COMPETITION BETWEEN WHEAT AND UNDERSOWN PASTURE WITH PARTICULAR REFERENCE TO THE LIGHT FACTOR.

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This thesis contains no material which has been accepted for the award of any other degree or diploma in any University and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except when due reference is made in the text of the thesis

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COMPETITION BETWEEN WHEAT AND UNDERSOWN PASTURE, WITH PARTICULAR REFERENCE TO THE LIGHT FACTOR

1.0.0. INTRODUCTION

The practice of establishing pasture under a cereal or other crop has gone on in many countries for a long time. The main purpose has been to obtain some return from the field in the year of seeding, since grazing in that year may adversely affect establishment. Apart from this economic factor it is also claimed that the cereal crop "nurses" the pasture seedlings in winter.

The cereal crop sown with the pasture is variously called "cover crop", "nurse crop" or "companion crop". The first term is also used where crops are sown to provide a cover to the soil to reduce the risk of erosion. The second term implies that the cereal crop nurses the pasture, which in fact, occurs only rarely; more often the growth of the pasture is harmed. These two terms are of wide use in the United Kingdom. The third is used mainly in the United States of America. In this thesis the practice will be referred to as "cover cropping" or "undersowing" and the cereal crop as the "cover crop".

The cover crops most commonly used are small grain cereals such as wheat, barley, oats and rye. Corn (maize) and some legumes and flax are also used in some parts of the world. The cover crop is usually harvested for grain, but may be grazed at an early stage in the growth cycle or cut for hay or silage. Removing the cover crop at an early stage is advocated particularly in dry areas in order to eliminate competition and thus improve the establishment of the pasture. Cover cropping is also practiced to provide winter feed for stock in areas where winter growth of pasture is low.

Particularly in dry years, undersown pastures often fail to establish satisfactorily. As a result the practice of undersowing has been abandoned in favour of pure cropping in many places, while in others attempts are being made to understand the processes involved, and to devise methods whereby satisfactory growth and yield of both crops can be obtained.

The phenomenon involved is one of competition between the cover crop and the pasture for those factors of the environment essential for growth, such as soil moisture, nutrients and light. Competition arises when in an association the demand of all plants present for one or more of the above factors exceeds the supply; when this occurs those plants best able to obtain a supply of the factor in short supply will flourish, while the others will become subordinate (suppressed). The extent of dominance of one species and the suppression of another depends on the difference between them at the initial stages of growth (embryo and seed size), the relative growth rates and the height and spread of shoot and root systems. Cereals in general have larger seeds, higher growth rates and taller shoot and deeper root systems than pasture species, and are therefore better able to exploit soil reserves. Even when the soil factors are in sufficient supply the cover crops, due to their greater stature, would shade the pasture, the growth of which would be reduced. Thus it would appear that there is always likely to be some reduction in growth of pasture when undersown.

Experience of sowing pasture seeds into already established cover crops has shown the practice to be generally unsatisfactory, due to greater competition from the cover crop. It is also well known that reducing the rate of sowing and/or increasing the row width of the cover crop improves the establishment of the pasture. In most instances the cover and pasture crops are sown together along the same row and experiments have shown that separating the two crops in alternate rows or sowing them at right angles to one another result in better establishment of the pasture. Recent work in U.S.A. has demonstrated that sowing in alternate rows running North-South result in better growth of both crops than where rows are sown East-West.

With a few exceptions these studies were concerned mainly with either the effect of the cover crop on pasture establishment or that of the pasture on the yield of the cover crop or both, with a view to making practical recommendations. Very little attention has been given to an analysis of the growth factors involved and the extent of competition for them.

In Australia the importance of the pasture phase in a rotation cannot be overemphasised, yet the best way of establishing the pasture has not been fully worked out. In South Australia, with a Mediterranean type of climate, wheat and other small grain cereals are widely cultivated. In the early part of this century farms were cropped to cereals continuously and as a result the yields dropped to very low levels. Following the introduction of wheat - fallow - wheat rotation there was some upward trend in yields; and inclusion of a few years of pasture in the rotation brought about a 50% increase over that obtained by continuous cropping to cereals. This increased yield is claimed to be due to high levels of nitrate nitrogen fixed in the soil by the clover and other legumes in the pasture. Furthermore a very high percentage of the sheep population of the state is maintained in the cereal belt. Thus a highly productive pasture in this area would have a two-fold advantage, and a marked swing to the use of a pasture phase in the rotation has been noted. A typical practice is to seed 2 lbs. subterranean clover (*Trifolium subterraneum* L.) and 1 lb. of annual rye grass

(Lolium rigidum Gaud.) with the last crop of cereal in the rotation, but in some places only the clover is sown as the amount of volunteer rye grass and other grasses is considered sufficient for a satisfactory sward. Some annual medics (Medicago spp.) are used in some parts instead of the clover.

In this thesis, after reviewing available literature on the subject and assessing the effect of cover cropping under Adelaide conditions, an attempt is made to determine the nature and extent of competition for the various factors, particularly light, by studying the microclimate and the growth of clover beneath wheat crops sown in various ways. While studying the effect of the cover crop on the pasture, the effect of the pasture on the cover crop was also taken into consideration.

2.0.0. LITERATURE REVIEW

In this section undersowing as an agricultural practice and the present opinion of it in various countries will be surveyed, and the literature on experimental studies examined to assess the effect of the cover crop on the pasture species and vice versa. Light and its availability under Adelaide conditions under different types of cover crops and its measurements will be dealt with in detail.

2.1.0 Undersowing as an agricultural practice

Undersowing is a long established practice in nearly all the temperate, sub-temperate and Mediterranean countries.

In England the climate is moist throughout the growing season. At least up to the first quarter of this century all pastures were established by undersowing usually to wheat, barley or oats and very occasionally rye, the cover crop being harvested for grain. In addition to the economic return from the cover crop, the practice was widely adopted because the cereal was supposed to protect the pasture seedlings in the winter and suppress weed growth. Davies (1945) considered that the system is satisfactory for short duration leys of rye grass and red clover, but risky in long rotation pastures unless the cover crop is grazed or ensiled. In the South West of England, where summer rainfall is high, grazing the crop early is practised and is highly successful.

In the drier districts of South East England failure or poor establishment of the pasture undersown to cereals was observed by Jones, Jones and Jones (1948). Williams and Jones (1949) observed that in East Anglia (another dry area) spring sowing under a cereal or autumn sowing under winter wheat resulted in unsatisfactory establishment of subterranean clover. Garner (1955) studying the establishment of leys in the Cambridge fens noted that undersowing was satisfactory in wet years and disastrous in dry years. In Northamptonshire Tristram (1956) obtained best results when lucerne was drilled alone, adding that annual weeds in the stand could be overcome with fertility adjustments.

The summer climate of Scotland is similar to that of England with good rainfall from April to October. The annual rainfall varies from 30" in the East to 80" in the West. Summer drought is considered exceptional. Jones (1945), discussing the establishment of sown pastures, stated that pasture seeds are sown with a cereal cover crop and there is little difficulty in getting good establishment. Any failure is due to heavy growth and/or lodging of the cereal. On this point Pritchett (1950) showed that with high nitrogen there would be heavier growth of the cereal which in turn would cause greater shade on the clover thus reducing its growth, an aspect which will be discussed later. Heddle (1948) working in the east of Scotland observed that a heavy application of nitrogen to a mixed crop of barley with Italian rye grass and broad red clover resulted in complete failure of the clover. In West Scotland seed mixtures are normally sown broadcast under oats and according to Hunt (1954) failures are rare; summer rainfall is sufficient for the development of both grass and oats.

The climate of Wales is wetter than that of other parts of the United Kingdom, with rainfall well distributed over the growing season. The annual rainfall varies from 50" in the lowlands to 80" in the uplands, with the Eastern border receiving between 30 and 35". According to Thomas (1945) experimental evidence in Wales showed better establishment in the absence of a cover crop. Cereals harvested for silage or grazed early make successful cover crops.

According to Kernohan, Williams and Howe (1948) grass and clover in Ireland are usually sown under a cover crop of oats or barley, and establishment is fairly satisfactory. Here again, rainfall is high.

In the United Kingdom and Ireland recent work on this practice appear to show, however, that establishment of pasture would be better if no cover crop is used.

The practice is wide spread in other European countries also. Schwanborn and Froier (1949) reviewing methods of herbage production in Scandinavia recorded that sowing of red clover in spring cereals (barley) is suitable. They consider that the cover crop should not be thick and only moderate amounts of nitrogen should be applied. Except in Denmark pasture sowing in an autumn sown cereal is also practised. Lier (1925) recommended spring sowing in cereal for Norway as autumn sowing is risky; while Nilsson and Erricson (1935) recommended sowing in spring cereals and harvesting early.

Sowing under winter or spring cereals is very common in France. Khatchadorian (1951) recommended that temporary pastures sown on bare ground or with Italian rye grass would give better stands especially in dry years than when sown under a cereal cover crop. Voisin (1960) stated that even though there is a reduction in pasture yield, the cover crop pays off, but pointed out that lodging of cereal causes poor swards. Application of nitrogen caused lodging of the cereal, and if the pasture is sown late into a cereal crop smothering will occur. Volkart (1934) working in Switzerland considered from experimental evidence that even though the pasture establishment was poor in cover cropping it was of significance only in the first pasture year where he observed a mean reduction of 12.6%; the reduction thereafter was only 2.9%.

The practice is widely employed in Russia particularly in the South East (Kudasev 1940) and in the Ufa province (Mohnatkin 1941). It is also practised in Hungary (Bittera 1935 and Gruber 1936). In the Italian plains (Oliva 1948) lucerne used to be undersown to wheat but now the practice is abandoned and the seeds are sown alone.

In the United States of America cover cropping is common, particularly in the high rainfall areas (Montgomery 1928 and Hughes and Hanson 1957).

In the North Great Plains where the rainfall ranges from 10" in the North-West to 27" in the South-East, Rogler (1945) recommended the use of flax in the West and spring cereals in the East both sown at reduced rates. In the North Central States where the rainfall is favourable throughout the growing season 75% of the grass and legume seedings are carried out with cereals. Ahlgren (1945) considered that the cereal protects the pasture or forage seedlings from wind and water erosion during the slow establishment, controls weed growth and provides an economic return during the year of seeding. Working in Ohio Willard et al. (1934) showed that autumn sown cereals protect early spring sown forage from freezing.

In the Pacific North Western States where the rainfall ranges from 100" along the coast to 10" inland Schoth (1945) considered that cover cropping is used to advantage where the soil moisture is satisfactory.

The North Eastern States (Sprague and Hein 1945) are humid with about 40" rainfall which is well distributed. In the Southern half of this region where crop rotation is practised timothy is drilled in with winter cereals. In the following spring the clovers are sown broadcast into the wheat. In the Northern half a spring cereal may or may not be used. In areas not suited for rotational cropping a spring cover crop may or may not be used.

In the South Eastern States with rainfall of 45 - 60" (Lovvorn 1945) there is no general agreement as to the use of cover crops. It is considered desirable in weedy lands but harmful in dry areas due to competition for moisture. When cover crop is used the rate of sowing should not be more than half the normal rate and should be cut when soil moisture become deficient.

In Australia arable agriculture is largely restricted to the southern coastal belt. South of a line from Canarvon to Sydney winter rainfall predominates with maximum plant growth in September and October. Davies and Christian (1945), reviewing pasture establishment, stated that pasture is sometimes sown with the last cereal crop in the rotation but did not consider it a good practice. Lucerne is also established with a cereal crop sown at a low rate and invariably the growth is retarded due to competition for soil moisture. Teakle (1957) investigating the establishment of lucerne at Biloela, Queensland, concluded that the wheat cover crop protects the lucerne seedling to some extent from frost. In the Victorian Mallee (Webb 1944) a cover crop of wheat at low rates helped to prevent sand drift and checked weeds in establishing lucerne. Morrow, Killeen and Bath (1948) after extensive investigations at Rutherglen, Victoria, concluded that wheat yields were higher in wheat - clover ley rotations, when the clover was sown with the last cereal crop, than in fallow - wheat cropping. Cook (1941) reviewing the establishment of lucerne with cover crops in South Australia considered that the rate of sowing of the wheat depends on the rainfall of the districts; in low rainfall areas it would be advisable to dispense with the cereal. Both Cook (1941) and Angove (1942 and 1952) consider the use of cover crop in areas liable to drift sand advantageous in lucerne establishment. Schraeder (1949) stated that good establishment of lucerne was obtained in the Murray Plains when sown with wheat in April. Best establishments were recorded in wet years. Cook (1947) dealing with the establishment of annual clovers, medics and grasses stated that successful establishments were obtained when a cereal cover crop was used.

In New Zealand (Department of Agriculture Bull. 250, 1956) the practice is confined to arable districts in short rotation pastures. Commonly used cover crops are wheat, oats, barley, rye, flax, turnips, rape and mustard. Flax, wheat and other crops with minimum of flag are more satisfactory than crops which produce more shade. Considerable success has been obtained with Montgomery red clover when sown with wheat early in spring. Brougham (1954) studying the use of barley as a cover crop to provide winter feed at Palmerston North concluded that barley adversely affected spring growth of pasture without increasing the feed available in winter.

2.1.1. Conclusion

In nearly all the pasture producing countries of the world, undersowing is frequently practised. Except in a few isolated cases the practice is not actively encouraged, while in dry areas it is definitely discouraged, because of the competition for soil moisture. It would appear then that the most important factor in undersowing is soil moisture. Very little attention has been given to nutrient competition, perhaps because it is difficult to isolate nutrient competition from soil moisture except under controlled experimental conditions. The shade cast by the cover crop on the pasture has also received some attention. This factor operates under all conditions; and would be more so where the growth of the cereal is favoured, both by soil moisture and nutrient supply.

