and K affect the dry weight and leaf areas of Tripleurospermum maritimum and Stellaria media. It was decided, therefore, to try and find out in what ways the weeds are affected in the field, on different plots.

a) Height measurements

It was impractical to attempt height measurements on Stellaria media in the field firstly, because of the low-growing habit of the plants and secondly, because of the dry season, the plants were few and generally small. Height measurements were, therefore, made only on Tripleurospermum maritimum.

Height measurements were taken on 21st July 1970 on seven plots in all, on the unsprayed headland between sections seven and eight.

Five readings were taken at random from each side of the plots. Visual observations had suggested that plants in blank rows (two rows towards the sides of the plots are not drilled and act as guides for the combine at harvest) differed from those grown in the crop. Two sets of ten readings, one from the crop and one from the blank rows were accordingly taken. Crop heights were measured too.

TABLE 28

Crop and Tripleurospermum maritimum heights

Plot	Mean heights of 10 plants (cm) Tripleurospermum in blank row	Tripleurospermum in crop	Crop	in bl row % crop	in crop % crop
2B (FYM)	42.7	62.7	86.4	68.1	72.6
3 (none)	18.8	22.6	71.6	26.3	31.6
5 (P,K,MgNa)	29.7	35.1	71.3	41.7	49.2
6 (N_1P,K,MgNa)	36.8	50.1	79.9	46.1	62.7
7 (N_2P,K,MgNa)	53.0	52.9	82.3	64.4	64.3
8 (N_3P,K,MgNa)	50.7	58.8	82.6	61.4	71.2
9 (N_4P,K,MgNa)	42.2	55.9	80.0	52.4	69.4

Crop heights showed the same trend to increase in height with N as in Experiment 5. Plot 2B(FYM) was the tallest, 86.4cm, but Plot 9 (N_4PKNaMg) was again not as tall as expected probably due to its previous treatment with only N_1.

Tripleurospermum heights in the crop showed a strikingly similar trend to the crop while plants in blank rows, though shorter followed the same pattern. Only on plot 7 (N_2PKNaMg) were the heights of plants from the blank rows and from the crop similar eg. 53.0cm from blank row and 52.9cm in the crop. The greatest differences between crop and blank row plants was on plot 2B(FYM) when blank row plants were some 20cm shorter than those in the crop (62.7cm)

For each plot the heights of Tripleurospermum in the crop and from blank rows were calculated as a percentage of the height of the crop on that plot. This showed that as the crop grew taller the Tripleurospermum plants also grew taller but not proportionally so, for as the crop height increased the height of Tripleurospermum expressed as a percentage of the crop height also increased.

b) Measurements of dry weight, number and size of plants.

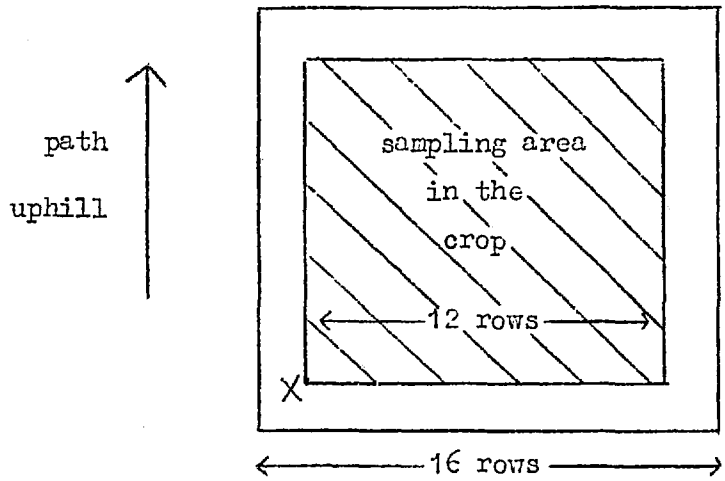
The results obtained from the previous experiment on height measurements had proved interesting so it was decided to extend the sampling and include dry weights and numbers of plants among the measurements.

Samples were accordingly taken from seven plots (2B(FYM), 3 (none), 5(P,K,NaMg), 6 (N_1PKNaMg), 7 (N_2PKNaMg), 8 (N_3PKNaMg) and 9 (N_4PKNaMg) and from blank and ordinary spaced rows on each plot, on 22/7/70. These samples were taken from the unsprayed headland between sections seven and eight on Broadbalk, because the weeds seemed more abundant here than on the unsprayed headland between sections eight and nine. This may have been because section seven grew beans in 1969 so this headland was fallowed as it was used for tractor turning.

Four samples from both the crop and blank rows were taken at random on each plot. Figure 12 shows a plan of the area on each plot where sampling was carried out.

FIGURE 12

Sampling area on the plots



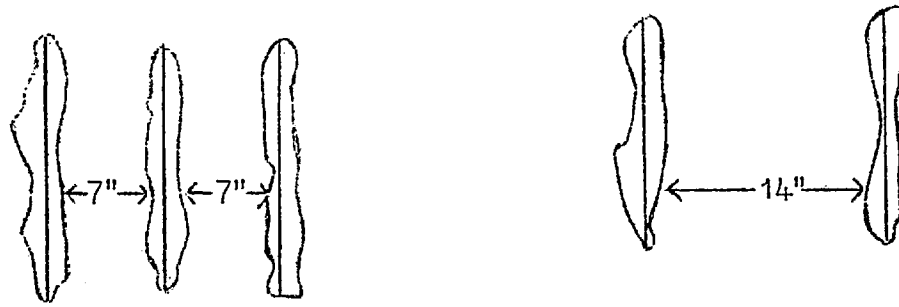
SECTION 8

The quadrats used for sampling were 12in long and 14in wide (ie. exactly two row widths or one blank row).

For random samples, two sets of random numbers were used to position the quadrats in the crop; the first gave the number of rows from the point X and the second the number of paces up the plot. In each case the quadrat was placed with its bottom left-hand corner on the given point. For blank row samples only one random point was required to give the position. The sides of the quadrat were placed along the middle of the rows as shown in figure 13.

FIGURE 13

To show the positioning of the quadrat in the rows.



Normal crop spacing

Blank row specing

Each sample was therefore, taken from an area 12" by 14", 168 sq.in. or 1050 sq.cm.

As the plants from each quadrat were collected great care was taken to include only those plants which were actually rooted within the area.

Samples were carefully labelled and returned to the laboratory where each sample was sorted after the roots had been removed. The plants were sorted into three categories as follows:-

A. Seedlings or plants with no flowers or flower initials.
B. Plants with flowers but with no branches from the base of the stem.
C. Plants with flowers and branches at the base of the stem.

These categories were found to be surprisingly consistent, very few plants intermediate between them being found. Several plants had obviously lost flower heads probably due either to handling, mechanical damage or the predations of animals. The heights and numbers of all the plants in each category were recorded and the total dry weights of each category measured.

A careful watch was kept during sorting for some evidence of the obvious differences in growth habit exhibited by Tripleurospermum in the glasshouse. However, they were not seen among the plants taken from among the crop. This was because the reduced light tended to draw the plants upwards even if their natural tendency was to spread outwards along the ground. Some plants along the sides of the plots, in areas not sampled did tend to spread outwards rather more but this was probably emphasised by their position.

Statistical analysis of the results showed that the categories used were indeed distinct and significantly different in all the variates analysed ie. height per plant, dry weight per plant and number of plants per sample (or per sq. meter.)

Categories A and B only were significantly different in dry weight per plant. Plant height and dry weight were significantly greater in Category C in blank rows. However, it was only plot 3 (none) that was most often significantly smaller than all the others in both height, dry weight and number of plants.

Height per plant (Table 30a)

The three chosen categories proved significantly different from each other. The plants in category B were significantly taller than those of category A or C in the crop but categories A and C were not significantly different except in blank rows.

TABLE 29

Heights of Tripleurospermum plants (cm)

Category	A	B	C	Mean
In crop	2.0	22.7	6.5	10.39
In blank rows	1.3	23.5	18.5	14.44
Mean	1.6	23.1	12.5	12.42

Only in category C were blank row plants significantly taller than 'in crop' plants but in the total mean over all plots and categories, blank row plants were 39% taller than 'in crop' plants.

This is contradictory to the results in the previous experiment when blank row plants were found to be shorter. It is probably because some of the smaller plants in the crop were overlooked when heights were measured in the standing crop and blank row plants were larger anyway.

In category A there were no significant differences between plots. All the plants were small, the biggest mean 4.25cm being on plot 2B(FYM) and the smallest 0.88cm on plot 9 (N_4PKNaMg).

In category B the plots fell into three significantly different groups: Group 1, plots 3(none) and 5 (PKNaMg) with a mean height of 13.3cm; Group 2, plots 2B(FYM), 6 (N_1PKNaMg) and 7 (N_2PKNaMg) mean height 24.5cm and Group 3, plots 8 (N_3PKNaMg) and 9 (N_4PKNaMg) mean height 30.8cm. The groups were all significantly different from each other. The increase in height over these three groups followed the increase in N fertiliser given.

Category C again divided into three groups but the reason for these was less clear. Plot 3(none) stood alone with a mean height of 0.88cm well below the others. Plots 2B(FYM), 5 (PKmin), 8 (N_3PKmin) and 9 (N_4PKMin) were now the next with a mean height of 12.1cm. Plots 6 (N_1PKmin) and 7 (N_2PKmin) were the tallest, mean height 19.0cm. The tallest plants were not produced on the plots with highest N but on those plots given only low levels of N.