This review also shows that the success of the practice depends to some extent on the type of pasture that is undersown. Permanent pastures of perennial species seem to be affected more than annual species. This may be because regrowth of perennial species depend on the number of plants that are established at the end of the season of sowing while in the case of the annual species the regrowth would depend on the seed produced. Unless the environmental conditions were so bad that all plants of a species died without any seeds being produced, a plant would usually produce some seeds; those in favourable positions would produce more, and

and with normal scattering of the seeds a stand of some sort would be produced in the next season. In other words, the reduced growth of the annual species would result in reduced production of seeds and this would result in less dense stands in the next season, but the effect would be lost with time as this thin stand grows and covers the area. A further bad effect on the perennial species may be that the plants may not have reached a stage of development in which they can overcome the ensuing dry period and do not persist.

2.2.0 The phenomenon of competition

From the preceeding section it is obvious that the presence of the cover crop reduces the growth of the pasture, a result of competition between the cover crop and the pasture species. To paraphrase Clements et al (1929) "Competition is a purely physical process". In this case "competition arises from the reaction" of the cover crop "upon the physical factors about it and the effect of these modified factors upon the" pasture species. Conversely the pasture plants would react and modify the factors about them and this would affect the growth of the cover crop. Competition would arise for soil moisture, nutrients and light as soon as one or more of them are in supply below the combined requirement of the association.

2.3.0. The effect of the cover crop on the undersown pasture

2.3.1. Competition for soil moisture

Very little work has been done to ascertain the extent and mode of competition for soil moisture. Pavlychenko and Harrington (1934) studying competition between cereals and weeds among which some were grasses (e.g. crested wheat grass) showed that the cereal roots from the time of germination to maturity have a greater horizontal spread and penetrate to deeper layers than the weeds. This spread gave the cereals the ability to draw their water requirements from a large volume of soil. This also caused the upper layers of the soil to be exhausted of moisture, thus leaving the shallower rooted weeds in dry soil.

Companion crops differ in their ability to alter the moisture conditions of the soil. Klebesadel and Smith (1959) working with winter wheat and rye, spring wheat and barley and peas found that the winter cereals depleted the soil moisture faster than the spring cereals, and winter rye more so than winter wheat. When yield and establishment of legumes under these crops were considered there was greater reduction from the winter cereals than from the spring crops. Stahler (1948) attempted to study the behaviour of soil moisture under different crops and weed infestations but could not attribute the failure of weed growth under certain crops to limitation of available soil moisture because when the crop was removed weeds began to grow with normal vigour. He also found that moisture content of the soils under the various crops did not drop below 15%, which amount was however sufficient for the growth of both crops. Staniforth (1948) studying the effect of soil moisture on the growth of soybeans and weeds, carried out experiments with soybeans grown alone and with weeds. The weeds were removed at various stages of the growth of the soybeans, and a range of moisture treatments was imposed. There was very little difference due to presence or absence of weeds in the yield of soybeans. Pritchett and Nelson (1951) pointed out that when moisture is adequate the cover crop would grow faster and shade the pasture. Scott (1960) subjected mixed and pure stands of lucerne and two cereals (grain sorghum and maize) to four levels of simulated drought and found no significant evidence of serious competition between crops for soil moisture. Klebesadel and Smith (1960) found that longer the oat cover crop remained uncut the greater was the depletion of available soil moisture and less dense the stand of lucerne beneath them.

2.3.2. Competition for nutrients

Plants compete for nutrients as well as for soil moisture. Kurtz et al. (1952) pointed out that competition would occur mainly for mobile substances like soil moisture and nitrogen. These workers showed that in absence of nitrogen fertilisation and irrigation corn yields decreased by about 75% due to an undersown forage crop but in the presence of both nitrogen and water the reduction was only 12%. Unfortunately no data were collected by them with respect to the growth of the intercrop. Scott (1960) studying the uptake of potassium by lucerne grown alone and in combination with sorghum at two levels of available soil potassium found total K in tops of lucerne grown alone to be higher than in that grown in association with sorghum. The lucerne was eight weeks old at the time of sampling. This work suggests that there could be competition for nutrients other than nitrogen. This is further supported by the findings of Vergris et al. (1953 and 1955) that increased application of phosphatic fertilisers resulted in greater growth of weeds and decreased yields of corn. They concluded that most weeds could extract phosphorus usually unavailable to crop plants. It is difficult to generalize how the pasture species would behave in this respect, but it is reasonable to assume that different species would extract to varying extent the various nutrients from the soil. Pritchett and Nelson (1951) showed that in presence of adequate nitrogen the cover crop grew better and cast more shade on the forage seedlings than at low nitrogen. Charles (1961) showed that when N was applied to Italian rye grass/red clover mixture undersown to spring oats, the grass yielded higher than in the absence of N while the reverse was true with clover.

It is well known that legumes could with the aid of the nodule bacteria fix nitrogen and hence when legumes are undersown to cereals they should not be seriously affected by competition for nitrogen.

2.3.3. Competition for Light

Unlike soil moisture and nutrients, which plants draw from a "reserve", light energy is instantaneous and has to be intercepted and utilised instantly or is lost for plant growth (Donald 1961). In this respect the foliage has to be exposed to incoming radiation and the stature of the associates assumes importance. Cereals are usually taller than the more leafy pasture species, and this would result in the pasture being shaded by the cereal and hence growing more slowly.

It was not till recently that the importance of light intensity in the growth of crops was appreciated. It was generally believed that since the incoming radiation was usually of a higher intensity than that required for the optimum rate of photosynthesis of detached leaves, there would be no shortage of light energy for the growth of a crop. Black (1955) reviewing the literature on light intensity and crop growth showed how reduction in the intensity of daylight reduces the growth of crops.

The first attempt at studying the effect of shade cast by the cover crop on pasture species was made by Klages in 1935. He measured the light intensity above the leaves of alfalfa and red clover growing under various cover crops and found a very close positive relationship between light intensity and vigour of the legumes. An exception was hemp, under which the light intensity compared to the other cover crops was high but the vigour of legumes was low. This was explained by him as being due to competition for soil moisture. Godel (1935) Pavlychenko and Harrington (1934), Rademacher (1940) and Stahler (1948) demonstrated that the shade cast by cereal crops would retard and in some cases eliminate weed growth. Rademacher further pointed out that a crop which could cause shading early in its growth and maintain this shading over long period not only at ground level but also throughout its profile, would be much more efficient in reducing weed growth. Stahler obtained similar results. In the present context such crops would seriously reduce the growth of pasture species.

Stahler (1948) was probably the first to record change in light intensity beneath a crop throughout the growing period. For various crops he showed that there were three distinct phases in the amount of light received at ground level. From planting there was a gradual reduction till a low value is reached; then a phase in which the light intensity remains at this low level for a period of time and then as leaves dry and the crop mature a phase of gradual increase in the amount of light received at ground level. Essentially the same pattern was recorded by Black (1952) and Klebesadal and Smith (1959). Stahler in addition recorded light intensity at different times of the day (8 a.m., 10 a.m., 12 noon, 2 p.m. and 4 p.m.). Bula et al. made their light measurements between 10 a.m. and 2 p.m. while Klebesadel and Smith recorded between 10 a.m. and 3 p.m. exclusive of the hour from noon and 1 p.m.

None of these works specify the direction of the rows of the crops studied, nor the exact position in which the measurements were made (directly beneath the rows or at some position in the space between rows). Rademacher appears to have made his measurements between rows. Bula et al. have worked with rows running E - W and measured along the interspace between rows, for they say "three readings were made down a row from east to west and three were made in a different row from west to east." Drill width is rarely specified and it could well vary from country to country and within a country from region to region.

Pritchett and Nelson (1951) studied the growth of leguminous seedlings in a greenhouse, using five intensities of light which they considered to be normally encountered in undersowing. They found that dry matter production decreased with a decrease in the intensity of light and that the growth of roots were affected more than the shoots. Root nodulation also decreased with decrease in the light intensity. Similar results were obtained by Gist and Mott (1957 and 1958), Bula et al. (1959) Bula (1960) and Rhykerd et al. (1960). Reduced light intensities had the greatest effect on birdsfoot trefoil followed by ladino clover, red clover and alfalfa. In a field experiment, Peters (1961) showed that these legumes behaved in similar manner when undersown to a cover crop of oats. Tossel and Fulkerson (1960) found that red clover and timothy were most sensitive, alfalfa and orchard grass less so and brome grass least when undersown to a cover crop. Dibbern (1947) studied growth of different clones of Bromus innermis at 100, 46, 14 and 5% of sunlight and found that all clones died at the lowest light intensity studied while 10 and 17 clones survived under 14 and 46% sunlight respectively, showing that some clones would tolerate shading compared to others.

2.3.4. Indirect effects and interaction of factors

The foregoing review concentrated mainly on the effect of the various factors for which plants compete. In practice a change in one factor affects the response of the plants to others.

Pritchett and Nelson (1951) showed that with increase in nitrogen level the cover crop produced more herbage which in turn produce greater shade and thus reduced the amount of light available to the undersown pasture. Gist and Mott (1957) studying the interaction of soil moisture, light and temperature on the growth of alfalfa, red clover and birdsfoot trefoil seedlings showed that seedlings responded to moisture only when light intensity was adequate. Burton et al. (1959) studying levels of light intensity and nitrogen on the yield of coastal Bermuda grass (Cynodon dactylon) concluded that in full sunlight treatments receiving 600 lbs. N./acre yielded higher than those receiving 200 lbs. N./acre, while the reverse was true under 29% of sunlight.

The response to any level of nitrogen was lower at 29% sunlight than at 100%.

2.3.5. Other factors

In addition to the factors already discussed, other factors may be involved. Rademacher (1940) showed that when weed seeds were sown with cereals their germination was reduced in comparison to pure sown controls in pots. He further showed that the reduction in germination was greater with rye than with wheat. It is therefore possible that when pasture species are sown with cereals there would be reduced germination resulting in a reduced stand to start with.

Another important factor is depth of sowing. Cereals are normally drilled at depths of about 1½" and if the pasture species are also drilled at the same depth there would be lesser emergence than when they are sown at shallower depths. In Adelaide (Waite Inst. Ann. Rep. 1941-42) it was shown that establishment of lucerne and subterranean clover under cover crops was better when planted at ½" depth than at 1". Lueck et al.(1949) found establishment of brome grass sown at or less than 1" depth to establish better stands than those planted deeper than 1".

2.3.6. Conclusion

From the above discussion it would appear that under all circumstances the cover crop is likely to reduce the growth of pasture species, purely by its morphology both above and below the soil surface. Above the soil surface the leaves are held at greater heights and thereby have priority for the interception of incoming radiation, to the detriment of the smaller pasture species. Below the soil surface the cover crop, by virtue of its large root system would be able to absorb moisture and nutrients. This advantage of the spreading and deep penetrating root system helps the cover crop not only in exhausting the soil faster at the shallower layers and causing dry conditions for the pasture species, but also in obtaining moisture and nutrients from lower layers. In this manner the cover crop would be able to continue its growth and progressively shade the pasture species when soil moisture is low, as in dry regions, or when nutrients are low, as in less fertile soils. Even when these two factors are present in adequate supply the cover crop would still reduce the growth of the pasture by the shade it casts, and under the reduced light intensity the pasture would not be able fully to utilise other factors.

2.4.0. Agronomic practices aimed at reducing the competition from the cover crop

Various methods have been adopted to reduce the competition from the cover crop, the chief among them being :-

(i) Time of sowing

(ii) Early removal of the cover crop

(iii) Type of cover crop

(iv) Rate of sowing of cover crop

(v) Row spacing

(vi) Row direction

2.4.1. Time of sowing

Nearly all recommendations on undersowing stress the importance of sowing the two crops at the same time. When pasture is sown in spring into autumn sown cereals there would be greater competition and consequent reduction in growth of the pasture. Pendleton (1957) obtained more successful stands of alfalfa when band seeded with winter wheat in the fall than when it was broadcast into the wheat crop in the following spring. In countries with autumn and spring sowing of crops, seeding with spring crops appears to be preferable. Foth et al. (1961) sowed a mixture of brome grass and lucerne in autumn with wheat, in spring into autumn sown wheat and in spring with oats and found that autumn sowing of the pasture mixture gave lowest yields followed by spring sowing into autumn sown wheat. In this connection the work of Klebesadel and Smith (1959) on the light and soil moisture status beneath different crops would explain the advantage of spring seeding.

2.4.2. Early removal of the cover crop

Because of the many failures encountered in cover cropping, attempts have been made to remove the cover crop at a stage earlier than maturity, such as by grazing, and/or cutting for hay or silage. (Griffith 1934; Thather et al 1937 and Davies 1952). Bates (1946) considered that grazing early to remove the cover crop would be injurious to the pasture seedlings and Brougham (1954) showed that using a cover crop of barley to provide winter feed only led to reduced growth of the pasture in the spring and summer. Klebesadel and Smith (1960) removed an oat cover crop at various stages of its growth and found that the later the cover crop was removed, the poorer the stand of the legume.

Removal of the cover crop at the hay stage would change the environment of the pasture species drastically and this may adversely affect their growth. Pritchett and Nelson (1951) transferred seedlings of legumes grown under reduced light intensities to the open and could not find any deleterious effects, but as they pointed out there could be other factors involved. Stern (1960) carried out a similar experiment with subterranean clover and did not observe any bad effects either. As Black (1955) comments the problem needs more extensive investigations under field conditions.

2.4.3. Type of Cover Crop

Different species and different varieties possess varying extents of competitive ability. Crops with the least amounts of leaves, small stature and stiff straw (Veisen 1960) are preferable as cover crop in that they cast the least amount of shade. Klebesadel and Smith (1959) showed that winter oats reduced light and soil moisture beneath it more than winter wheat. Collister and Kramer (1952) obtained a negative correlation between height of oat varieties and yield of clover beneath them, while recognising effect of competition for soil moisture and nutrients. However Smith et al (1954) studying the establishment of legumes under four varieties of oats could not obtain significant difference over a four year period. Bula et al. (1954) found no difference in the light intensity beneath five varieties of oats and there was no difference in the number of legumes per unit area beneath them.

2.4.4. Rate of sowing of the cover crop

The majority of recommendations on cover cropping advocate the use of cereals at rates less than normal (Znamenskii 1939 and Ryzikov 1941). Smith et al. (1954) found no increase in legume stand with decrease in rate of oats on heavy soils where weed growth was heavy at the low rates of oats. On a sandy soil however there was considerable improvement in the legume stand at the low rates of oats. The authors attribute the overall low legume establishment on the sand to soil moisture stress and the better stands at lower rates of the cover crop to less severe competition for soil moisture. Tossel and Fulkerson (1960) studying establishment of grasses and legumes under nine rates of oats (0 to 4 bush./acre at ½ bush. increments) at 7" row spacing concluded that 1½ bush/acre oats allowed the establishment of more and vigorous alfalfa plants than did 2½ bush./acre., the normal rate of sowing in Ontario. Bula et al. (1954) studying light intensity beneath Clinton oats at different rates of sowing obtained higher light values in low rates at the early stages of growth but later there was very little difference. They attributed the lack of difference to increased growth of weeds with decreased rates of sowing of oats, so that the combined canopy of oats and weeds became similar at all rates of oats sown. This is supported by their data on the total yield of oats and weeds where there was no significant difference. The yield of legumes was not significantly different between rates of sowing of oats, nor was there a consistent trend. In both years (1949 and 1950) rain fall was ample and it would have been interesting to see whether the light intensity and the yield of legumes would have responded to rates of sowing of cover crop had there been no weeds. Tanner and Peterson (1960) measured the fraction of light received at the soil surface beneath corn crops to that above it, spaced 40" apart. For rates of 13000, 16000 and 22000 plants/acre the fraction of light received between 7 a.m. and 5 p.m. were 0.27, 0.26 and 0.18 respectively.

From these studies it may be concluded that legume establishment would be better under reduced rates of cover crop, particularly when soil moisture is limiting. When soil moisture is adequate there do not appear to be/much difference due to the rate of the cover crop sown, and perhaps because under these circumstances the suppression would be mainly due to the shade cast by the cover crop. This factor, particularly at the conventional row spacing of about 7" for small grain crops, would not change materially with the rate of sowing.

2.4.5. Row spacing

When the space between rows of the cover crop was increased, better establishment of the undersown pasture has frequently been noticed. Most of the studies were carried out in the United States of America, either with oats or corn.

Hughes and Nelson (1949) obtained increasing number of alfalfa and brome grass seedlings per 1000 cm^2. with increase in the row space of oats from 7 to 21". Similar results were obtained by Pendleton and Dungan (1953) in 1950 when rainfall in May and June was below average, but not in 1951 and 1952 where rainfall in those months was adequate. Harper (1946) also observed better establishment of *Melilotus alba* in 15½" than in 7" spaced rows, particularly in dry years. Stringfield and Thatcher (1951) Schaller and Larson (1955) Pendleton et al. (1957) and Tesar (1957 all working with different spacings of corn found that there was an increase in forage establishment with increase in the row space, particularly in dry years.

Tanner and Peterson (1960) measured the fraction of light received at soil surface beneath the crop to the total above it in corn rows spaced 40, 60 and 80" with similar number of plants/acre and obtained values of 0.26, 0.31 and 0.44 respectively.

Schaller and Larson (1955) observed better establishment between rows of corn than beneath the rows and Tesar (1957) recorded no establishment of legumes $8\frac{1}{2}$" on either side of the rows of corn and an increase in the number of plants from $8\frac{1}{2}$" to the mid position in 40, 60 and 80" spaced corn rows. Haynes et al. (1959) studying "proximity effect" of corn on alfalfa found that the shoots of the legume were affected upto 20" from the base of the corn rows. The effect on roots (diameter of spread) extended 3" further in 42" drilled rows and 42 x 42" hills than in any of the other patterns of plantings. These observations on the available light and the "proximity effect" would explain the advantage recorded in establishment of pasture and forage seedlings in wide spaced rows of cover crops. That there was no improvement in the establishment with wider spacing of the cover crop when rainfall was satisfactory would be rather difficult to explain on the findings of Tanner et al. (1960) on the available light energy. This however will be considered under the next section. These findings would explain the recommendations of Kudasev (1940), Kerjakina and Zurukin (1950)

Schindler (1941) who recommended sowing of pasture and cover crop in alternate rows; which in effect is doubling the row width of the cover crop compared to normal sowing and drilling the pasture along the middle of the interspace.

2.4.6. Row direction

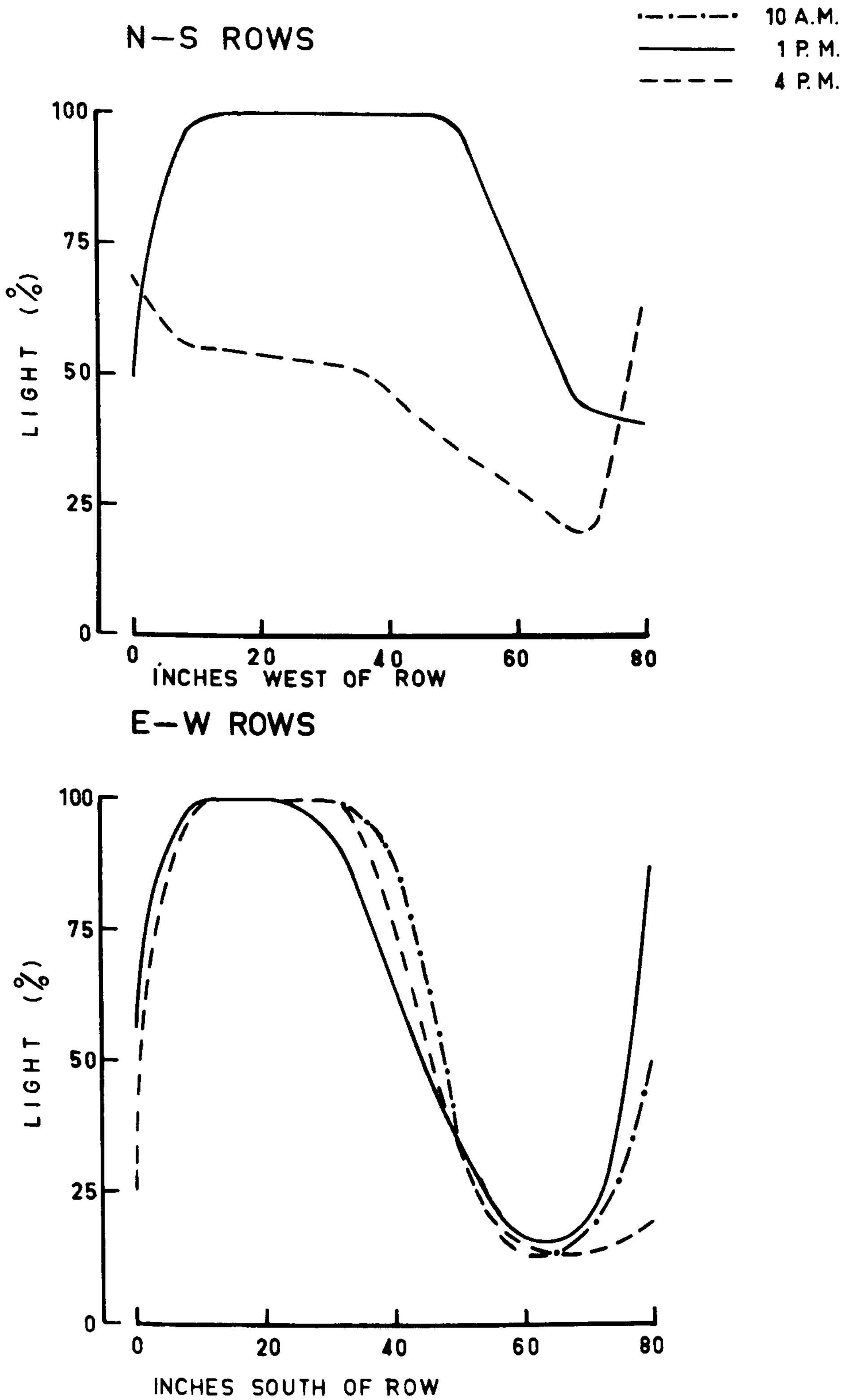
Kislev (1936) observed that cross sowing at 5" spacing was better than in the same direction. He considered that cross sowing would provide a better light micro-climate to the plants, which would result in better utilisation of soil moisture and nitrogen. Kilcher and Heinrichs (1960) obtained better establishment of pasture when sown at right angles to the rows of cereals than when the two crops were sown on the same row. Contrary to this, Versinin (1945) concluded that sowing of clover and timothy between rows of cover crop instead of broadcasting them or sowing across the rows resulted in quick establishment of plants which were able to withstand drought and other severe conditions better.

Pendleton et al. (1957) recorded better establishment of legumes between corn rows planted north - south than in an east - west direction. Larson and Willis (1957) studied the establishment of legumes in varying spacing and direction of corn rows. They concluded that in 80" spaced rows running E - W the number of legumes per sq. ft. increased with an increase in the distance from south of the row. Soil moisture increased and soil temperature decreased in that direction. The light intensity measured at normal incidence

4" above the soil surface decreased in the same direction (Fig. 1). There was no appreciable difference in the light intensity with time of measurement (10 a.m., 1 p.m. and 4 p.m.). In similarly spaced N - S rows the mean soil temperature was slightly higher on the immediate western side and the soil moisture followed a reverse pattern. The light measurements followed the same pattern as did the soil temperature. Light intensities in 40" spaced rows were similar in both directions while those in 60" spaced rows were intermediate between those recorded for 80" and 40" rows. They also concluded that legume establishment was more uniform in N - S rows than in E - W rows. That there was little difference between 40" spaced rows is supported by the findings of Tanner and Peterson (1960) who observed 0.27 and 0.28 of total light in N - S and E - W rows of corn at 40" spacing respectively.

It is interesting to note that in the 30" spaced E - W rows legume growth was positively correlated to soil moisture and negatively to the amount of light received. The soil temperature during the period of the experiment was very high (90°F) and the season was very dry, and under the circumstances the heating effect of the sun probably far exceeded the photosynthetic advantage. This was again noted with the western side of N - S rows; the authors claim that the afternoon sun caused greater heating on that side - at a time when the air temperature was high - than in the morning on the eastern side. The assumption that growth of undersown

Fig. 1. Percentage daylight, 4" above ground level between rows of corn at different times of the day. (After Larson and Willis, 1957).


10 A.M.
1 P.M.
4 P.M.
N—S ROWS
100
75
50
25
0
LIGHT (%)
0
20
40
60
80
INCHES WEST OF ROW
E—W ROWS
100
75
50
25
0
LIGHT (%)
0
20
40
60
80
INCHES SOUTH OF ROW

legumes was determined by available soil moisture in these experiments is supported by the findings of Krietemeyer (1955, quoted by Larson and Willis) who observed poor growth on the immediate eastern side of N - S rows which corresponded with the region of maximum shade in a season where rainfall was plentiful. That is, when soil moisture was not limiting the growth was related to the amount of light available.

2.5.0. After effects

The effect of the cover crop on the undersown pasture would be of economic importance only in the year the pasture is being utilised. When either due to soil moisture or shade there had been no establishment at all in the year of sowing there could be no pasture growth in the following year, but where some stand was established the growth and yield in the following year would depend on the density - yield relationship. At the early stages of regrowth the yield of a pasture would be linearly related to the density of the stand, but with time the same ceiling yield would be reached (Donald 1951). If the pasture is needed for utilisation early in the following season, a high density would be necessary, although eventually there would be little difference in the feed available. Two other important factors are weed growth in thin stands and the relative proportion of the pasture species (e.g. grass and clover).

Tossel and Fulkerson (1960), studying the effect of varying rates of oats on the establishment of undersown pasture species, could not find a relationship between the number and vigour of alfalfa plants established in the fall of the year of seeding and the hay yield at the early stages of the following season. They concluded : "This is probably due to the fact that in all years a good level of establishment was obtained, probably a level high enough to provide the plant population needed for satisfactory hay yields." Schaller and Larson (1955) recorded number of plants, yield of hay and % weeds in hay of an alfalfa - red clover - timothy mixture in the year following establishment (Table 1) which

Table 1

The establishment, yield and weed growth in pastures in the year after undersowing to corn at two spacings.
(After Schaller and Larson 1955)

Row Width	Plants/Sq. Ft.			Hay Tons/Ac.	Weeds % of Total
	Alfalfa	Red Clover	Timothy		
40"	5.4	0.8	2.5	0.92	55
80"	10.2	2.4	2.6	1.75	18

illustrates the effect of corn spacing on the establishment and growth of undersown pasture. The mixture was sown in June 1953 and establishment counts made in April 1954, showed that there was an increase in the number of legume plants per sq. ft. with increase in row width of corn, but not in the number of grass plants. Hay yield also increased with spacing and there was less weed growth in 80" than in 40" spaced corn rows, probably due to a denser stand of pasture.

2.6.0. Effect of the pasture on the cover crop

Undersown pastures would compete with the cover crop for soil moisture, nutrients and even light, depending on the relative stature of the two crops. Charles (1958) reviewed the available literature and concluded that the effect on the cereal depended on the type of pasture species undersown. The various groups of pasture species and their effect on the cover crop are shown below :-

Pasture type	Effect on Cover Crop	
	Grain yield	Straw yield
Legumes	Little or none	Little or none
Grass/Legume Mix.	Slight reduction	Slight reduction
Grass	Low to marked reduction	

From the evidence presented it appears that when legumes are undersown to small grain cereals they would not be competing for nitrogen even if they do not release sufficient nitrogen at the right time for utilisation by the cover crop. The grass species on the other hand would compete for nitrogen with the cover crops, and the competition would increase with increase of the stature and growth rate of the grass concerned; when the cover crop and the pasture species assume similar stature then competition for light would also be a significant factor. In most instances where the yield of the cover crop was reduced competition for soil moisture was also of significance (Evans 1933).