Dry weight per plant (Table 30b)

Differences between categories again held good but the increase in dry weight between categories B and C was not significant in the mean although on plots 2B(FYM), 5 (PKNaMg), 6 (N_1PKNaMg) and 7 (N_2PKNaMg) category C was significantly bigger

than category B. Category B was 33.7% bigger than the mean of plants in category A; thus although the tallest plants occured in Category B, plants with the most dry matter occured in category C.

Significant differences between crop and blank row plants were obvious on many plots, blank row plants being 19.2% heavier than 'in crop' plants in the mean. Blank row plants were significantly heavier than 'in crop' plants in categories B and C but showed no differences in category A.

As in height there were no significant differences between plots in category A. In category B the plots fell into two groups: plots 3(none) and 5(PKNaMg) and plots 6(N_1PKNaMg), 7(N_2PKNaMg), 8(N_3PKNaMg) and 9(N_4PKNaMg) with plot 2B(FYM) not significantly different from either plot 5 or 6. Addition of N appeared to increase the dry weight of plants after their seedling stage.

In category C, plot 3(none) was well below the other plots with a mean of only 0.0125gm/plant. Then plots 5(PKNaMg)and 6(N_1PKNaMg) with plants of mean dry weight 0.474gm. (plot 2B(FYM) fell between these two groups with a mean of 0.343gm). Plot 7(N_2PKNaMg) was the best of all with a mean dry weight per plant of 0.665gm.

These results suggest that increase of fertiliser and decrease in light are the controlling factors here, and that only when these are in optimum balance will the category C plants reach their maximum weight ie. plot 7(N_2PKNaMg).

Number of plants (Table 30c)

Again the three categories held good, category B having significantly greater numbers of plants.

eg.	Category	No. of plants/sample	No of plants/sq.m
	A	0.71	6.8
	B	6.52	62.1
	C	0.54	5.1

Categories A and C were not significantly different in numbers. This distribution of plants over the three categories was probably because the main peak of germination was over and fewer plants were germinating. Those of category B were probably the survivors of the main germination peak and those of category C probably germinated earlier, while category A were the most recent arrivals.

There was no overall significant difference in numbers between 'in crop' and blank row samples but on plots 2B(FYM) and 3(none) samples from blank rows had a significantly greater number of plants per sq. meter

eg.	in crop	in blank row
2B (FYM)	30.2	38.1
3 (none)	8.8	15.9

This was probably caused by a better survival, rate in conditions of reduced competition.

In category A the numbers of plants on plots fell into two groups. In group one, plots 6(N_1PKNaMg),7(N_2PKNaMg),8(N_3PKNaMg), 9(N_4PKNaMg)the mean number of plants per sq. meter was less than 2.4. Plots 2B(FYM), 3(none) and 5(PKNaMg),however, had a mean number of plants per sq meter of 13.5. This may be explained by the fact that Tripleurospermum needs light for germination and at this stage of crop growth, the amount of light reaching the ground in highly fertilised crops was very small and so few seeds would be able to germinate. The large number of category A plants present on the very well fertilised plot 2B may be because plot 2B soil was particularly suitable for seed germination because of large additions of organic matter.

In category B, plot 3(none) had the smallest number of plants per sq. meter, 23.8, but plots 5(PKNaMg) and 9(N_4PKNaMg) had a mean of only 41.0 plants per sq meter, plot 7(N_2PKNaMg) had 71.4 plants per sq meter and plots 6(N_1PKNaMg), 8(N_3PKNaMg) and 2B(FYM) 85.7 plants per sq meter. This rather strange distribution of plants is

difficult to explain but was probably due to interaction of fertilisers and light availability, the best balance being achieved on plots 6(N_1PKmin) and 8(N_3PKmin) Plot 2B(FYM) probably had large numbers because additional seeds are brought in with the farmyard manure added to this plot.

In category C the numbers were all low, the largest being on plot 8(N_3PKmin); 10.8 plants per sq meter. Plot 3(none) had only 1.2 plants per sq meter. The other plots were similar ranging from 3.6 to 6.0 plants per sq meter. Large numbers of category C plants may reduce the number of category A plants by overshadowing them. However, this is not likely to reduce the category A numbers very greatly on poorly fertilised plots eg plot 3(no fertiliser) since very few category C plants occurred under these conditions. On better fertilised plots a much greater shading effect is produced by the crop.

Results showed that the shortest, lightest plants and smallest numbers of plants per sq meter occurred on plot 3(none) among the crop. The shortest plants with small amounts of dry matter were mainly placed in category A which included those plants with no flowers or flower initials. i.e. included seedlings.

Those plants with flowers and stems branching at the base ie Category C. were fewest in numbers. Taller plants with more dry matter occurred more often in blank rows than in the crop. Plot 8(N_3PKNaMg) had the greatest mean height per plant - 16.0cm, plot 7(N_2PKNaMg) the greatest mean dry weight per plant - 0.32gm and plot 2B(FYM), the greatest number of plants per sq.meter -34.1

Lack of any fertiliser, therefore, gave small short plants in small numbers. Added N_2 seemed to provide good conditions producing the largest heaviest plants whereas N_3 tended to make the plants taller. This was probably caused by the increased height of the crop, cutting down the light available and causing the weeds to grow taller.

TABLE 30

Tripleurospermum maritimum samples from the field

a) Mean height per plant (cm)

Plot	In crop				In blank rows			
	A	B	C	mean	A	B	C	mean
2B(FYM)	4.1	22.0	0	18.7	4.4	22.7	18.1	21.3
3 (none)	0.8	9.5	0	8.5	2.1	12.8	1.8	8.2
5 (PKMgNa)	1.7	18.1	4.5	15.7	1.9	12.7	18.3	13.4
6 (N_1PKMgNa)	0.5	25.1	16.5	24.9	1.0	26.1	19.3	26.4
7 (N_2PKMgNa)	2.3	25.9	10.5	25.7	0	26.3	22.1	28.9
8 (N_3PKMgNa)	3.0	29.7	13.8	28.8	0	33.0	16.6	33.9
9 (N_4PKMgNa)	1.8	28.7	0	27.9	0	31.9	25.8	32.7

b) Mean dry weight per plant (gm)

Plot	In crop				In blank rows			
	A	B	C	mean	A	B	C	mean
2b(FYM	0.03	1.47	0	0.15	0.01	1.55	0.81	0.22
3 (none)	0.005	0.11	0	0.05	0.02	0.31	0.03	0.08
5 (PKMgNa)	0.02	0.42	0.03	0.07	0.01	0.28	2.16	0.33
6 (N PKMgNa)	0.005	1.60	0.24	0.25	0.01	2.94	0.71	0.39
7 (N PKMgNa)	0.01	1.23	0.32	0.21	0	3.42	1.67	0.57
8 (N PKMgNa)	0.01	2.67	0.58	0.27	0	3.59	1.65	0.51
9 (N PKMgNa)	0.003	0.70	0	0.15	0	1.59	0.80	0.44

c) Number of plants per sq. meter

Plot	In crop				In blank rows			
	A	B	C	mean	A	B	C	mean
2B(FYM)	21.9	69.5	0	90.5	9.5	98.0	7.6	114.3
3 (none)	9.5	17.1	0	26.7	14.3	31.4	2.9	47.6
5 (PKMgNa)	12.4	45.7	2.9	61.9	14.3	33.3	9.5	57.1
6 (N PKMgNa)	2.9	81.0	4.8	85.7	2.9	90.5	4.8	98.1
7 (N PKMgNa)	2.9	66.7	2.9	69.5	0	76.2	7.6	60.0
8 (N PKMgNa)	4.8	98.1	4.8	107.6	0	79.0	17.1	95.2
9 (N PKMgNa)	2.9	42.9	2.9	45.7	0	42.9	9.5	52.4

Experiment 10

Preliminary experiment on competition between crop and weeds

Before starting on a large scale competition experiment it was necessary to carry out a small experiment to find a suitable 'pattern' of plants to use in competition studies. The literature has shown that workers have used all sorts of patterns from rows to rectangles, circles to hexagons. So it was decided that it would be best to test some of these patterns with this set of plants and see which would be the most suitable. Owing to the growth habit of Stellaria it was impractical to think of adopting a complicated pattern since it would be impossible to separate the plants at the end of the experiment. Two basic patterns were accordingly adopted and a random arrangement was also used.

Experimental procedure

Sixteen seed boxes (plastic) 14 x 9 x $2\frac{1}{2}$" deep were filled with 5Kg soil as used before. 5.11g NH_4NO_3 and 2.23g K_2HPO_4 were added to each box giving a final concentration of 150ppm N, 200ppm K and 103ppm P.

Cardboard templates of patterns for seeding were made as follows :-

1) Wheat rows: 3 rows, $2\frac{1}{2}$" apart, 2" from the box edge, 6 plants per row.
2) Weed rows: 4 rows, $2\frac{1}{2}$ - $2\frac{1}{4}$" apart, 1" from the box edge 7 plants per row.
3) Weeds random: random pattern of 28 plants.
4) Circular pattern: 1 plant in the centre, 6 at equal distances round it.

Combinations of these templates gave eight different arrangements and 18 day-old seedlings were planted into the following arrangements on 10/2/71.

a) Wheat rows and Stellaria rows
b) Wheat rows and Tripleurospermum rows
c) Wheat rows and Stellaria random
d) Wheat rows and Tripleurospermum random

continued...

e) One wheat and circular Stellaria
f) One wheat and circular Tripleurospermum
g) Circular wheat and one Stellaria
h) Circular wheat and one Tripleurospermum

The boxes were randomised in two blocks and kept in a cool glasshouse and watered regularly. The plants were all harvested on 22/4/71 since this was to be only a short term experiment. Unfortunately and for some inexplicable reason, many of the wheat plants failed to survive and insufficient replacements were available;. thus the results were not as valuable as it was hoped they would be.