Charles (1960 and 1962) studying the effect of undersown pastures on spring oats found that Italian rye grass reduced the straw yield and panicle number particularly when nitrogen was applied. Kurtz et al. (1952) found that in absence of nitrogen and irrigation forage growth depressed the yield of corn, but in the presence of both factors there was no reduction. Similar results were obtained by Stivers (1956) with ladino clover and nitrogen fertilisation.

2.7.0. Rate of sowing, row spacing and direction on the yield of crops.

Of the various methods adopted to improve the establishment of the undersown pasture species, the decrease in the rate of sowing, increase in the space between rows and the direction of the rows of the cover crops were the most important. These factors must have some effect on the yield of the cover crops.

Holliday (1960) has reviewed the literature on yield and plant population. For the present purpose let it be assumed that the optimum area per plant for maximum production per acre is a square. Haynes and Sayre (1956) working with individual rows of corn at varying spacing showed that with decrease in the within-row distance between plants there was an increase in the extension of roots into the interspace at right angles to the rows. This root extension would in some measure enable the plants to utilise more efficiently the soil factor. But when the row space is widened beyond the optimum area necessary per plant then the soil factor will not be utilised to the full.

While root extension with increase in inter-row space and decrease in intra-row space would contribute to maintaining maximum yields per acre, no data are available to show to what extent the aerial environment (e.g. light) would be utilised. There is no evidence on the extension of the shoot system under the same circumstances as already discussed for root extension. If proportionate spread in the shoot system does not occur, the light available for photosynthesis may be limiting and yield per acre would fall below the maximum as row space increased and/or rate of sowing decreased.

It is also necessary to reconsider whether the rate of sowing now adopted in the various countries is optimal since the work of Tossel and Fulkerson (1960) in Ontario and that of Thomas and Cariss (1951) in West Australia would show that considerable reduction in the rate of sowing would result in no loss of yield.

The influence of row direction on the establishment and growth of undersown pasture has been pointed out earlier. Perekaljskii (1951) with wheat, Abe and Takahaski (1957) with potatoes, Pendleton and Dungan (1958) with oats and Screiber (1961) with sugar beet obtained higher yields when the crops were planted in North - South rows than in East - West. These workers all attributed the higher yield in planting in N - S rows to better illumination which enabled the plants to utilise the soil factors more efficiently. However, very little information is available on the illumination between N - S and E - W rows of crops. Pendleton and Dungan (1958) showed that the difference between N - S and E - W rows increased with increase in the inter-row space of the crops. Screiber (1961) observed that at lesser row spacing (16 and 22") the N - S was superior to E - W but at 28" spacing the E - W row yielded higher than N - S. Tanner and Peterson (1960) measuring radiation received beneath corn crops found little difference between N - S and E - W rows at 40" spacing. Similar results were obtained by Larson and Willis (1957) for 40" spaced corn rows, but at wider spacings (60 and 80") there was overall increase and uniformity in N - S than in E - W rows.

2.8.0. Conclusions

This review has shown that methods of sowing markedly affect the establishment and growth of undersown pasture species. In the main, the various methods tried had been either to decrease the density of the cover crops or to arrange the relative positions of the two crops so as to reduce the competition between them. Soil moisture appears to be the most important factor in the success of undersowing and light become important when soil moisture is in sufficient supply. Very little or no consideration had been given to nutrient competition between the two crops. Unless the reduction in establishment is very severe, a moderately low stand would be able to yield as much as a high density stand in subsequent years. The yield in the following year and the proportion of the components needs more detailed study, particularly with annual species where their regrowth depends on the seeds produced and not on the number of plants established as in perennial species.

3.0.0. THE PROGRAMME OF INVESTIGATION

The effect of undersowing and subsequent growth and yield of pastures in a "Mediterranean" climate have not been previously studied in detail. Experiment 1 measured these effects during the course of the growth of the crops and attempted to assess the available soil moisture and light under the various treatments in the year of sowing; the regrowth and yield of the pastures in the first pasture year was also followed.

Since wheat and pasture species are of different stature the former would be expected to reduce the light available to the latter, and the extent of that reduction would depend on the rate of sowing, space between rows and row direction. In experiment 2 and 2A light profiles were measured at regular intervals. The light penetrating a crop would depend on the distribution of plant material available for interception; the leaf area distribution of these wheat crops were therefore measured in vertical and lateral layers. As an ancillary project the experiments were sampled at intervals to follow the growth and yield of wheat.

The light available at various positions within rows of wheat crops vary considerably depending on the distance between rows and the direction of the rows. Experiments 3 and 3A were planted to measure the growth of clover sown in rows at various positions relative to wheat rows spaced 14" apart in both N - S and E - W directions.

Finally in Experiment 4 the optimum rate of sowing of wheat at 14" spacing and N-S direction for the satisfactory growth of clover was studied. An attempt was also made to relate the growth of the clover at the various positions to the light energy received at those positions and the leaf area distribution of the wheat crops.

4.0.0. MATERIAL AND METHODS

Four field experiments were undertaken during the growing seasons of 1960 and 1961. Experiment 1 was planted in May 1960 and after observations were completed in that year was carried over into the 1961 season.

4.1.0. Description of the fields.

4.1.1. 1960 Experiment

Experiment 1 was planted in the Waite Institute Field W.5., where the soil has been described by Litchfield (1951) as "red brown earth usually with 10" or more of top soil of fine sandy loam texture, a prismatic structured clay subsoil and a calcareous deep subsoil, transition from top soil to subsoil marked but rather defuse; free from gravel or stones. (Urrbrae series A-1)". This field was sown to pasture in 1953 with Wimmera rye grass (*Lolium rigidum*. Gaud.) and subterranean clover (*Trifolium subterraneum* L.) with 2 cwt. superphosphate/acre. It remained under pasture for the next three years during which time it received 1 cwt. superphosphate/acre/year. In 1957 it was left fallow and in the following year was planted to rows of wheat and barley in a selection experiment, during which no fertiliser was applied. In 1959 it was again left fallow.

4.1.2. 1961 Experiments

Experiments 2, 3 and 4 were planted in field W.4

the soil of which is of the same type as that of W.5. This field had been under pasture from 1954 to 1959, and received 1 cwt./acre superphosphate each year. In 1960 it was planted to oats for hay with 1 cwt./acre superphosphate. Dry conditions were experienced following planting of Expts. 2 and 3 and emergence was unsatisfactory. It was decided to abandon them and replant the experiments with some modifications in field W.25.

Most of the soils of W.25 is of the same type as Urrbrae series A-1 as in the previous fields except for the South Western corner, where portions of Blocks 4 and 5 of Experiment 3 were situated. According to Litchfield the soil here consists of "mosaics of red brown earth, lime enriched black earths and variable and mottled and layered transitional soils; sometimes with variable stones or gravel; incipient gilgai features may be apparent." The field was under pasture from 1956 to 1959 during which time it received 1 cwt. superphosphate/acre/year. In 1960 it was planted to oats for hay, with 1 cwt./acre superphosphate.

Subsequent examination of the discarded experiments in W.4 appeared encouraging and they were allowed to remain in the programme so that additional information could be obtained. Further reference to these two experiments on the two fields would be as follows:-

those planted in June in W.25 as experiments 2 and 3;
those planted in May in W.4 as experiments 2A and 3A.

4.2.0. Planting methods

The fields were ploughed twice at fortnightly intervals and harrowed once before planting. Finer seed bed preparations were not undertaken as there is a risk of surface sealing in these soils if very wet conditions are experienced immediately after planting, conditions which would seriously affect seedling emergence.

The experiments were planted with a standard 11 hoe drill with drills 7" apart in 1960. Superphosphate was drilled in with the seeds at 1 cwt./acre in all experiments except Experiment 4 where the same amount was broadcast.

Except for Experiments 2A and 3A all others were kept free of weeds throughout the growing period by hand weeding. Experiment 4 was irrigated with overhead sprinklers from early October to maturity; all other Experiments received only the normal rainfall. The 1960 rainfall was favourable while that of 1961 was relatively less so, and finished early. The monthly rainfall for the two years and the monthly mean over 37 years (1961 inclusive) for the Waite Institute are shown in Table 2. In all experiments the variety of wheat used was Gabo; grass was rye grass (*Lolium rigidum* Gaud.); and the legume was subterranean clover (*Trifolium subterraneum* L.) var. Bacchus Marsh.

4.3.0. Harvest methods

All experiments were harvested at frequent intervals so that

Table 2

Monthly rainfall for 1960 and 1961 and mean for 37 years at the Waite Institute, Adelaide.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1960	0.38	2.13	0.91	2.73	6.88	2.33	1.81	1.97	4.40	1.20	3.30	0.09
1961	0.24	0.43	0.26	4.63	1.67	2.79	3.13	2.21	1.33	0.76	1.56	0.87
Mean (1925-61)	0.87	1.07	0.82	2.16	3.15	3.02	3.21	2.88	2.42	2.14	1.14	0.55

the progress of competition could be studied. To this end all plots were divided into sections and for each harvest the section to be harvested was chosen at random. In the chosen section, the central region was harvested leaving areas on all sides to eliminate border effects. The plants were cut at ground level and placed in labelled paper bags. They were then taken to the laboratory, where the total sample of any species was sufficiently small after sub sampling for other determinations (described later) to be made. Samples were placed in an oven at 85°C and left there for 24 hours to dry before being weighed to determine dry matter yield. Where however the total fresh sample was large they were weighed and a weighed sub-sample was oven dried.

Sub samples were taken to determine tiller weight, leaf weight, stem weight and leaf area measurements. In all experiments the final harvest included wheat grain yields determined by threshing a weighed sub sample in addition to dry matter yield estimations.

In some experiments weight, length, number of fertile spikelets and head/straw ratios were also determined.

4.4.0. <u>Leaf distribution measurements</u>

In 1960 leaf area measurements and leaf area index calculations were made as a single factor without considering leaf distribution. In 1961 a technique was developed to measure the distribution of leaf area along the height and breadth of the rows of wheat crops. Immediately after the main sample of the harvest had been taken a rectangular board of masonite with grid lines marking out 13 horizontal strips of 3", and into vertical strips 3½" each labelled A to E, allowing for 17½" spread between rows of crops. This board was placed not more than 3" behind a row of crop from the end of the row after the main sampling. Care was taken not to disturb the leaves and tillers while placing the board in position. (Plate 1). It was then centred so that the central vertical strip C was directly behind the plants on the row. A metal frame divided into rectangular grids with cross wires was placed in front of the row, and the board and the frame were then brought together to hold the leaves and tillers in position between them; the edges were then clamped with welding clips. The tillers that were so held between the board and the frame were cut off at ground level. The assembly was then taken away from the plot and the leaves and stems within each rectangle were cut with a scalpel

Plate 1. (a) Masonite board with grid lines placed behind the plants to be sampled for leaf area distribution measurements.

(b) The metal frame placed in front and clipped to the board to hold the leaves in position.


13
12
11
10
9
8
7
6
5
4
3
2
1


13
12
11
10
9
8
7
6
5
4
3
2
1

and placed in appropriately labelled plastic bags. Two such composite samples were made for each plot.

The samples were then taken to the laboratory and placed in a refrigerator for temporary storage. The material in each bag was later separated into stems, dead material and leaves. The stems and dead material were oven dried and leaf areas obtained in the air flow planimeter (Jenkins 1959) after which they were oven dried and weighed.

4.5.0 Soil moisture measurements

Soil moisture measurements were made in Experiment 1 in 1960, when a one inch Veihmeyer tube was used to obtain samples between rows at depths of 0-9 and 9-18" of soil. Samplings were made at fortnightly intervals during the growing season, four samples being taken in each plot. The four samples from each depth were placed in air tight tins and taken to the laboratory where the contents of each tin was thoroughly mixed and a subsample of about 200 gms. was weighed, dried in an oven at 105°C for 24 hours and weighed again to obtain moisture contents.

4.6.0. Light measurements

All light measurements were made with a Weston Illumination meter Model 756. In 1960 measurements were made within 30 mins. of mean solar noon (12.15 p.m. Local Standard Time). Measurements were made at 3" intervals from ground level to above the crop. These series of measurements were repeated at $3\frac{1}{2}$" intervals across the rows commencing from the base of a row. Examination of these data showed that the relative illumination were related to the azimuth of the sun. In the 1960 Experiment, the rows were planted approximately N-S, and it was observed that asymetry in the light intensity between 14" spaced rows was related in the main to the time of measurement. Another contributing factor of lesser significance was that the rows were 3° West of true North. To eliminate these errors the 1961 Experiments were planted in strictly N-S and E-W directions taking into account the magnetic declination which according to Sutton (Personal communication) is 7-$7\frac{1}{4}$° West of North in Adelaide. The True Solar Noon (T.S.N.) was calculated from the relationship :-

T.S.N. = 12 hrs. + 16 min. ± Equation of time of day

Based on this, and since shadow movement would not be expected to be serious in E-W rows, all measurements in N-S rows were made within 10 mins. of T.S.N.; while the measurements in E-W rows were made before and after this period.

In addition to these measurements at noon, in Experiment 2 similar measurements were made 4 hours before and after noon. All these three sets of measurements were made on the same day, and were repeated at weekly intervals. At fortnightly intervals, measurements were made at ground level only at noon beneath and between rows in all plots of Experiment 2 for the purpose of statistical comparison. In Experiment 2A detailed fortnightly measurements were made only at noon. In Experiment 3 light measurements were made at fortnightly intervals at noon immediately above the clover rows and directly above the crop in all plots, again for statistical purposes. No light measurements were made in Experiment 3A. In Experiment 4 detail measurements were made at T.S.N. at fortnightly intervals. On those occasions hourly readings commencing from noon, were made at ground level across the rows to study the movement of shadow with time of day.