Results

The results proved extremely difficult to analyse due to the failure of many of the plants.

In general the dry weight per box depended upon the number of plants in the box, the largest number producing the greatest dry weight as might be expected. The dry weight per plant was more useful.

Wheat

The largest dry weight per plant was in the treatments with one wheat plant and six weed plants. Six wheat plants and one Tripleurospermum also gave a good weight per plant for wheat. Wheat seemed to compete fairly well with Tripleurospermum but not so well with Stellaria. The low dry weight per plant in patterns with rows of wheat was probably due as much to intra specific as to interspecific competition and to the reduced volume of soil per plant.

Tripleurospermum maritimum and Stellaria media

Again the dry weights per plant were greatest in patterns with a 1:6 or 6:1 ratio. When grown in larger numbers in rows of wheat the dry weights were low.

The results of this experiment were not good but there was not time to repeat it. However, the results did show that patterns containing large numbers of plants did not give good results (due, in part to increased possibility of plant mortality) and were difficult to handle and analyse. It was, therefore, decided to use the 6:1 ratio patterns for a larger more complicated competition experiment.

Experiment 11

The effect of fertilisers upon the competition between weeds and wheat

The previous competition experiment was designed to test different patterns for use in competition experiments. However, due to the death of many plants, it was not as successful as hoped and so the choice of patterns for this experiment was not made much easier. The circular pattern where one plant was surrounded by six others seemed a suitable choice and is also easier to use in pots.

Experimental procedure

128 7" plastic pots with saucers were filled with 5Kg soil as before. 1.295g KCl were added to all pots in 40cc distilled water since competition for K was not to be tested. (100ppm K)

N (150ppm), 5.11g NH_4NO_3 was added to half the pots, and P (100ppm), 2.24g solid Ca $(H_2PO_4)_2 2H_2O$ to half the pots, to give all possible combinations of N and P. ie. 0, N, P, NP.

Eight patterns of weeds and wheat were used, these being replicated twice and providing two harvests.

Patterns: (see photographs)

a) 1 Tripleurospermum, 6 Tripleurospermum
b) 1 Tripleurospermum, 6 wheat
c) 1 Tripleurospermum, 6 Stellaria
d) 1 Stellaria, 6 Stellaria
e) 1 Stellaria, 6 wheat
f) 1 Stellaria, 6 Tripleurospermum
g) 1 wheat, 6 Stellaria
h) 1 wheat, 6 Tripleurospermum

Stellaria and Tripleurospermum were sown into these patterns pn 12/3/71 and thinned out as necessary. The wheat was sown separately on 30/3/71 and transplanted on 16/4/71. Two harvests were taken on 12/5/71 and 9/8/71, eight and twenty weeks after sowing respectively and dry weights in gm were recorded. The wheat used was spring wheat Kolibri (Rothamsted farm 1969).

Results

Some treatments showed poor germination and some plants died during the experiment but were not replaced since this would have upset the competition and disturbed the fertiliser balance. The death of some plants may have been attributable to competition but in some cases other factors must have been acting. The pots receiving N alone seem to have been particularly prone to loss of plants and poor germination and it is possible that N in large amounts has a deleterious effect upon small seedlings and may even depress the germination. (Sinyagin and Teper 1967)

This loss of plants made the final analysis more difficult and with the loss of single plants it was impossible to separate the interactions. Great differences in weights of plants also caused a problem but this was partly overcome by analysing the results on a Log_{10} scale.

TABLE 31

Effect of fertilisers and competition on Tripleurospermum

NOTE: Standard errors have not been adjusted for missing values.

a) Effect on $\log_{10}$ dry weight of six Tripleurospermum plants at the first harvest

Competition from	Log dry weight of six Tripleurospermum				
	0	P	N	NP	Mean
One Tripleurospermum	0.1238	0.4530	-0.6576	0.4703	0.1199
One Stellaria	0.0790	0.5136	-0.9120	0.6324	0.0782
One wheat	-0.0633	0.5032	-0.7101	0.5073	0.0593

SE of treatment means = 0.0787

b) Effect on $\log_{10}$ dry weight of six Tripleurospermum plants at the second harvest

Competition from	Log dry weight of six Tripleurospermum				
	0	P	N	NP	Mean
One Tripleurospermum	0.899	0.889	1.055	1.402	1.0836
One Stellaria	0.788	0.774	1.141	1.284	0.9966
One wheat	0.650	0.826	0.741	1.172	0.8472

SE of treatment means = 0.202

c) Effect on $\log_{10}$ dry weight of one Tripleurospermum plant at the first harvest

Competition from	Log dry weight of one Tripleurospermum				
	0	P	N	NP	Mean
Six Tripleurospermum	-0.6131	-0.0353	-0.5469	-0.1089	-0.3260
Six Stellaria	-0.8389	-0.2658	-0.7180	-0.2800	-0.5257
Six wheat	-0.4702	0.2414	-0.4310	-0.2291	-0.2222

SE of treatment means = 0.1183

d) Effect on $\log_{10}$ dry weight of one Tripleurospermum plant at the second harvest

Competition from	Log dry weight of one Tripleurospermum				
	0	P	N	NP	Mean
Six Tripleurospermum	0.398	-0.303	0.009	0.133	-0.0072
Six Stellaria	0.351	0.543	0.109	-0.481	0.1305
Six wheat	0.250	0.723	0.347	0.205	0.3814

SE of treatment means = 0.217

Tripleurospermum maritimum

In the first harvest, the dry weight of six Tripleurospermum plants was not significantly affected by any single plant if no fertiliser was provided. Addition of N significantly decreased the dry weight in all patterns while P significantly increased it, whether N was given or not. (Table 31a)

None of the single plants affected the dry weight of six Tripleurospermum plants in the second harvest if no fertiliser was given. Addition of N improved the dry weight except when wheat was also grown. Giving N and P, significantly increased the dry weight when grown with wheat or Tripleurospermum but not with Stellaria. (Table 31b)

In the first harvest all plants were competing for P but none was more successful than the others. N was deleterious to all the small plants. By the second harvest this affect had vanished and Stellaria and Tripleurospermum were competing for N. If this was plentiful P improved the growth. Wheat and Tripleurospermum were, on the other hand, competing mainly for P and, when a good supply was available, N improved the growth of Tripleurospermum.

In the first harvest, when no fertiliser or just N was given, the dry weight of one Tripleurospermum plant was significantly decreased by six Stellaria plants. Addition of N significantly decreased, although P improved, the dry weight of single plants no matter which plants were grown with it. Given P, the deleterious effects of N were slightly alleviated except when six wheat plants were grown, (Table 31c)

The dry weight of one Tripleurospermum was significantly decreased, at the second harvest, by six Stellaria, or six Tripleurospermum plants when both N and P were given. P alone decreased the dry weight when six Tripleurospermum plants were grown, but increased it when six wheat plants were included in the pattern. (Table 31d)

EFFECT OF FERTILISERS AND COMPETITION ON *TRIPLEUROSPERMUM MARITIMUM*

Seven Tripleurospermum plants per pot



No fertilisers P N PN

Six Tripleurospermum surrounding one spring wheat plant



No fertilisers P N PN

As for six Tripleurospermum plants, P improved the dry weight of single plants and N decreased it regardless of the other plants grown, at the first harvest. Competition was clearly, mainly for P except when wheat was grown. In the second harvest, competition was again mainly for P, but when P was given the single plant did not compete well with six of the same species. If both N and P were given the single plant suffered most when grown with six Stellaria. This is probably because, at this stage in the life of Stellaria, its early requirement for P has been partially replaced by an N requirement. (see experiment 1 and 2) The N requirement is fulfilled, the plant increases in size, requiring more P depriving the single Tripleurospermum which still needed quantities of P. Stellaria was the most and wheat the least formidable competitor throughout.

Stellaria media

In the first harvest, P tended to increase the dry weight of six Stellaria plants and N significantly decreased it, particularly if one Tripleurospermum plant was also grown. Addition of P nullified the deleterious effect of N no matter which plants were included in the pattern, (Table 32a).

N gave a significant increase in the dry weight of six Stellaria plants in the second harvest, and this increase was maintained when P was added. The increase was greatest when one Tripleurospermum plant was included in the pattern. (Table 32b)

Once again, the young plants were harmfully affected by N and beneficially by P. Later N gave an increase in dry weight which was particularly noticeable when a single Tripleurospermum plant was in competition. Tripleurospermum was the least formidable competitor while single Stellaria and wheat plants competed equally well with six Stellaria except when N and P were given, when Stellaria became the stronger.

EFFECT OF FERTILISERS AND COMPETITION ON *STELLARIA MEDIA* 9/6/71

Seven stellaria plants per pot



No fertilisers P N PN

Six Stellaria surrounding one spring wheat plant



No fertilisers P N PN

TABLE 32

Effect of fertilisers and competition on Stellaria

NOTE: Standard errors have not been adjusted for missing values.

a) Effects on $\log_{10}$ dry weight of six Stellaria plants at the first harvest

Competition from	$\log_{10}$ dry weight of 6 Stellaria				
	0	P	N	NP	Mean
One Tripleurospermum	0.457	0.689	-0.396	0.907	0.4143
One Stellaria	0.430	0.745	-0.020	0.857	0.5030
One wheat	0.327	0.586	0.088	0.704	0.4263

SE of treatment means = 0.207

b) Effects on $\log_{10}$ dry weights of six Stellaria plants at the second harvest

Competition from	$\log_{10}$ dry weight of 6 Stellaria				
	0	P	N	NP	Mean
One Tripleurospermum	1.0727	0.9466	1.6865	1.7160	1.3554
One Stellaria	0.9823	0.8992	1.4226	1.6788	1.2454
One wheat	0.8574	0.8919	1.3639	1.7610	1.2186

SE of treatment means = 0.0767

c) Effect on $\log_{10}$ dry weight of one Stellaria plant at first harvest

Competition from	$\log_{10}$ dry weight of one Stellaria				
	0	P	N	NP	Mean
Six Tripleurospermum	0.021	-0.020	-1.699	-0.416	-0.528
Six Stellaria	-0.630	-0.538	-1.001	-0.420	-0.647
Six Wheat	-0.481	0.370	-0.531	0.076	-0.142

SE of treatment mean = 0.410

d) Effect on $\log_{10}$ dry weight of one Stellaria plant at second harvest

Competition from	$\log_{10}$ dry weight of one Stellaria				
	0	P	N	NP	Mean
Six Tripleurospermum	0.6197	0.5623	1.0170	1.2440	0.8608
Six Stellaria	0.1898	0.1460	0.3766	0.8331	0.3864
Six wheat	0.7583	0.8497	1.1153	1.1441	0.9668

SE of treatment means = 0.1215

TABLE 33

Effects of fertilisers and competition on spring wheat

NOTE: Standard errors have not been adjusted for missing values.

a) Effect on $\log_{10}$ dry weight of six wheat plants at the first harvest

Competition from	$\log_{10}$ dry weight of 6 wheat				
	0	P	N	NP	Mean
One Tripleurospermum	-0.450	-0.087	missing	0.076	-0.005
One Stellaria	-0.270	-0.055	-0.268	-0.500	-0.394

SE = not quoted as it is not comparable due to number of missing values.

b) Effect on $\log_{10}$ dry weight of 6 wheat plants at the second harvest

Competition from	$\log_{10}$ dry weight of 6 wheat				
	0	P	N	NP	Mean
One Tripleurospermum	1.2964	1.0992	1.3588	1.7361	1.3726
One Stellaria	1.0342	1.0628	1.2803	1.71158	1.2733

SE of treatment means = 0.0756

c) Effect on $\log_{10}$ dry weight of one wheat plant at first harvest

Competition from	$\log_{10}$ dry weight of one wheat plant				
	0	P	N	NP	Mean
Six Tripleurospermum	-0.209	-0.196	-0.585	-0.036	-0.2566
Six Stellaria	-0.181	0.063	-1.155	-0.141	-0.3534

SE of treatment means = 0.178

d) Effect on $\log_{10}$ dry weight of one wheat plant at second harvest

Competition from	$\log_{10}$ dry weight of one wheat plant				
	0	P	N	NP	Mean
Six Tripleurospermum	1.072	0.762	1.300	1.222	1.089
Six Stellaria	0.913	0.613	0.695	0.901	0.781

SE of treatment means = 0.290

In the first harvest, dry weight of single Stellaria plants was not significantly affected by P, but when six wheat or six Tripleurospermum plants were included in the pattern, N significantly decreased the dry weight, Tripleurospermum having the greatest effect. (Table 32c)

In the second harvest, dry weights of single Stellaria plants were much improved with NP and, except when six Stellaria plants were grown, N alone increased the dry weight. No matter what the fertiliser treatment, six Stellaria plants gave a single plant dry weight significantly lower than those grown with six wheat or Tripleurospermum.

P did not improve growth at the first harvest but this may be because most of the P was absorbed by the other six plants. Once again, N proved deleterious to young plants. Wheat had the least effect upon a single Stellaria when any fertiliser was given. Later Stellaria became its own most formidable competitor while Tripleurospermum gave the least effect.

Wheat

In harvest one, no wheat plants grew in the N treatment and many were missing from the others. The standard error calculated from the remaining results is not an accurate reflection of these results, and has not been quoted. However, Table 33a shows that P gave an increase in the dry weight of six wheat plants and N, a probably decrease in dry weight.

In the second harvest, addition of P, N, and NP increased the dry weight of six wheat plants with one Tripleurospermum but with Stellaria P had no effect. The six wheat plants grown with Stellaria were significantly smaller than with Tripleurospermum when no fertiliser was given. (Table 33b)

Throughout, Stellaria proved a stronger competitor with wheat than Tripleurospermum. P improved and N decreased the dry weight in young plants and both N and P improved it in older plants.

Single wheat plants improved in the first harvest when provided with P but their dry weight decreased with N, particularly when six Stellaria plants were also grown. Addition of P nullified the effect of N to some extent. (Table 33c)

In the second harvest no significant effects were seen but the dry weights of single wheat plants tended to be smaller when grown with Stellaria particularly in the N - treatment. (Table 33d)

Again Stellaria proved to be the strongest competitor throughout and affected the wheat plants most in the N-treatments.

The ear yield of wheat per treatment was not statistically analysed but results suggested that addition of N and P gave the highest yield over all patterns. N alone or no fertiliser gave the next highest and P alone gave the lowest yield.

The highest yields were when six wheat plants were grown with one Tripleurospermum plant and these results were barely significantly different from those obtained when one Stellaria replaced the Tripleurospermum. Six Tripleurospermum and one wheat gave a lower yield as would be expected but six Stellaria plants reduced the single plant yield much more.

From these results it seems probable that in the field an infestation of Stellaria will produce a much greater effect upon the crop than one of Tripleurospermum. However, it is unlikely that sufficient numbers of the weeds would occur to seriously decrease the yield since all the weeds would be of different ages and those germinating later would not compete so effectively with the crop as those grown in this experiment.

Throughout the experiment, it was obvious that the most efficient and vigorous competitor was Stellaria media. It competed successfully with both Tripleurospermum maritimum and spring wheat particularly when P was low in the first part of the experiment. Most of the significant differences due to Stellaria showed up when it was in the majority but a single Stellaria plant did compete well with six wheat or Tripleurospermum plants during the first few weeks.

Wheat generally proved to be a poor competitor particularly with Stellaria. Wheat also suffered, in most cases, if six Tripleurospermum plants were grown with it.

Tripleurospermum plants competed fairly successfully with wheat when in the majority. It was generally unsuccessful when grown with Stellaria except in the first part of the experiment when no N was provided. Then it managed to hold its own and even decreased the dry weight of six Stellaria plants.

Stellaria is such a good competitor that in competition with plants of the same species, some may suffer drastically. The single plants in the last part of the experiment decreased in dry weight most when grown with six of the same species.

In all the pots competition was taking place and sometimes the reasons for the competition were obvious from the results of the experiment. In others, it was difficult to separate the effect of fertilisers from the species effects but sometimes it was obvious that competition was mainly for certain fertilisers. (see next para.) Observations suggested that other factors such as light and space may be involved in competition. These came into play in particularly well-fertilised pots in which the plants grew well.

In early growth competition for P was the most important. Provided P was given all plants grew well, particularly if provided with N as well. If P was not available then competition

was evident. Stellaria tended to do best in competition for P and wheat did not seem to require or be able to absorb so much, so it proved less competitive in low P conditions.

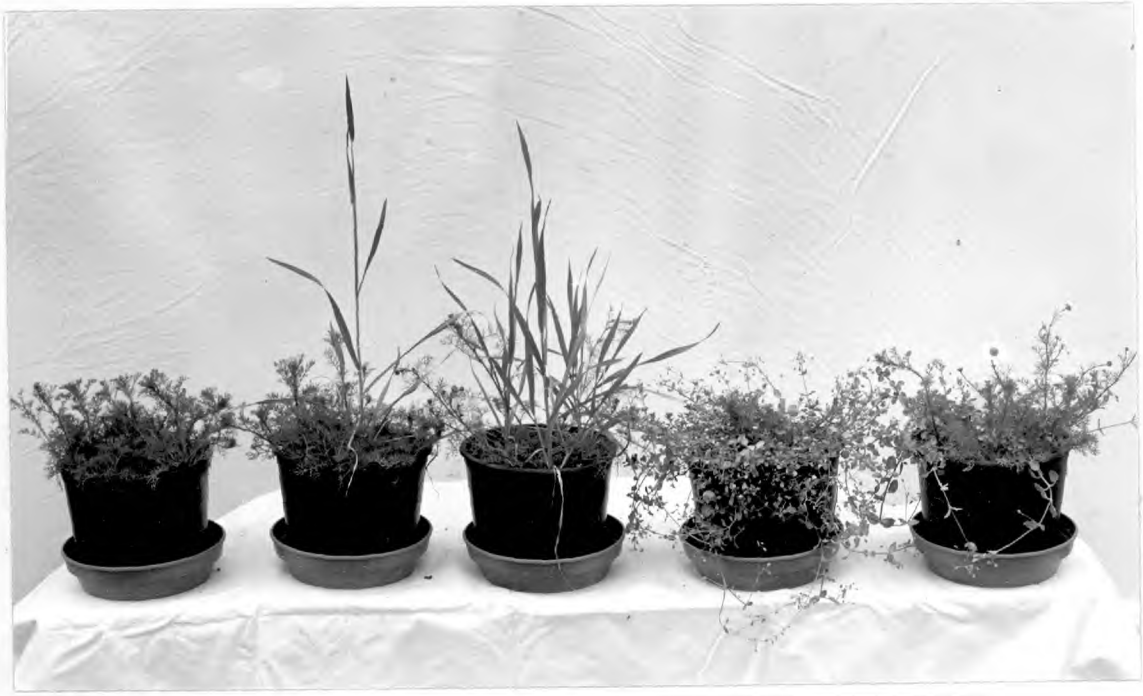
The competition for P between Stellaria and Tripleurospermum was not evident in the second harvest but there was an obvious competition for it between wheat and Stellaria. Competition for N was also evident and again Stellaria proved the most vigorous competitor particularly when six plants were grown. However, a single wheat plant decreased the dry weight of six Tripleurospermum plants more than a single Stellaria. This may involve light as well as fertiliser competition although one Tripleurospermum plant was less affected by six wheat plants than by six Stellaria or Tripleurospermum.