Wherever detailed measurements of light profiles were made, only one replicate of the experiment was considered, since the measurements had to be made at T.S.N. In each plot studied there was some internal replication of the measurements, since in all 7" spaced crops three sets and in 14" crops two sets of measurements were made. Because of this limitation however, the data could not be treated statistically.

4.7.0. Details of Experiments

4.7.1. Experiment 1

This Experiment was designed to study the competition between wheat and undersown pasture in a range of planting patterns. At the same time data were collected of the soil moisture status through the growing season and light available for the growth of the pasture. Regrowth of the pasture in the following season was also measured. There were 7 treatments in 5 blocks :-

T_1 Wheat only at 7" row spacing.

T_2 Pasture only " " "

T_3 Wheat and Pasture mixed at 7" spacing

T_4 Wheat and Pasture in alternate rows at 7" spacing

T_5 Wheat only at 14" spacing

T_6 Pasture " " " "

T_7 Wheat and pasture mixed in 14" spacing.

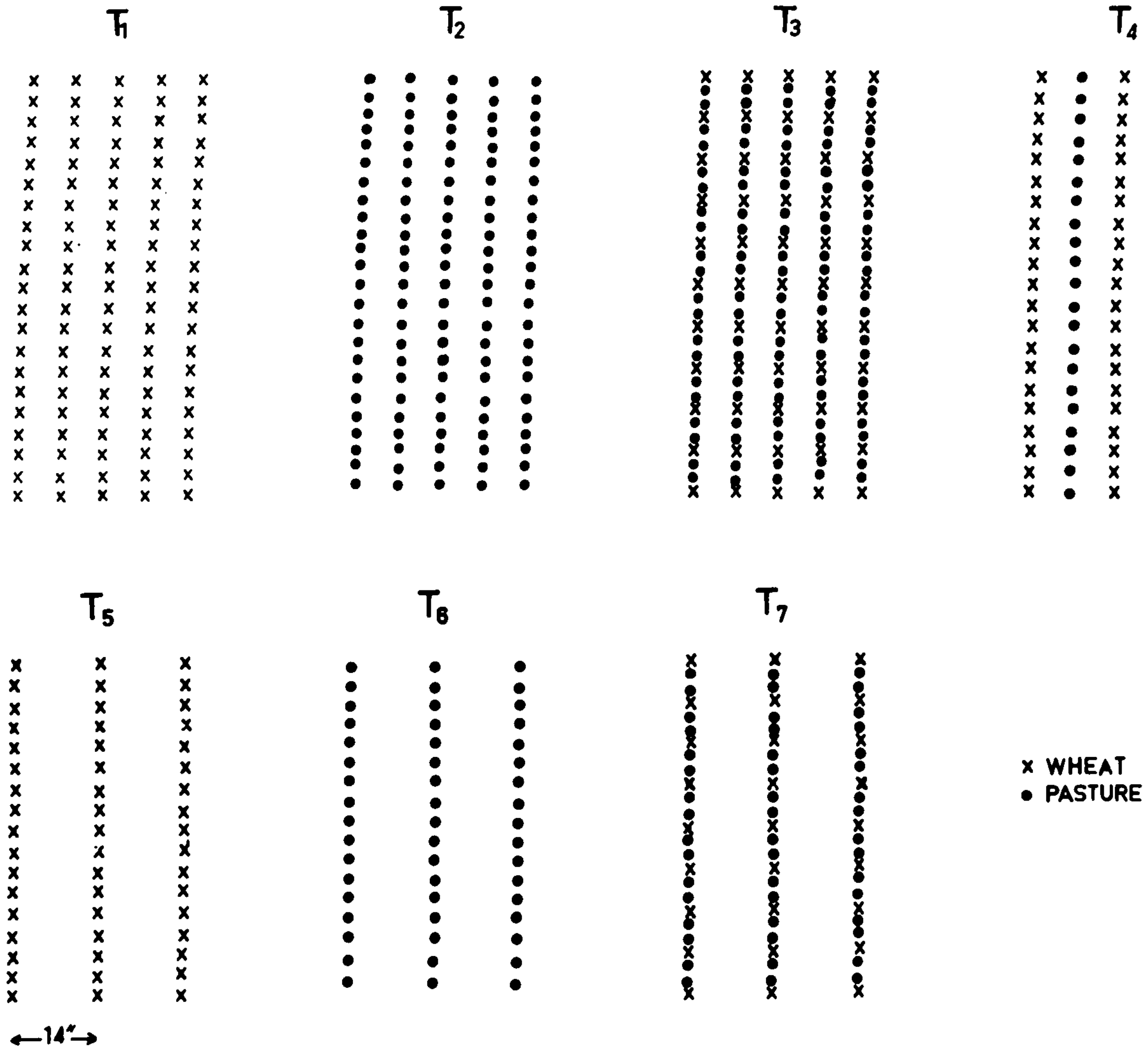
These are shown diagramatically in Fig. 2.

The drill was set to sow 60 lbs./acre wheat and 10 lbs./ acre pasture, when planting at 7" spacing. The rate per acre would therefore be half when planting at 14" spacing. The pasture seed mixture consisted of Wimmera rye grass (Lolium rigidum Gaud.) and subterranean clover (Trifolium subterraneum L.) var. Bacchus Marsh in the ratio of 3:2 by weight.

The plots were 15 m. long and 1.75 m. wide (i.e. width of one 11 hoe drill). A pathway of 0.5m. was left between plots. All plots were planted in an approximately N-S direction although the significance of row direction was not appreciated at that time; the rows were, in fact, only 3° West of True North. The layout is shown in Figure 3.

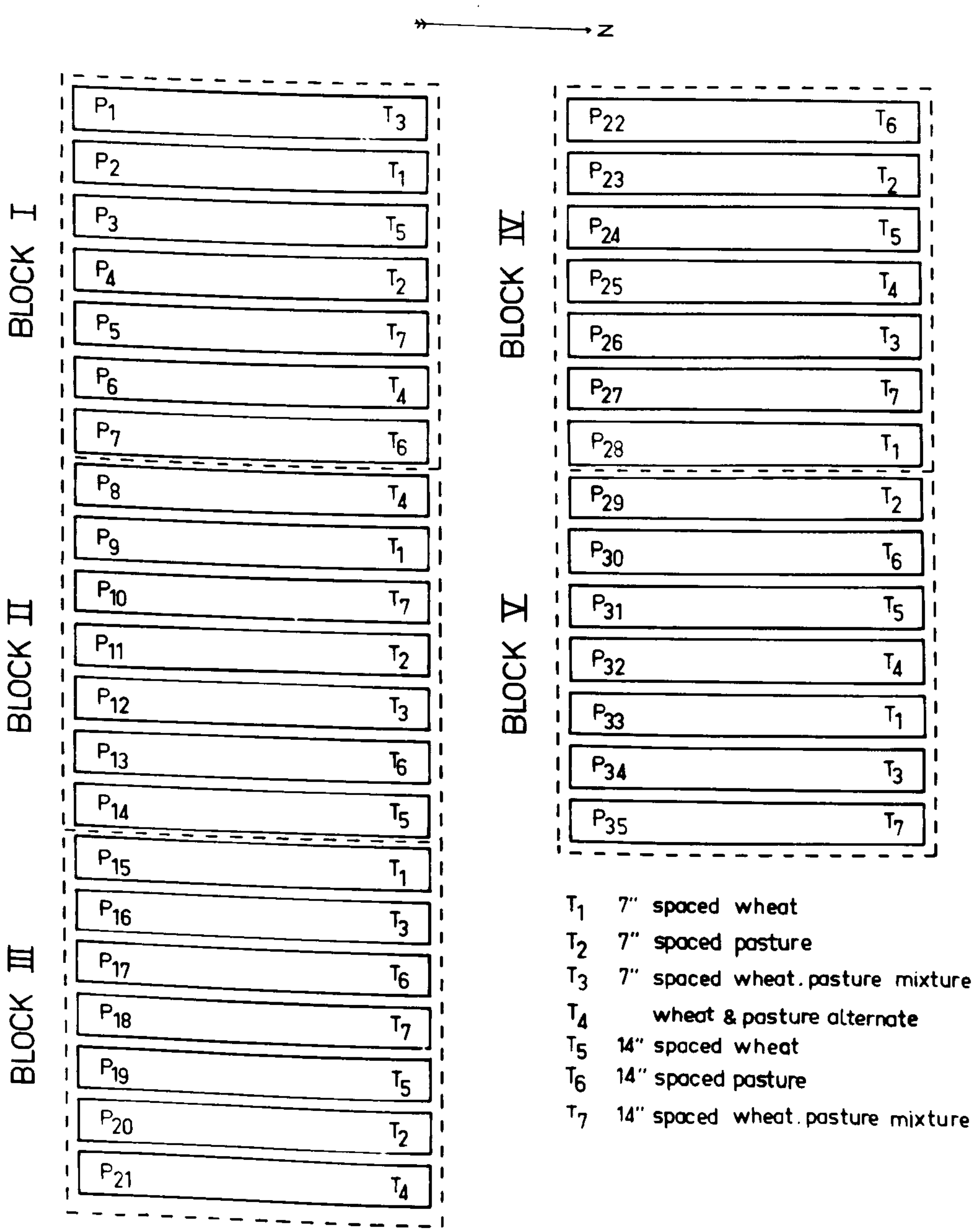
When planting this experiment, T_6 (pasture only at 14" spacing) was drilled first, by shutting off completely the wheat box, and the fertiliser box filled with superphosphate and pasture seed mixture to feed the "odd number" hoes and superphosphate only to

Fig. 2. Diagram of the treatments of Experiment 1. (The spacing of plants along the rows is not representative)



T1
T2
T3
T4
T5
T6
T7
× WHEAT
● PASTURE
←14″→

Fig. 3. Layout of Experiment 1



N
BLOCK I
P1 T3
P2 T1
P3 T5
P4 T2
P5 T7
P6 T4
P7 T6
BLOCK II
P8 T4
P9 T1
P10 T7
P11 T2
P12 T3
P13 T6
P14 T5
BLOCK III
P15 T1
P16 T3
P17 T6
P18 T7
P19 T5
P20 T2
P21 T4
BLOCK IV
P22 T6
P23 T2
P24 T5
P25 T4
P26 T3
P27 T7
P28 T1
BLOCK V
P29 T2
P30 T6
P31 T5
P32 T4
P33 T1
P34 T3
P35 T7
T1 7" spaced wheat
T2 7" spaced pasture
T3 7" spaced wheat.pasture mixture
T4 wheat & pasture alternate
T5 14" spaced wheat
T6 14" spaced pasture
T7 14" spaced wheat.pasture mixture

feed the "even number" hoes. When the 5 Blocks were drilled with this treatment the wheat box was turned on and by allowing only the "odd number" hoes to plant, T_7 (wheat and pasture mixed at 14" spacing) was drilled. After that those compartments of the fertiliser box containing the mixture of fertiliser and pasture seeds were emptied, cleaned and filled with superphosphate only to drill T_5 (wheat only at 14"). Following this the superphosphate in "even number" compartments were emptied and filled with the fertiliser seed mixture and T_4 (wheat and pasture alternate at 7") was drilled. Then the remaining compartments of the fertiliser box containing superphosphate only were emptied and filled with the mixture and by completely shutting off the wheat box T_2 (pasture only at 7") was planted. By allowing all the hoes of the wheat box also to plant T_3 (wheat and pasture mixed at 7") was drilled. On completing this the fertiliser box was again emptied and filled with superphosphate only and with all the hoes of both boxes planting T_1 (wheat only at 7") was drilled.

The drill was set to deliver 1 cwt. superphosphate/acre. When phosphate only in some hoes and the mixture in the others were sown there may have been some difference in the amount of the fertiliser applied along the rows. The field had, however, received considerable quantities of phosphatic fertilisers over the years, and any such differences would not be serious.

At emergence it was noticed that the central row of pasture in T_4 was not sown in all Blocks due to some blockage of that hoe during planting and they were hand sown; however, during harvesting this row and the central row in all other treatments were discarded.

Each Plot was divided into 9 harvest areas 1.25 m. long, separated by 0.5 m. of border area. In the 5 treatments with pasture a group of three adjacent harvest sections were selected at random and were left for observations in the 1961 season. The remaining 6 sections were randomly allocated for harvesting in 1960. At the first four harvest occasions, herbage yields of the three species were determined. At the fifth occasion, the grain yield of wheat also was estimated. On the sixth occasion only seed yields of the pasture species were obtained. The harvest dates and stage of growth of wheat were as follows:-

Harvest	Date	Stage of wheat
1	22/8	Flag leaf
2	19/9	Anthesis
3	17/10	Milk stage
4	14/11	Dough stage
5	12/12	Mature
6	9/1/61	Stubble

In the first three treatments, the outermost rows on either side of the plots and the centre row were discarded and the remaining eight rows harvested, while in the last three ($T_{5, 6 \text{ and } 7}$) four rows were harvested, omitting the two outer rows. In T_4 the wheat was harvested as in $T_{5, 6 \text{ and } 7}$) and for pasture, four rows were harvested omitting the centre row. It should be noted that the harvesting was based on unit area, eight rows being harvested in 7" row spaced treatments and four rows in 14" row space. This can be summarised as follows:-

$T_{1,\ 2 \text{ and } 3}$ (7" row space) — 8 rows harvested

T_4 (alternate rows of wheat and pasture at 7") — 4 rows of each

$T_{5,\ 6 \text{ and } 7}$ (14" row space) — 4 rows

At the first harvest the three species were harvested separately, and the plants counted. In subsequent harvests they were harvested as wheat and pasture; the pasture samples were then separated into grass and legume. After the fifth harvest, and when all pasture seeds had been shed, the wheat was harvested and the whole experiment grazed down with a flock of sheep to remove the stubble. In those treatments including pasture, seeds of grass and clover were collected from two 1 ft. square quadrats placed at random on the 6th harvest section. All material including the soil to the depth of seed burial were collected and the two sub-samples bulked for each plot. They were then cleaned as far as possible and yield of grass and clover seeds obtained.

The plots were then left undistrubed and with the rains in early April 1961, the pasture seeds germinated. On April 11, using a 3" core sampler, 8 cores in 2 rows of 4 cores each with 7" distance between cores were taken per plot. The position of the rows were selected at random. From each of these cores the number of grass and clover seedlings were counted.

Further growth of these plots showed severe nitrogen deficiency and on May 18, each plot was divided into north and south halves. One half selected at random received a top dressing of urea at 1 cwt./acre. With the imposition of the nitrogen treatment the experiment took the form of a 5 x 2 split plot design with 5 replications.

Each subplot was then divided into four harvest sections, 25 cm. long and 1 m. broad, with border strips 20 cm. between harvest sections and 50 cm. along the sides. On the dates of harvesting, a metal quadrat was placed over the area to be sampled and all plant material within the quadrat was removed. At the first harvest the total fresh material was separated into grass and legume fractions which were then dried in an oven to determine dry matter production. At subsequent harvests the fresh material was too large to be dried in its entirety, and after weighing to obtain fresh weight, a subsample of 250 gms. was separated into grass and clover and dried. Total dry weight was then determined from the ratio of fresh to dry weight of the subsample and fresh weight.

4.7.2. Experiments 2 and 2A

These experiments were planted to study the light microclimate in wheat crops planted at different densities, such as might be used when sown with pasture species. In particular it was intended to relate the light profiles to the distribution of the leaf area of the wheat and, in addition, the effect of these planting densities on wheat yields. In these experiments two directions of sowing (N-S and E-W), two rates of sowing (60 and 30 lbs./acre) and two row spacings (7 and 14") were studied on a 2 x 2 x 2 split plot design with five replicates. The two directions of sowing formed the main plots and the four combinations of rates and spacings formed the subplots. The four combinations of rates and spacings gave the following seed populations:-

Treatment	Rate	Spacing	Seeds (lbs./acre)	No. of seeds per m. row length
D_1	60	7"	60	28
D_2	30	7"	30	14
D_3	60	14"	30	28
D_4	30	14"	15	14

The first combination (D_1) would represent the normal method of sowing wheat in South Australia. D_2 and D_3 would have the same number of plants/acre but differ in the number of plants per unit length of the row. The directions of the rows were determined with a compass and corrected for magnetic declination.

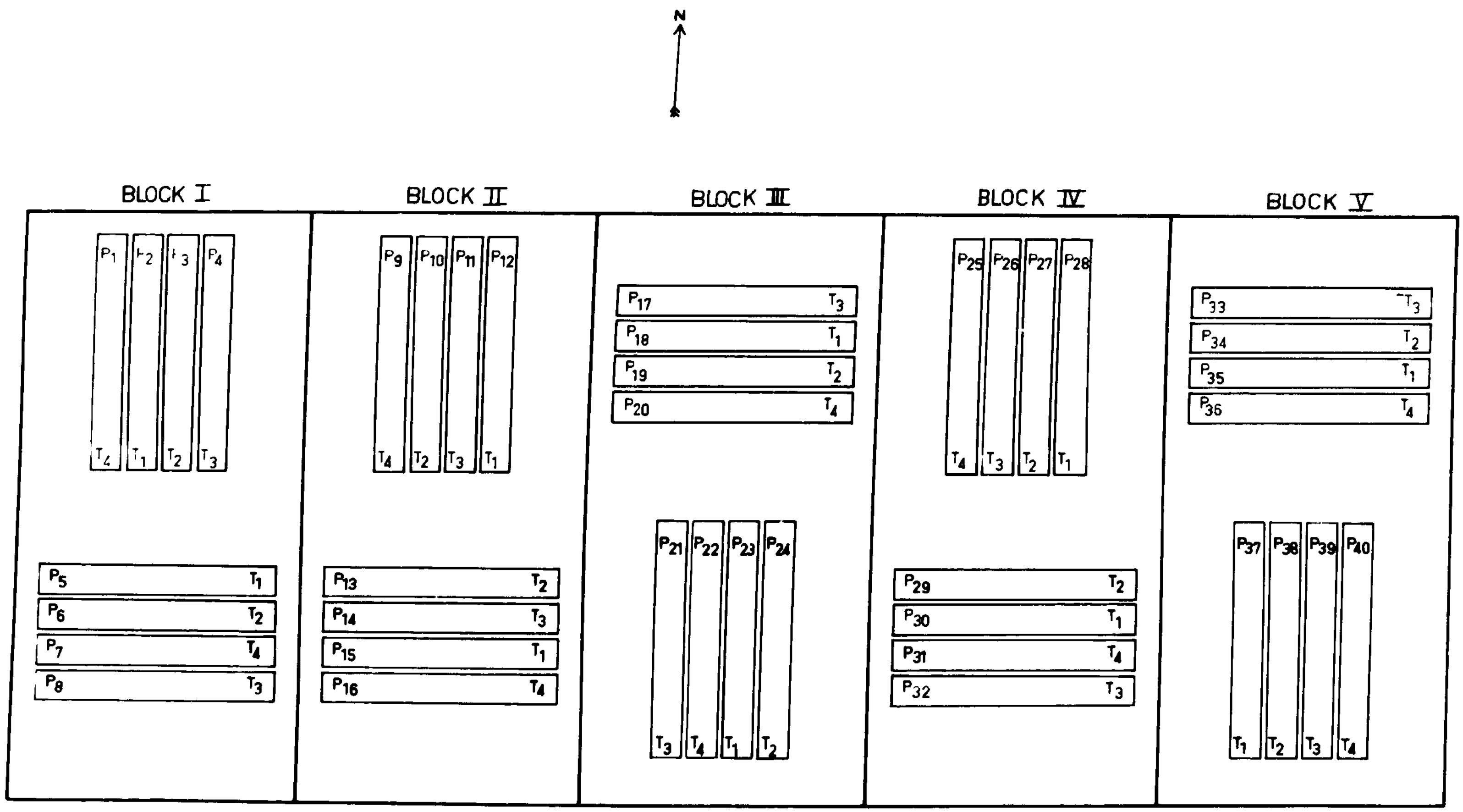
The experiments were planted with a 9 hoe drill. The fertiliser box was set to deliver 1 cwt. superphosphate per acre through all hoes.

Experiment 2A was planted on 12 May, 1961 in Waite Institute Field W4, and Experiment 2 four weeks later on 9 June, in Field W25. Even though the design and layout were similar in both instances they were separately randomised. The layout of Experiment 2 is shown in Fig. 4.

The main plots were 6 m. apart, this space being necessary for the manipulation of the tractor. The subplots were 10 m. long and 1.25 m. wide (width of one 9 hoe drill). There was 0.25 m. space between subplots. Each subplot was divided into harvest areas with border strips as in the previous experiment. The length of the harvest area was 1 m. Five harvest areas were allowed for, although not all were used in Experiment 2A. Harvesting was based on unit number of rows, i.e. in 14" spaced treatments 3 rows each a metre long were harvested omitting the outer rows; and in 7" spaced treatments the 3rd, 5th and 7th rows were harvested. This was done for two reasons : firstly the individual hoes of the drill varied considerably in their rates of sowing, so that by harvesting the same rows this source of error could be eliminated. Secondly considerable time was saved in harvesting and handling of the material.

Leaf area measurements as described earlier were made at the first harvest in Expt. 2A., and at the first two harvests in Expt. 2. Originally it had been intended to make such measurements at all harvests in Expt. 2 but the senescence of nearly all the

Fig. 4. Layout of Experiment 2



T_1 — 60 lbs/acre 7" spacing

T_2 — 30 lbs/acre 7" spacing

T_3 — 30 lbs/acre 14" spacing

T_4 — 15 lbs/acre 14" spacing

leaves between the second and third harvests made this impossible.

4.7.3. Experiments 3 and 3A.

These experiments were designed to study the effect of wheat on clover planted in rows at different positions relative to the rows of wheat, and the effect of clover planted in these ways on the growth and yield of wheat.

The design was a 2 x 6 split plot with 5 replicates. The main plots were the two directions of sowing, N-S and E-W rows. Each main plot was divided into 6 subplots; two were controls of wheat and clover, both planted at 14" spacing. The other four were wheat with clover planted at different positions between the wheat rows. The wheat in these were planted at 14" spacing and the distance between the clover rows was also 14". The six treatments were :-

T_1 Wheat only 14" row spacing

T_2 Clover only 14" row spacing

T_3 clover rows 0" from wheat rows (Mixed planting on the same row) P_0

T_4 clover rows $3\frac{1}{2}$" to right of wheat rows $P_{3\frac{1}{2}}$

T_5 clover rows 7" to right of wheat rows P_7

T_6 clover rows $10\frac{1}{2}$" to right of wheat rows $P_{10\frac{1}{2}}$

The positions were relative and determined in the case of E-W rows by facing east and measuring left to right; and in N-S rows by facing south and again reading left to right. An alternate form of presentation, in line with that of Larson and Willis (1957) would be :-

For E-W rows

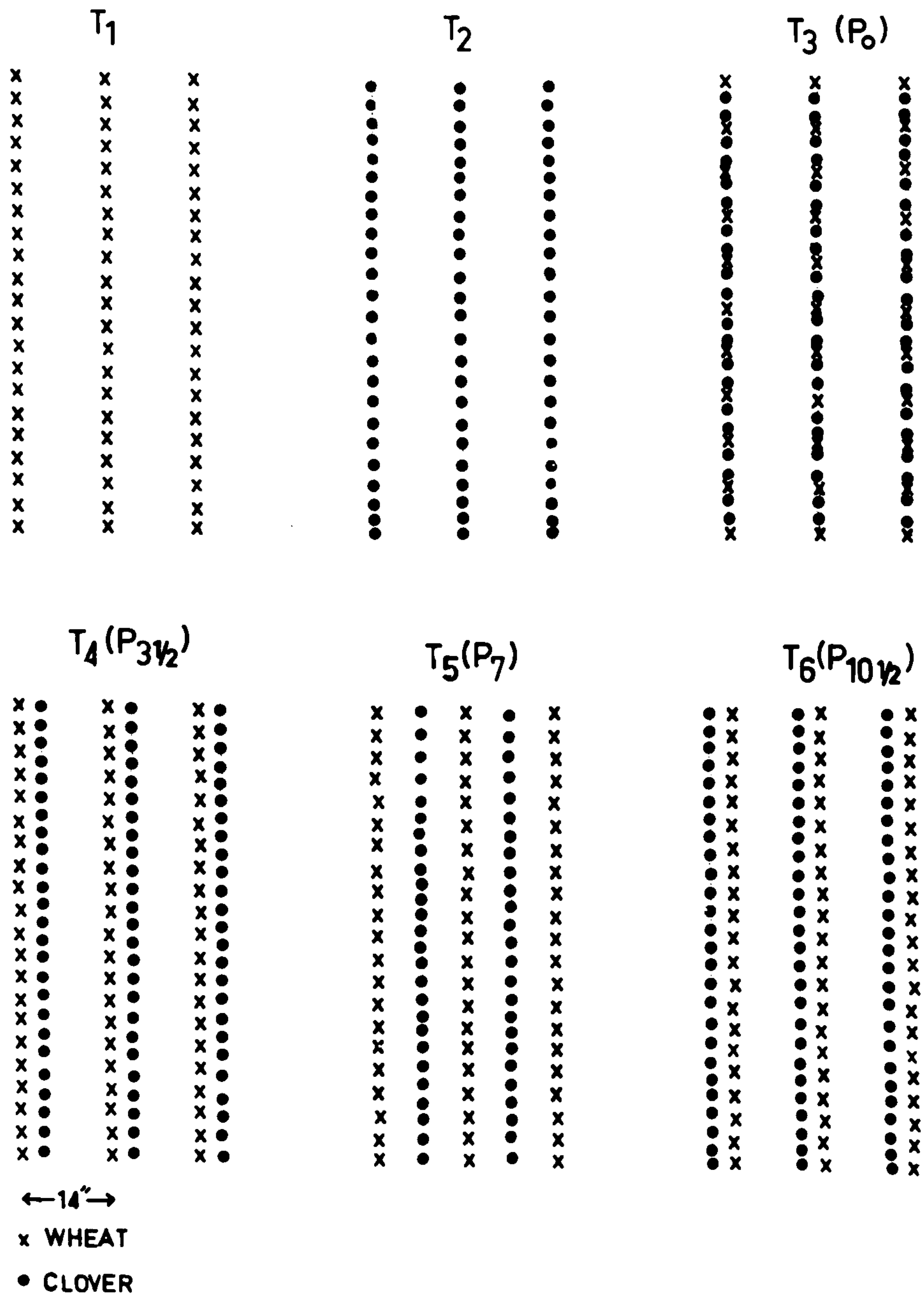
Clover rows 0" south of wheat rows	P_0
Clover rows 3½" south of wheat rows	$P_{3\frac{1}{2}}$
Clover rows 7" south of wheat rows	P_7
Clover rows 10½" south of wheat rows	$P_{10\frac{1}{2}}$

The scheme of treatments are shown diagrammatically in Fig. 5, and the layout of Experiment 3 in Fig. 6.

The experiments were planted with a 9 hoe drill using 1 cwt./acre superphosphate. In Experiment 3A wheat was sown from the wheat box with the 2nd, 4th and 6th and 8th hoes blocked. The clover seeds were in a separate box attached in front of the wheat box. Wheat only plots were sown with the clover box completely shut off and the clover only plots with the wheat box shut off. Plots of P_0 were sown with both boxes feeding only the "odd number" hoes. Then the "odd number" hoes were shut off and "even number" hoes were opened in the clover box to plant the plots of P_7. To plant $P_{3\frac{1}{2}}$ and $P_{10\frac{1}{2}}$ the "even number" hoes that were planting clover were shifted 3½" to the right of the "odd number" hoes planting wheat, and in any main plot the tractor was driven in one direction to plant $P_{3\frac{1}{2}}$ and in the opposite direction to plant $P_{10\frac{1}{2}}$. It should be noted that both wheat and clover seeds were sown at the same depth.