These results suggest that Stellaria media will produce its greatest effect upon the crop in low phosphate conditions, particularly if plenty of N is available. It would therefore be adviseable to provide ample P and then at least although a lush crop of Stellaria will probably result the wheat will not suffer so much.

PATTERNS OF WEEDS AND WHEAT USED IN THE COMPETITION EXPERIMENT

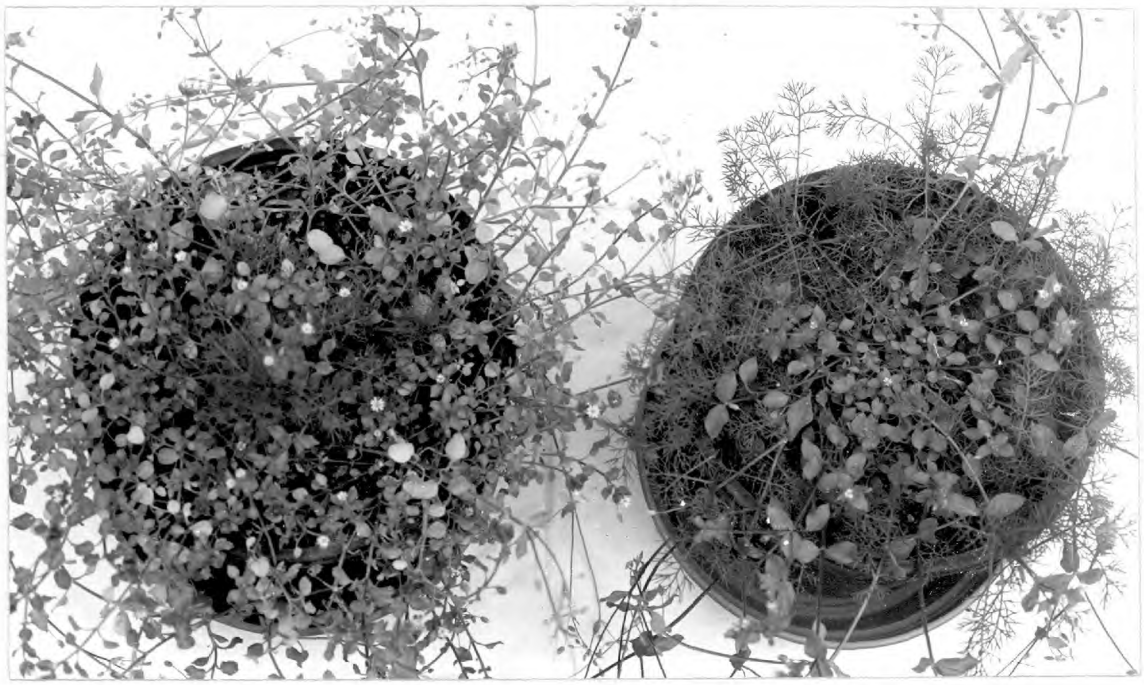


1s6s 1w6s 1s6w 1s6t 6s1t



1t6t 1w6t 1t6w 1t6s 1s6t

Tripleurospermum and Stellaria grown together in competition



6S1T

1S6T

CHAPTER 7

Variation in Weeds

Genetical variation and morphological plasticity, characteristics of many weed species,are often the reason for their success. Stellaria media and Tripleurospermum maritimum are both very variable.

Visual observations

During pot experiments in the glasshouse it was noticed that the plants differed in several characters. At first this was thought to be an effect of the treatments but closer examination showed that variation within treatments was as noticeable as variation between them.

Stellaria media

Variations in leaf size, shape, colour and possibly thickness were observed. The first two appeared to be in some way related since larger leaves were of a more circular shape whereas smaller leaves were more pointed. Some colour variations were brought about by treatments eg. plants receiving much N were darker green, but plants under the same treatment did differ in colour considerably. Differences in leaf thickness are not easy to see or to measure but there appeared to be differences.

The production of sideshoots also varied. Some plants produced large numbers of side shoots at each node of the main stem. Their leaves tended to remain fairly small and the side branches except the first two from the cotyledon node did not elongate much. Some plants produced fewer, larger side shoots whereas others seem to have only side shoot initials which showed no inclination to elongate unless the main shoot was damaged.

Some variation in the mode of growth was observed. Many plants were quite clearly adpressed to the surface of the soil, many

adventitious roots being produced from nodes, with only the tips of the branches turning upwards. Others seemed to grow mainly vertically, only the longest branches, being too weak to remain upright, becoming prostrate.

Sinha (1965) suggested that Stellaria media was a tetraploid formed from Stellaria pallida and S. neglecta and Haskell (1949) observed variations in the number of stamens in Stellaria media. These and other observations suggest that variations, although affected by external conditions, mar arise from genetic variation within the plants.

Tripleurospermum maritimum

This also shows many morphological differences but these are not as noticeable in early life. The first two true leaves may be strap-like in appearance while in other seedlings the first two leaves may be several-times divided. The true leaves are deeply divided with only narrow strips of lamina. Examination shows that the width of these varies considerably and in such cases it is likely the thickness of the lamina varies too, playing an important part in the rate of photosynthesis. The leaves also show different amounts of subdividing being either bi- or tri-pinnate. Leaf colour varies tooalso the rate and number of side shoots produced.

Plants under identical treatments in the glasshouse showed variations in the time of flowering, size of flowers, in height, colour and angle of flowering stem. Most plants had near-vertical flowering stems but some were very bushy and almost prostrate, not due to some external condition (eg. water stress) but rather to some internal factor. (see photos of variation within pots).

VARIATION IN WEEDS

Variation in *Tripleurospermum maritimum* when grown in Saxcil cabinets



High light High light & N

Variation in *Stellaria media* when grown in Saxcil cabinets



High light & N

Variation in *Tripleurospermum maritimum* in the fertiliser experiment

Variation between replicates



N_2 P_1K_2 N_2K_2

Within pots



N_2P_1 $N_1P_2K_1$ P_2 N_1P_1

CHAPTER 8

D I S C U S S I O N

'And some (seeds) fell among thorns, and the thorns sprang up and choked them' Matthew XIII vv 7.

The history of weeds and their effects upon cultivated crops has long been known but it is only in the past 50 years that scientific interest has really been aroused. Many new methods and chemicals have been developed to control weeds and new varieties of crop plants bred, but still the problem of weeds remains, although today's problem weeds are different from those of 50 years ago.

Tripleurospermum maritimum ssp. inodorum and Stellaria media are now important weeds. Both occur widely on cultivated land but the habitat to which these studies is particularly related is rather specialised. The experimental field, Broadbalk, has been treated with the same fertilisers on the same plots for almost 130 years, and this has produced characteristic weed floras. Both weeds occur throughout the field but are more important on certain fertiliser treatments. Experiments were carried out in an attempt to answer the following questions and to discover a little about the general biology of these two weed species.

1) What are the direct effects of fertilisers on the weeds and how closely do these correspond with the distributions of the weeds between different plots?
2) How far do data on growth on differently fertilised plots correspond with growth in fertiliser experiments?
3) What other environmental factors are important?
4) What is the effect of competition?
5) How is the ecology of the weeds affected by their annual cycle?

Fertiliser experiments in the glasshouse and observations in the field have shown that although both Tripleurospermum maritimum and Stellaria media can grow and set seed in soil with very little additional nutrients both benefit from additions of certain fertilisers. Experiments 1 and 2 have shown that phosphate greatly improves the growth of both weeds during their early life. In Experiment 2, the results of the first harvest showed that plants not given additional P had dry weights much smaller than those provided with P. In Experiment 3, this was demonstrated clearly in both species. However, both weeds, if provided with P later, recovered and grew well.

Growth without P was sparse; the mature leaves were slightly chlorotic; young leaves bright green (McAvoy and Gold 1970) and fewer flowers were produced. Atkinson and Davison (1971) have demonstrated that phosphate deficiency drastically affects the growth and may even prevent flowering in Epilobium montanum L. P deficiency also affected time toflowering, individual seed weight and number, and seed viability. Hammerton and Nuttall (1971) showed that the number of inflorescences, seed production and seed weight of Polyganum lapathifolium were drastically reduced under low nutrient regimes. Although growth of Tripleurospermum and Stellaria was undoubtedly retarded by low P levels, it is unlikely that concentrations of P on Broadbalk, even on plots not receiving additional P eg. Plot 10(N_2) would be low enough to bring about such drastic effects on the weeds as those described. It is unlikely, therefore, that P seriously influences the distribution of these two weeds on Broadbalk except perhaps on plots 3(no fertiliser) and 10(N_2) when low concentration of P may exert some influence upon the growth and production of seeds. P had little or no effect upon other plants unless they were already deficient in P (Experiment 3), then addition of P improved the growth.

Nitrogen tended to retard the growth of seedlings of both Tripleurospermum and Stellaria. Tripleurospermum was particularly

affected when no additional P was available. There were indications (Experiment 11) that germination (particularly in Tripleurospermum) was adversely affected by N.

In the glasshouse, the weeds benefitted less from P as they grew older and N came to be the most effective in improving growth, particularly of Stellaria. This response to nitrogen agreed well with the observations on Broadbalk. Stellaria media was plentiful on plots with nitrogen and the numbers increased with added N. (Plots 5, 6, 7, 8) Plot 9 (N_4PKNaMg) did not have the highest numbers of Stellaria as expected but this is probably because of its previous low N treatment given as nitrate of soda and not ammonium nitrate.

Tripleurospermum also benefitted by addition of N in later life. Broadbalk plots given N support large numbers of Tripleurospermum plants but increase in N does not increase the numbers as in Stellaria.

The high N plants were dark green (in the glasshouse experiments) but tended to wilt very easily. However, if the crop acts as a windbreak, evapotranspiration will be favourably affected and moisture conserved, (Shah & Kalra 1970) so that high N plants will rarely be subject to wilting in the field.

Potassium had no effect upon Stellaria (except when the plants were very young) but depressed the growth of Tripleurospermum especially when the treatment included N_2 and no P. Germination was also poor in this treatment. Sinyagin and Teper (1967) showed that when they grew species of Matricaria in different concentrations of fertiliser solutions, 71% of the seeds germinated in 0.01 eq/l KNO_3 but only 22% in 0.1 eq/l KNO_3.

Blaser and Brady (1950) demonstrated that weeds accumulated more K than grasses and that when given extra K or N they accumulated still more K. Shah and Kalra (1970) showed that windbreaks improved N uptake in some plants. It may be that the wheat crop

acts as a windbreak, improving N uptake and, therefore, K uptake. If K is present in the soil in large amounts then the amount of K taken up by plants may reach toxic proportions. This may happen in Tripleurospermum particularly if it is less tolerant of high K conditions.

Fertilisers on Broadbalk certainly influence the distribution of these two weeds. Stellaria is abundant on plots given N and the numbers increased with increase in N. Tripleurospermum also grows well on N-fertilised plots provided P is available but the larger amounts of N do not increase the numbers. Tripleurospermum did not grow well in the glasshouse when only K_2 and N were provided but on Broadbalk only plot 20(N_2KNaMg) has a similar treatment, and this plot is only a half plot at the side of the field so does not provide a good comparison. Both weeds prefer plots which have added P.

Chapter 5 compared the growth of Tripleurospermum on different fertiliser treatments in the field. It is not possible to compare the heights of plants in the field with those of plants grown under glasshouse conditions since light, temperature, density and age of plants were so different. However, at the end of the second fertiliser experiment, the plants would mainly have fallen into Category C (plants with flowers and stems branching at the base) and visual observations showed that many plants, particularly those in treatments with high concentrations of N and P were much taller than any Category C plants found in the field (Experiment 13).

The mean dry weight per plant (Table 30b) increases when N was given but increasing N gave no further increase in dry weight. Giving P, K, Na, Mg (Plot 5) gave a four-fold increase in dry weight of plants in Categories A and B. Dry weight of Tripleurospermum responded similarly to N and P in the field and in the glasshouse. The effect of K on the dry weight of plants in the field was not measured.

Although fertilisers do to some extent influence these weeds on Broadbalk, their effects do not fully explain the distributions of Tripleurospermum maritimum and Stellaria media. It is necessary, therefore, to examine other environmental factors which may have some influence upon the growth and development of weeds.

Seasonal variation in weather (Warington 1924) farming practices and crop diseases cause annual fluctuations in weed seed numbers throughout the field. Tripleurospermum tends to fill the gaps in the crop caused by wheat bulb fly (Leptohylemyia coarctata.Fall) attack and gives locally high numbers of weed seeds. Brenchley and Warington (1945) recorded the number of weed seeds per 15 sq.ft. on several plots of Broadbalk for the period 1925-1940. The figures showed seasonal fluctuations particularly after fallowing.

	No of seeds/15 sq.ft.	
	Highest	Lowest
Stellaria media	1193	182
Tripleurospermum maritimum	130	21

Previously Brenchley and Warington (1933) gave figures for number of seeds present in $8\frac{2}{3}$ sq.ft. of light soil just before fallowing in wheat and barley.

	No of seeds/$8\frac{2}{3}$ sq.ft.	
	Wheat	Barley
Stellaria media	280	915
Tripleurospermum maritimum	3185	234

(Tripleurospermum maritimum was then called Matricaria inodora)

However, usually the number of seeds per unit area on a plot is fairly constant (Brenchley and Warington 1945) allowing for seasonal fluctuation and this is mainly due to the fact that seed grown on a plot produces next year's plants on that plot. Some transfer of seed from plot to plot does occur during ploughing, drilling and particularly baling straw.

If large numbers of weeds are present on a plot then not only must large numbers of weed seeds have been present but there must also have been large numbers of suitable germination sites. Plot 2(FYM) is particularly favourable for germination as the organic matter added each year gives a good tilth admirably suitable for a seed bed. A high seed viability will improve the numbers of weeds on the plot but low nutrient status may reduce the percentage viability (not tested for Stellaria and Tripleurospermum) Poorly fertilised plots then, are low in seed numbers and the seeds may have a reduced viability.

Experiment 9 demonstrated this reduction in numbers of plants on poorly fertilised plots. The highest numbers of Tripleurospermum plants occurred on plots 2B(FYM), 7(N_2PKNaMg) and 8(N_3PKNaMg) while the lowest numbers occurred on plots 3(no fertiliser) and 5(PKNaMg).

Other factors which affect the growth of weeds are carbon dioxide concentration and soil water. It is rarely that the carbon dioxide concentration of the air falls far enough to limit growth so that this will have little effect upon the distribution. Soil water is obviously very important to the successful growth of both crop and weeds but in this country, except in exceptional circumstances, soil water is regularly replenished, However, on Broadbalk, plot 2(FYM) retains moisture better than the rest of the field because of its high humus content and so plants on plot 2B are less likely to suffer during drought.

If there is ample soil moisture and essential soil nutrients are plentiful, light becomes an important factor in influencing the distribution of the species (Stahler 1948)

In 1948 Stahler measured the amount of light intercepted by certain crops. Broad-leaved crops such as alfalfa intercepted as much as 98% of the total incident light. Winter rye made rapid early growth and had reduced the incident sunlight to 10% by May. Winter wheat behaved similarly but developed more slowly. It

retained its leaves better than rye and consequently the dense shade extended later into the summer.

Santhirasegaram and Black(1968)showed that 75% of the total leaf area of wheat plants was concentrated in a band $3\frac{1}{2}$" wide over the centre of a row. They also demonstrated that light penetration within crops in rows running N to S was more uniform and higher than in rows running E to W.

Fortunately the rows of wheat on Broadbalk run almost N to S so that more uniform results of light measurements were possible. However, variations were bound to occur so that the tube solarimeters were used to try to eliminate this variation as much as possible.

The light intensity readings obtained at or about midday in the field (Experiment 5) are approximately the maximum reading for the day. Light intensity begins to increase before dawn but seldom reaches plant compensation points until after dawn. It continues to increase until it reaches its maximum around noon. After that the light intensity declines, usually falling below compensation point for most plants slightly before sunset. This is why, in the cabinets (Experiment 6) although the standard light intensity is only 20% of full summer daylight, 16 hours of this constant intensity supplies energy equal to that of a full summer day of varying intensity. Those measurements taken on Broadbalk are not indicative of the total radiation in a day but rather of the reduction in light intensity falling on an area at a point in time. However, a reduction in the maximum light intensity will give a reduction in the total light energy falling on and area in a day.

All plants require light to live and grow but some plants need less light. The experiment in the controlled environment cabinets showed that Stellaria was very little affected by the lower light intensity except when the plants were very small. Tripleurospermum however, required the higher light intensity to produce good growth Retardation of growth was produced by light intensities of less than

10% full daylight. However, growth of Tripleurospermum, is likely to be retarded by light intensities greater than 10% full daylight as measured in the field since the total daily radiation available to a plant in the field receiving 10% fu l daylight at midday will be much less than that available to a plant receiving 16 hours of 10% full daylight in a controlled environment cabinet. Any plant, therefore, receiving less than 50% full daylight at noon in the field is likely to be suffering from a shorter photosynthetic day and a greatly reduced daily receipt of radiation.

This reduction in available light energy seriously affects the growth of Tripleurospermum. If the light is reduced enough a critical point is reached and the plant dies (Experiment 8) The cabinet experiment showed that there was a critical period during the early part of the life of a Tripleurospermum plant when, if insufficient light energy was available, flower production might be affected. This may account for the numbers of Tripleurospermum plants found in the crop at flowering time which showed no signs of flowering at all. It may be that the plants germinated later and were not mature but it is also possible that the light intensity was too low to initiate flowering.

Although man has long been concious of the reduced light below forest canopies, it is only during the last 50 years that we have begun to realise that the same applies to the light below the canopies of crops and pastures and its importance in husbandry.

Light intensity measurements on Broadbalk were expected to show a decrease in transmission through the crop with addition of fertiliser to the crop. The results agreed well with those expected except that on some plots the amount of light penetrating to the soil surface was lower.

The poorly fertilised plots transmitted most light; plot 3 (no fertiliser) allowing as much as 70% full daylight to reach the ground in mid June. The well-fertilised plots with dense crops intercepted as much as 90% of the incident light. On plot 2B(FYM) unsprayed section, the dense growth of crop and weeds permitted only 3% light to reach the ground. These results agreed well with those obtained by Blackman and Black(1959)who found that in high density cereal crops only 2-6% of light was reaching the soil surface.