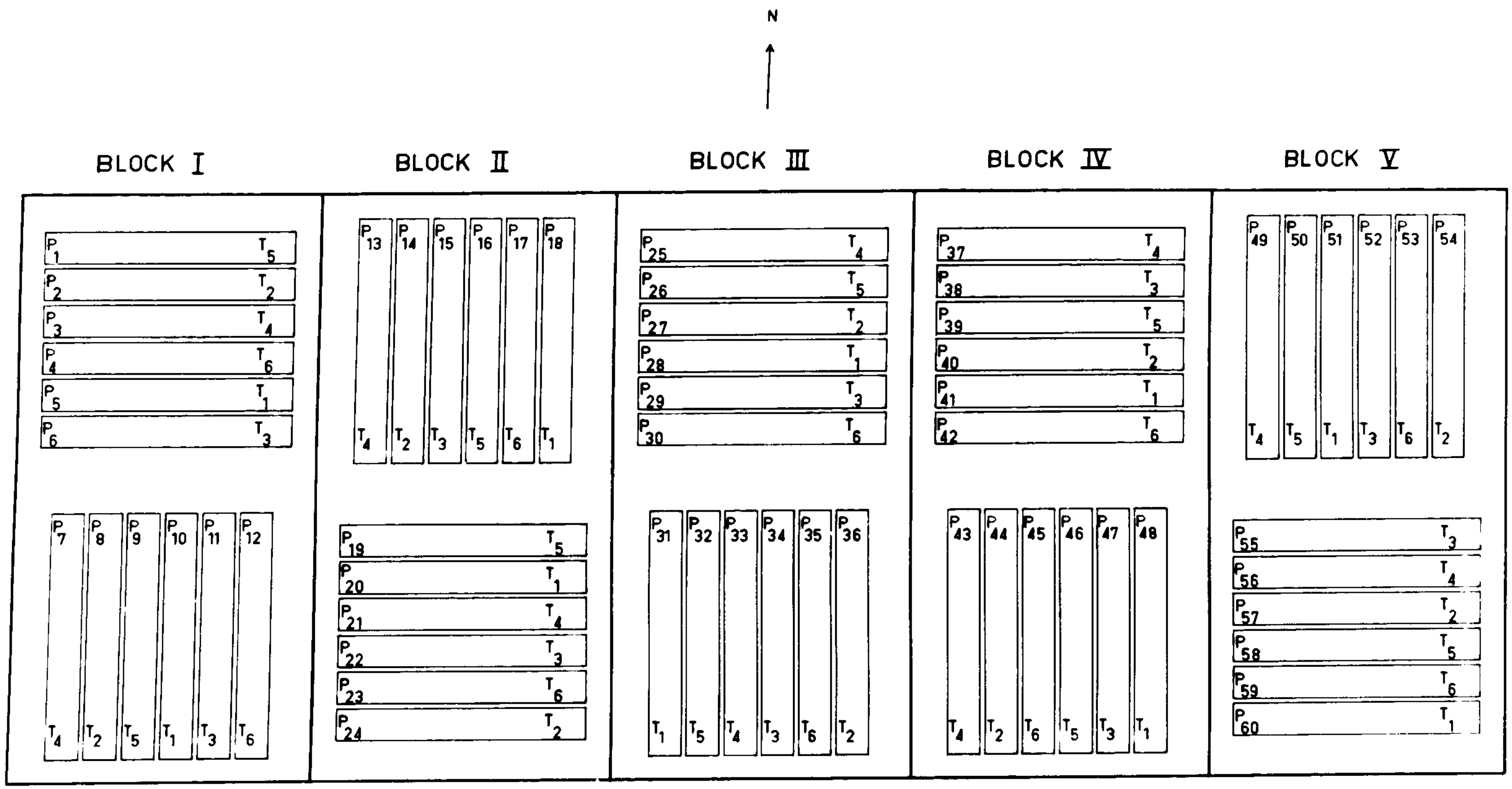
In Experiment 3 the planting technique was essentially

Fig. 5. Diagram of treatments of Experiments 3 and 3A. (The spacing of plants along the rows is not representative)



T1
T2
T3 (Po)
T4(P3½)
T5(P7)
T6(P10½)
←14"→
x WHEAT
• CLOVER

Fig. 6. Layout of Experiment 3



T_1 WHEAT CONTROL		T_4 CLOVER $3\frac{1}{2}''$ FROM WHEAT	($P_{3\frac{1}{2}}$)
T_2 CLOVER "		T_5 " 7" " "	(P_7)
T_3 WHEAT & CLOVER MIXED	(P_0)	T_6 " $10\frac{1}{2}''$ " "	($P_{10\frac{1}{2}}$)

the same except that the clover seeds were led along separate tubes to allow them to fall onto the ground surface at the different row positions. This method was adopted so that the clover seeds could be planted shallower, enabling better establishment, but it involved a risk of spreading the clover seeds and consequently some inaccuracy of row position; however, subsequent establishment showed that this was not serious.

Experiment 3A was planted on May 12, in Waite Institute Field W4 with wheat at 15 lbs./acre and clover at 7.5 lbs./acre. Experiment 3 was planted on June 9, on field W25 with wheat at 30 lbs./acre and clover at 11 lbs./acre. Each subplot was 11 m. long and 1.25 m wide with 0.25 m pathway between. They were divided into harvest sections with border strips 0.5 m. long. When harvesting, the three centre rows were taken in the control plots, and T_3. In the others, wheat was harvested as per control plots. The clover harvest consisted of the two centre rows plus one of the outer rows chosen at random for each plot at each harvest. Experiment 3A was harvested on three occasions. At the first harvest both species were harvested, at the second only clover was harvested, while only wheat was taken at the third. Experiment 3 was harvested on five occasions. While at the first four occasions both species were harvested, the fifth harvest consisted only of wheat as all the clover had died and disintegrated.

4.7.4. Experiment 4

This was the final experiment undertaken in this series of investigations. It set out to determine for undersown clover the optimum rate of sowing of wheat at 14" spacing and in a N-S direction; to confirm the growth of clover in relation to their position to the wheat and the effect of the clover on the wheat. The design of the experiment was rather complex and the statistical analysis proceeded in 3 stages.

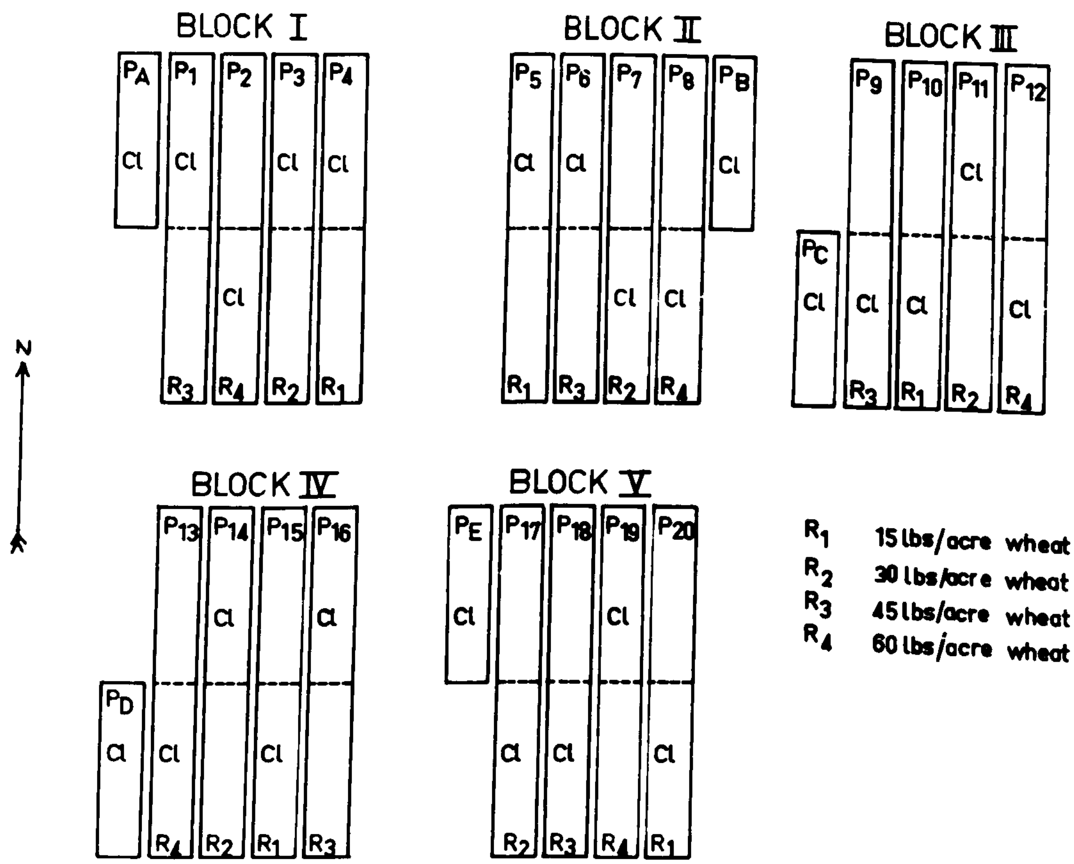
(i) 4 x 2 split plot design with 5 replicates consisting of main plots of 4 rates of wheat with split plots of presence and absence of clover.

(ii) Randomised block design of 5 levels of wheat on the growth of clover. Four of these levels of wheat would be the four wheat clover plots of the previous arrangement with a 5th plot of clover only.

(iii) 4 x 4 split plot design with 5 replicates. The four main plots here would be the wheat - clover subplots of (i) and the split plots would be the 4 positions as in Experiment 3 and 3A. The layout is shown diagrammatically in Fig. 7.

The clover in this experiment was broadcast, and position P_0 was a strip $3\frac{1}{2}$" wide running $1\frac{3}{4}$" on either side of the wheat rows. $P_{3\frac{1}{2}}$ would be another strip $3\frac{1}{2}$" right of P_0 and so on. While in Experiment 3 and 3A, where the clover was sown in rows,

Fig. 7. Layout of Experiment 4.

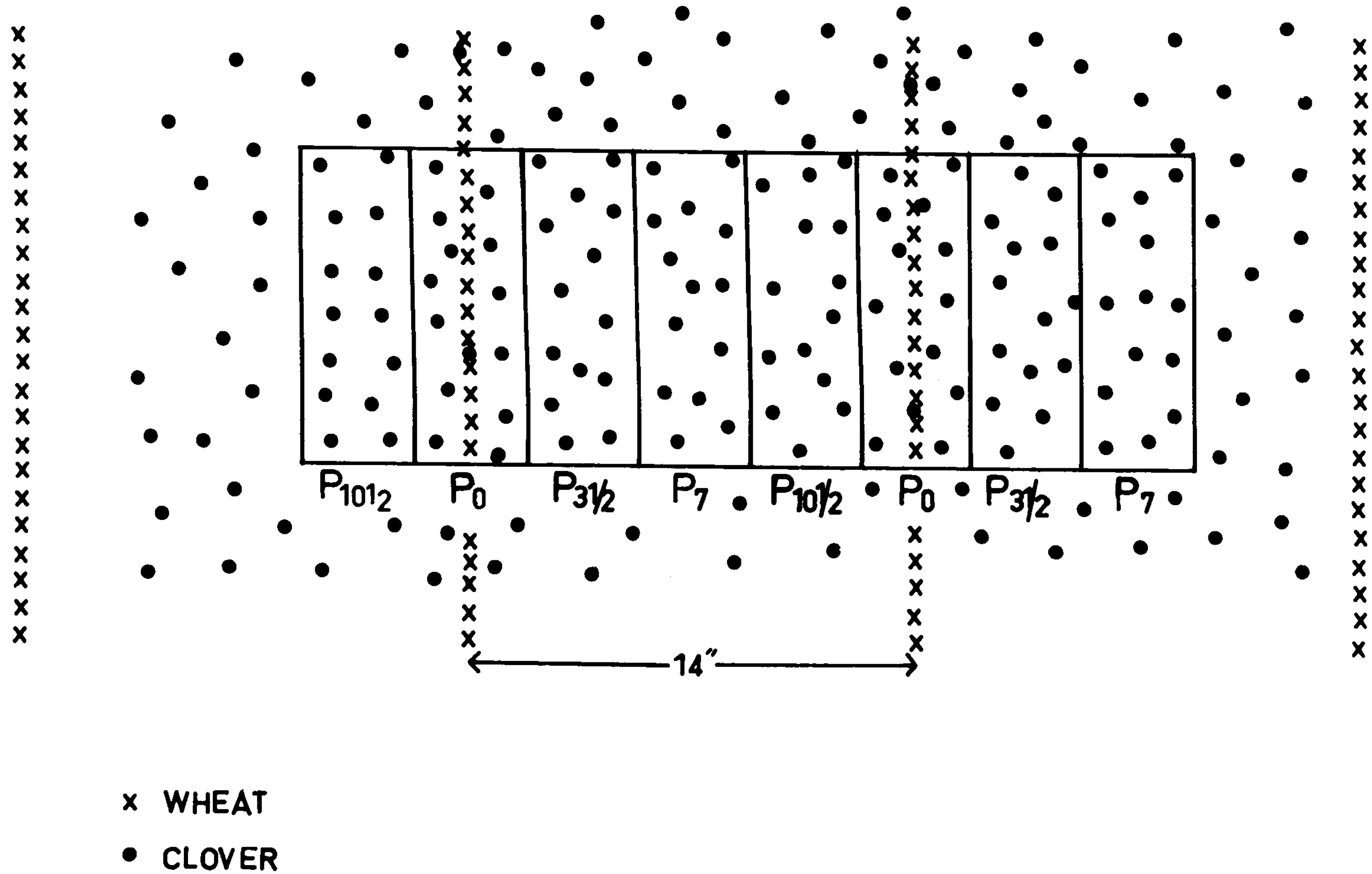

BLOCK I
PA
P1
P2
P3
P4
Cl
R3
R4
R2
R1
BLOCK II
P5
P6
P7
P8
PB
R1
R3
R2
R4
BLOCK III
P9
P10
P11
P12
PC
R3
R1
R2
R4
N
BLOCK IV
P13
P14
P15
P16
PD
R4
R2
R1
R3
BLOCK V
PE
P17
P18
P19
P20
R2
R3
R4
R1
R1 15 lbs/acre wheat
R2 30 lbs/acre wheat
R3 45 lbs/acre wheat
R4 60 lbs/acre wheat

the positions were in effect lines, here, with broadest clover they were strips, the centre lines of which were comparable to the rows in Experiments 3 and 3A.