Comparing Tables 21 and 30, the Tripleurospermum plants with the greatest dry weight occurred on plots given N. The tallest plants in greatest numbers occurred on the same plots. These same plots 6(NPKNaMg), 7(N_2PKNaMg), 8(N_3PKNaMg) and 9(N_4PKNaMg) had among the lowest percentages of light transmitted to the ground throughout the season. Plot 2B(FYM) although producing the best crop had neither the biggest, tallest or greatest numbers of Tripleurospermum plants. However, the amount of light penetrating was lowest (11% on 27/5) so that although the fertiliser encourages the growth of Tripleurospermum the amount of light energy available must discourage their growth. On all plots Tripleurospermum plants had a greater dry weight and height in blank rows. More light was available in the reduced competition so plants were stronger and able to grow taller.

Light transmitted through plant canopies is often somewhat altered in quality (Cowan 1968). Dunn (1970) grew Portulaca olevacea in different coloured lights and showed that white light gave the best results while yellow light greatly decreased the growth. Light transmitted through the crop on Broadbalk will be slightly altered in quality and may affect the growth of the weeds, particularly Tripleurospermum.

All green plants need light above their compensation point to survive and reduced light produces reductions in growth as demonstrated earlier for weeds. Light also affects the production

of leaves, tillers and spikelets in wheat and other crop plants. Puckridge (1968) showed that the potential grain yield for a wheat ear was affected by the light environment of the shoot at any stage before ear emergence. The weight of a single wheat seed is dependent upon the photosynthesis in the head and upper leaves, particularly the flag leaf. (Green, Finkner and Duncan 1971). It is obvious that the amount of light falling on the wheat plant is of utmost importance in obtaining the maximum possible yield of grain.

Light is not available in reservoirs as is soil water but is instantaneously available so must be instantaneously intercepted. The vital relationship is therefore one of physical position. (Dunn 1961)

Plant height, therefore, becomes of great importance since a plant able to display its foliage above that of its neighbours is immediately placed at an advantage in the race towards successful growth and reproduction. This physical striving for success at the expense of neighbours is competition for light. It is not only a competition between species of plants but also between individual leaves, since the shading of a leaf will depress its photosynthesis whether it is on the same plant as its superior or not. Leaf position in relation to other leaves is of great significance in a dense weedy crop.

Tripleurospermum is very variable and as shown in Chapter 7 the plants may be very upright or nearly prostrate. On plots where competition for light was at its greatest no prostrate plants were found. The plants have either adapted to the conditions and grown taller or the prostrate plants have been eliminated by the reduced light intensity.

In a newly sown crop no competition for light occurs between crop and plants since the seedlings are not big enough to shade

each other. However, if weed seedlings are present shading may begin very early and continue throughout the periods in which adequate light is vital to maximum grain yield. It is very important to make sure that the young crop is not shaded by weed seedlings so that its initial growth is good and strong. Later growth of weed seedlings is not so important since by then the crop will be producing its own shadows, cutting down the light, and indeed causing the death of many of its own lower leaves. There are some weeds which can survive and grow under these reduced light conditions and given time can reach a height greater than that of the crop, causing shading.

Stellaria media although a low-growing plant is little depressed by the low light intensities found near the ground in wheat crops. It continues to grow slowly, spreading outwards. When the crop is cut at harvest time the Stellaria is suddenly out in full daylight and will rapidly produce vigorous growth and large numbers of seeds to reinfest next year's crop.

Tripleurospermum maritimum, on the other hand, as shown earlier, is depressed by low light intensities and the smaller seedlings, if heavily shaded, may never flower, in addition Tripleurospermum requires light for germination. However, if the seedlings were not too heavily shaded when young, then they are able to grow with the crop, sending up long stems, bringing their topmost leaves near to the top of the crop, where they can benefit from the light. This was shown well in Experiment 9a. The increase in N fertiliser caused the crop to grow taller, and the mean height of the Tripleurospermum plants within the crop was increased but their height as a percentage of the height of the crop also increased.

Although it is unlikely that these two weeds actually shade the crop except in a very dense infestation, they do compete for other things important to the good growth of the crop. Since the

distribution of Tripleurospermum on Broadbalk may well be influenced by light availability, it is possible that by making sure that weed seedlings are at a minimum during early crop growth, and by seeding the crop at a slightly higher rate, Tripleurospermum could be well controlled in annual crops without the use of so many chemicals. This method will not give good control of Stellaria since it will survive and even flower in very dense shade.

Blackman and Templeman (1938) suggested that it was only in extreme situations that crop and weeds competed for light or moisture. Wiese and Vandiver (1970) were able to show that competition between species for soil moisture was significant. Soil moisture conditions definitely affected the competitive ability of weeds and this may partly explain why weed problems vary in different farming areas. Fabricius and Nalewaja (1968) showed that wheat ~~wheat~~ increased in N content and dry matter with soil moisture. When grown in competition, wheat required more water per unit of nitrogen taken up. They also showed that efficient water use decreased with plant maturity or high soil moisture but increased with high soil fertility.

Competition for soil moisture between crop and weeds may play an important part in crop production in certain areas. However, it is not likely that this will be a problem on Broadbalk since the soil is clay with flints and so retains much water. The soil may dry out during dry periods in the summer but usually by then the crop plants are beginning to ripen and do not require so much water.

As we have seen plants do compete for both light and water but by another important factor involved in competition in this country is nutrients. (Blackman and Templeman 1938). Much work has now been done upon competition between species including that between crop and weeds. (Blackman and Templeman 1938), Hammerton and Nuttall (1971), Koch (1967), Mann and Barnes (1945), (1947),(1950), (1952), Pavlychenko (1937), Pavlychenko and Harrington (1934) and Welbank (1963).

Most of the literature demonstrates the effect of the weeds on the crop under different fertiliser treatments. In some cases (Blackman and Templeman 1938) it has been shown that weeds decrease the yield of the crop less at high levels of fertility but Welbank (1963) demonstrated that high N levels sometimes increased the depressive effect of weeds upon the crop. Koch (1967) showed that charlock depressed the growth of oats by 25-32% up to the time of shooting but that after this the effect of weeds was much reduced with high nutrients and negligible with low nutrients. Sometimes the addition of N tended to counteract the effect of the weeds. This was shown only in the latter part of Experiment 11 when the addition of N gave an improvement in the dry weight of six wheat plants regardless of the species in competition. In the early part of the experiment addition of N decreased the dry weight of six wheat plants particularly when grown with Stellaria media.

Blackman and Templeman (1938) showed that, in competition N improved the uptake of K but had little or no effect upon P. There seem to be no references in the literature dealing specifically with competition between crop and weeds for P. P and K deficiencies do reduce the number of tillers and fertile shoots of cereals. Experiment 11 has shown that P is very important in competition between Stellaria media, Tripleurospermum maritimum and wheat in pots particularly during the early life of the plants.

The evidence suggests that on the soil used in the experiments, one of the most important factors in the early life of the two weeds and of spring wheat was an adequate supply of P. In Experiment 11 competition was particularly evident in treatments given no additional P. If P was added, the effects of competition were somewhat mediated. On Broadbalk there are only six plots which do not receive additional P. Of these six, two receive FYM and one castor meal both of which contain P. Thus only on plots 3(no fertiliser), 10(N_2) and 20(N_2KNaMg) is P likely to be in short enough supply to cause vigorous competition between crop and weeds.

Vengris, Drake, Colby and Bart (1953) suggested that some weeds could utilise soil phosphates unavailable to crop plants. If Tripleurospermum or Stellaria were able to do this, then addition of P to pots would not improve weed growth as much as crop growth.

On Broadbalk plots, not provided with additional P, competition between crop and weeds for P must begin very early in the life of the plants Brenchley (1929) showed that cereals absorbed all their necessary P during their early stages of growth and the fertiliser experiments show that these weeds do the same. As the plants mature their P requirement decreases and so competition for P will decrease too.

Little work has been done on the effect of K supply upon competition. Hall (1971) grew Desmodium intortum (a legume) with Setaria anceps and found that low K conditions greatly restricted the growth of Desmodium. If competition for nutrients was prevented or additional K was provided, growth of Desmodium was no longer restricted. Setaria was the more successful competitor for K. Although Experiment 11 did not include K among the fertilisers, Experiments 1 and 2 suggest that there was no competition for K between Tripleurospermum and wheat and since K appeared to be detrimental to Tripleurospermum particularly at high concentrations K does not affect the growth of Stellaria except when the plants are very small. There are seven Broadbalk plots which do not receive additional K but three of these are provided with K in FYM or castor meal. The remaining plots support large numbers of Tripleurospermum plants except for plot $10(N_2)$ which is the only one which receives no additional P.

The effects of N in competition has been much studied and the results vary greatly with the conditions and plants used in the experiment.

Welbank 1963 grew single wheat plants with 16 weed plants in pots at two different N levels. He was able to show that, compared

with the other weeds he grew eg Sinapsis arvensis, Matricaria inodora (= Tripleurospermum maritimum in old literature) was not a particularly efficient competitor but that the amount of N in the leaves of the crop and weeds was much the same whether the plants were given high or low N. Stellaria media was not tested with wheat but proved to be a poor competitor with kale, whereas Tripleurospermum competed better with kale.

Mann and Barnes (1945, '47, '50 and '52) grew various weeds with barley. They found that with a constant number of weeds an increase in the number of barley plants decreased the injurious effect of the weeds. The yield of a constant number of barley plants was not affected with increase in number of weeds until the number of weeds was greater than that of barley. They were also able to show that under slight N stress barley was able to secure 75% of the N no matter how many weeds.

At high levels of N, Mann and Barnes (1945) showed that decreases in the yield of barley were due to weed competition. They were able to demonstrate that Tripleurospermum maritimum decreased the barley yield by 45%. The results of Experiment 11 show that wheat is similarly affected though under slightly different conditions. Addition of N to one wheat plant and six Tripleurospermum plants decreased the dry weight of wheat and increased that of Tripleurospermum.

In 1950 Mann and Barnes also grew Stellaria media with barley and were able to compare the effects of Stellaria and Tripleurospermum on the crop.

Stellaria proved to be a much more powerful competitor with barley than did Tripleurospermum. Six Stellaria were able to reduce the yield of eight barley plants by 62% being only little affected themselves. Only when the barley was sown very densely did the Stellaria really show signs of being seriously affected.

TABLE 34

Effect of weeds upon the yield of barley from Mann and Barnes 1950

No of plants/pot		% reduction in production			
		chickweed (Stellaria)		mayweed (Tripleurospermum)	
barley	weed	red. in B	red. in W	red. in B	red. in W
1	6	90	4	61	70
2	6	87	12	42	76
4	6	78	17	35	79
6	6	82	4	22	85
8	6	62	32	20	87
Mean		80	14	36	79

This table demonstrates well the comparative effects of Tripleurospermum and Stellaria upon barley. In Experiment 11 when wheat was grown six Stellaria plants decreased the dry weight of one wheat plant by 66% more than Tripleurospermum. This result agrees well with those of Mann and Barnes using barley.

Increase in density of barley may halve the production of Tripleurospermum but Stellaria will remain unaffected and will still be able to reduce the crop to two thirds of its weed-free yield.

The total amount of weed produced was reduced more by addition of Stellaria than by the addition of a similar number of barley plants. Stellaria, then is a very active competitor both with barley (and wheat from Experiment 11), other weeds and itself (also shown in Experiment 11)

Mann and Barnes found that the competitive abilities of Tripleurospermum: Stellaria were 1:1.5 with barley. Welbank(1963) showed that competitive abilities were 1:0.4 but he used different indicators eg. kale. The relative competitive abilities cannot be calculated from this experiment. However, comparing these results with those of Mann and Barnes, it seems likely that they would be very similar to theirs eg. 1:1.6 since evidence suggests that wheat is slightly more decreased than barley by Stellaria.

Stellaria was able to absorb much more N than barley and Tripleurospermum much less (Mann and Barnes 1950); thus in an N-stressed environment Stellaria will be most successful, barley next and Tripleurospermum would suffer most. Despite the different conditions a similar result was obtained in Experiment 11 .

It is important to note that in competition a single plant is affected by and affects all the others. To the farmer, the effect of the weeds on the crop is most important but the biologist is also interested in the reverse process. The literature provides virtually no examples of the effect of the crop on the weeds.

The effect of shading by the crop on the weeds has already been discussed and it has been shown to be of particular importance to Tripleurospermum.

Experiment 11 has also shown that the crop influences the weeds to some extent. The dry weight of six Tripleurospermum plants was decreased by a single wheat plant if no fertilisers were given but if P was provided then the Tripleurospermum recovered (Table 31a) In some examples six wheat plants decreased the dry weight of a single Tripleurospermum less than other weed plants (Table 31 c & d) This was also true of Stellaria which was less affected by a single wheat plant than by another Stellaria (Table 32a)

The wheat has less effect upon Tripleurospermum and Stellaria than the weeds did upon wheat. Stellaria in particular, was affected less by wheat than by other Stellaria plants.

Throughout the competition experiment Stellaria had proved a very vigorous competitor. In the field it survives and grows well but appears to exert very little effect upon the crop. There may be some competition for light when the plants are young but if nutrients are plentiful what is its reason for success?

It may be that Stellaria has a more efficient root system and a better ratio of roots to shoots. The main root system of Stellaria plants occupies a similar depth in the soil to much of a cereal plant root system. However, the numerous adventitious roots from nodes on the stems of Stellaria can utilise soil nearer the surface. Stellaria roots appear to grow more quickly than barley roots.

Pavlychenko(1937) suggested that the whole basis of competition lies in the root systems of plants. At germination the seedling is released and until the shoot emerges is dependent upon its root system and food reserves. Pavlychenko quotes 12.62 inches as the average length of a glasshouse-grown Marquis wheat plant's root system at shoot emergence. He cites very direct, though circumstantial, evidence of root competition between crop and weeds from an early date after seedling emergence.

But, as has been shown, if sufficient fertilisers are provided and water is supplied the roots of crop and weeds have little to compete for. Perhaps, therefore, competition is for root space in the soil and opportunities to exploit as big a volume of soil as possible. The fertilisers on Broadbalk may affect not only the growth of the weeds but their germination too. Although the wheat plants have an enormous advantage in their seed size and amount of food stored, the growth rate of the weeds may be much more rapid, so that provided the weeds are able to germinate, competition for root space may begin almost immediately.

From this surmise it is obvious that the relative times of germination are extremely important (Milthorpe 1961). If the weeds germinate at or near the same time as the crop then competition for root space in the soil will soon be acting. At a later time, as the nutrient supply becomes depleted, direct competition for nutrients becomes important and, in the case of Tripleurospermum and some other weeds, light is also of some consequence in the success or failure of the plant.

Competition is very complex and it is extfemely difficult to study a single aspect of interference between plants. Welbank 1963 has expressed doubt as to whether the results of competition experiments in pots have any bearing upon the performance of weeds in the field. It seems though that pot experiments are the only practical way of discovering something about the forces acting during competition and that, when some pointers have been found, the work can then be taken out into the field for further study.

Wheat has been bred so that when sown the seeds all germinate together and none remain dormant. This is an advantage to the farmer but if some of the seedlings fail there will be no more seeds to replace them. Stellaria and Tripleurospermum, although at a disadvantage because of their small seed size, produce so many seeds, which can remain dormant for some years, that if some seedlings fail there are plenty more seeds (Roberts and Stokes 1966) to germinate and take their place. Although both Tripleurospermum and Stellaria have certain peak periods of germination both can germinate all the year round and, because of their dormancy, germinate only when conditions are favourable.

Both these weeds produce very large numbers of seeds. Tripleurospermum flowers from June to early October. Many plants are able to set seed before harvest, and after the crop is cut, very often more plants are able to flower and set seed. Stellaria is not so restricted in this way since it flowers all the year round, and after the wheat is harvested, often a flush of growth occurs and very many seeds are produced.

The main reasons for the distributions of Stellaria media and Tripleurospermum maritimum on Broadbalk are related to competition between the crop and the weeds and indeed, from other weeds. Phosphate is the most important factor in weed success on plots receiving no additional phosphate. Tripleurospermum particularly is decreased by N if no phosphate is provided. High concentration

of K can also seriously affect Tripleurospermum. Both weeds grow well with added N (if P is provided) and numbers of Stellaria plants increase with added N.

Low light intensity plays an important part in the distribution of Tripleurospermum especially retarding those plants which germinate later in the year. Low light intensities also affected young Stellaria plants but it is doubtful whether this would have much effect upon their distribution on Broadbalk.

Competition between crop and weeds for nutrients, light and water are all important but it is possible that the single most important factor in determining the distribution of these weeds on Broadbalk is their ability to germinate in certain fertilisers. Sinyagin and Teper (1967) have shown that Tripleurospermum does not germinate well in high concentrations of KNO_3 or KH_2PO_4. Stellaria germinated fairly well in all the fertiliser solutions they used except in distilled water and high concentrations of $(NH_4)_2\ SO_4$.

The advantage in controlling these weeds successfully would be considerable since, according to Roberts and Stokes (1966) Stellaria occurred in numbers between 97.1 millions/and 0.2 millions per acre and Tripleurospermum from 5.2 millions to 0.1 millions per acre, depending upon the area and the crop, throughout the country, Norman (1968) says that Stellaria occurs in 53% and Tripleurospermum in 13% of the cereal acreage of this country but that Tripleurospermum is a greater problem because it is not so easily controlled with herbicide except ioxynil. Bleasdale (1959) showed that early weeding improved the yield of onions and red beet and there are many other instances when yield was improved with weeding both in the agricultural and horticultural field. Tomlinson, Carter el al 1970 showed that weeds may be hosts of important viruses so their eradication from cultivated land is of double importance. The evidence of increasing weed resistance to herbicides (Harper 1956) make it imperative to find methods of weed control without the use of enormous quantities of expensive chemicals.

Control of these weeds on Broadbalk, except by using herbicides would be very difficult because of the classical nature of the field experiment. However, these studies do suggest that sowing spring cereals after herbicidal spraying may help in their control. A better method might be to sow a crop which enables hoeing between the rows. However, to obtain a good control of these two weeds a check must be made on the number of seeds returning to the soil each year. Reducing the seeds returned to the soil for one year will do little good since both weeds have seeds which can remain dormant in the soil for some time. Perhaps the best method of gaining control over bad infestations would be to put the whole field down to grass for several years. Neither of these weeds grows well in grass and a herbicidal spray would control them still more. After some years many of the seeds reserved in the soil would have germinated or died and a return to cereal cropping could be made.

However, there is one lighter note to the study of weeds. Eradicate them from our crops we must but weeds have a high mineral and protein content and, in these days of food shortage in parts of the world, 'their value as a feed, so far as they are palatable should not be underestimated'. (Vengris, Drake, Colby and Bart 1953)

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