The wheat was planted with a 9 hoe drill with the even number hoes blocked. No fertiliser was drilled in, but all the plots were broadcast with superphosphate at 1 cwt./acre. The clover was broadcast at 50 lbs./acre and was gently raked in. Each subplot was 5 m. long and 1.25 m. wide. They were divided into 3 harvest sections, each 1 m. long and separated by border strips 0.5 m. long.

After the two crops had emerged, quadrats were placed in the clover plots, one in each of the harvest sections. Each quadrat was 10" x 28" with cross wired dividing it into 8 strips each 10" x 3½". The 8 strips would represent an internal replication of 2. (See Fig. 8 and Plate 2). Since only two rows of wheat were necessary one of the outer rows was omitted at random. The quadrats were then placed across the two selected rows such that either the 1st, 2nd or 3rd strip enclosed the outer row of wheat. Again the position was selected at random. Only those three strips were permitted to cover the outer row as the fourth strip would carry the quadrat too far to the edge of the plot. The three centre rows of wheat were harvested and the clover plants in each of the strips were placed in separately labelled paper bags. Three harvests were taken, in the third of which clover was harvested only for seed yield.

Fig. 8. Diagram showing a quadrat frame dividing the area between rows of wheat into positions for harvesting clover.



$P_{10\frac{1}{2}}$
P_0
$P_{3\frac{1}{2}}$
P_7
$P_{10\frac{1}{2}}$
P_0
$P_{3\frac{1}{2}}$
P_7
14"
x WHEAT
• CLOVER

Plate 2. (a) General view of one of the undersown subplots with the quadrats frames for harvesting clover across the rows of wheat.

(b) A close-up view of one quadrat frame in position.

5.0.0. RESULTS

5.1.0. Experiment 1

5.1.1. Plant numbers

The number of plants per meter length of row was counted on two occasions (3 and 14 weeks from sowing). The first occasion was after all species have emerged and the second was at the time of first harvest.

Wheat

There was no significant difference in the number of wheat plants per meter length of row between treatments at either count or between counts. The mean number of plants per meter length of row at the first count was 11.1 and at the second 10.7.

Grass

At both counts there were highly significant differences ($P < 0.001$) between treatments, as shown in Table 3.

Table 3

Mean Number of Lolium Plants/m. length of row

	T_2	T_3	T_4	T_6	T_7	L.S.D. 5%
At emergence	18.9	14.8	23.3	30.6	19.9	
At 1st Harvest	18.2	12.3	19.4	24.6	15.4	
Mean	18.6	13.6	21.4	27.7	17.7	3.4

The difference between the controls (T_2 and T_6) and the undersown treatments may be attributed to a suppression of establishment of the grass by wheat, but it would be difficult to explain the big difference within the controls. The only difference between these treatments was that in T_2 the rows were 7" and in T_6 14" apart. It would be difficult to imagine that at such an early stage in growth there was some effect of competition between rows; on the other hand, the overall reduction in numbers at the second count may be attributed to competition.

Clover

Treatment differences were again significant ($P < 0.01$) at both counts and the effect was similar to that of the grass as shown in Table 4. No significant differences were observed between counts.

Table 4

Mean number of Clover plants/m. length of row

	T_2	T_3	T_4	T_6	T_7	L.S.D. 5%
At emergence	8.5	7.6	9.7	12.6	10.2	
At 1st Harvest	9.5	5.3	8.1	13.3	7.3	
Mean	9.1	6.5	8.9	13.0	9.0	2.1

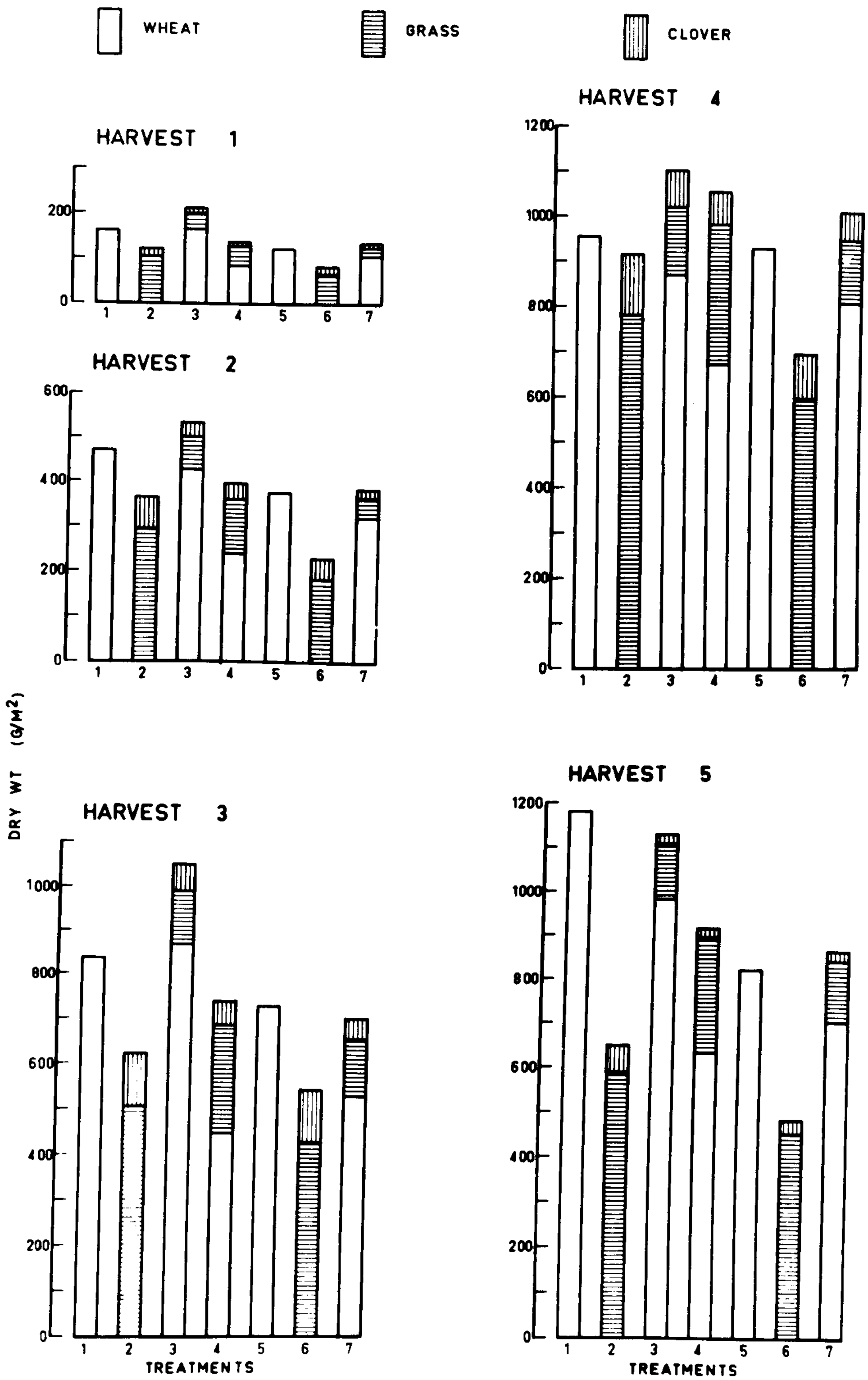
5.1.2. Dry matter yield

At all harvests those treatments sown at the higher rate of sowing (30 lbs./acre wheat and 10 lbs./ acre pasture) both individually and in combination, yielded significantly higher ($P < 0.001$) than the corresponding treatments with half the rate of sowing. At the high rate of sowing the yield of the wheat control was always higher than the pasture control. The combination of wheat and pasture was higher than the wheat control, at the first four occasions, while at the fifth occasion there was no significant difference, (Fig. 9). At the low rate of sowing, the relationship was essentially similar to that of the high rate except that the mixed treatment (T_7) was not significantly different from the wheat control (T_5) except at the fourth harvest occasion. In the three mixed cropping treatments (T_3, T_4 and T_7) the 7" spaced treatment was consistently higher than the other two. The alternate row treatment (T_4) was not different from the 14" spaced treatment (T_7) at the first occasion, but was higher at the third and fourth occasion. This increased yield was not significant at the fifth occasion.

<u>Yield of wheat</u>

At the first harvest occasion the 7" spaced wheat treatments yielded more than the 14" spaced treatments and this difference between the two groups was maintained throughout the experiment. At the first occasion there was no difference between the 7" control and the 7" mixed treatment. This relationship was maintained till the third harvest, and at the last two occasions the yield of the control was greater than the mixed treatment, indicating a competitive

Fig. 9. Dry matter yield/m^2 of the three species at successive harvests.

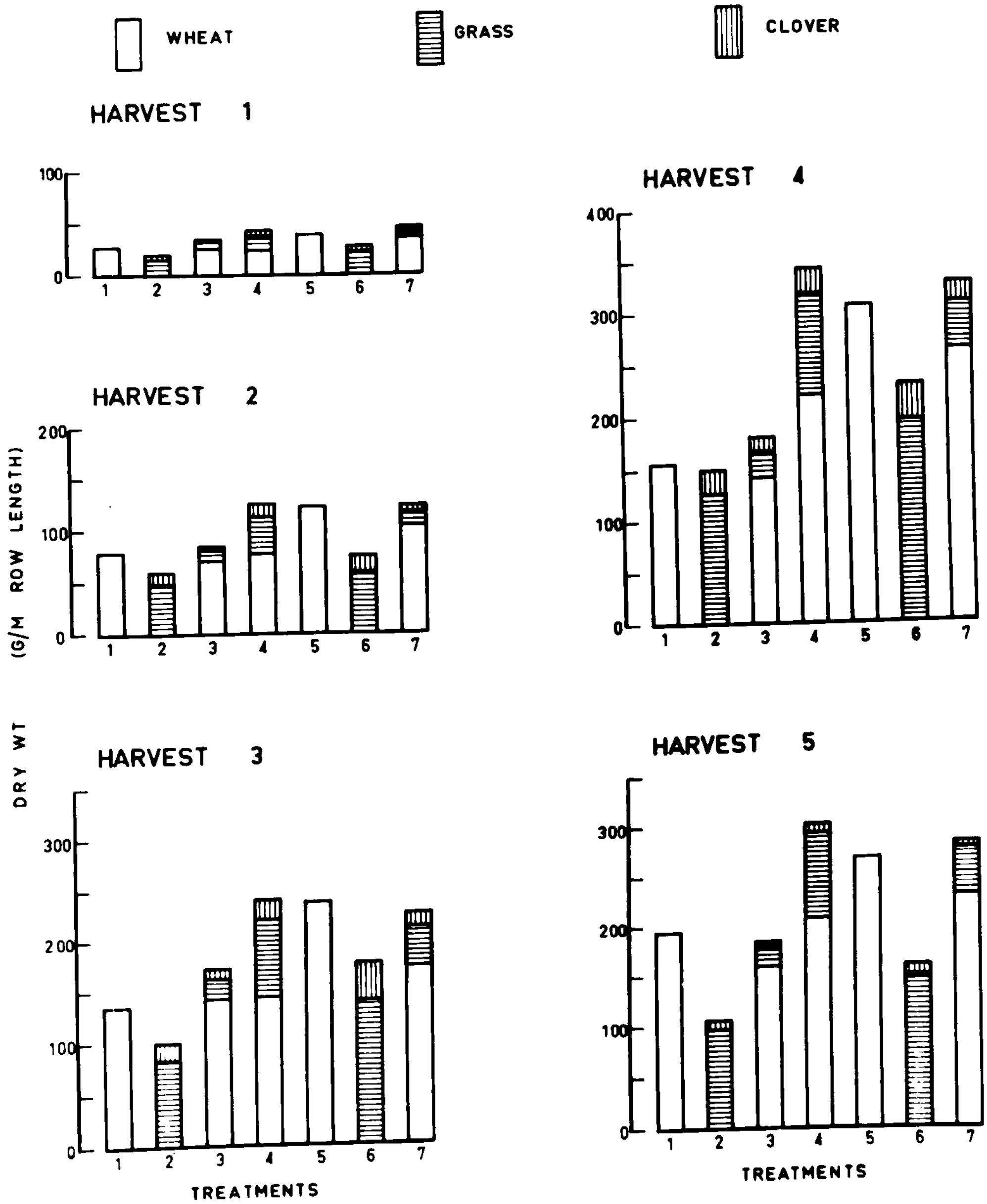

WHEAT
GRASS
CLOVER
HARVEST 1
HARVEST 2
HARVEST 3
HARVEST 4
HARVEST 5
DRY WT (G/M²)
TREATMENTS
TREATMENTS

effect of the undersown pasture on the wheat. Among the 14" spaced treatments the control always yielded higher than the two mixed treatments. The difference was slight at the first occasion, but increased with time. Of the two 14" mixed treatments, that with the two crops on the same row (T_7) yielded consistently higher than that with the two crops in alternate rows (T_4), even though both had the same number of plants per unit area. In other words where the two crops were in alternate rows there was greater depression of wheat than when they were mixed on the same row.

So far dry matter production has been considered on a unit area basis, but the effects of competition might be better understood by studying the yield per plant. Plant counts were however made only at the first harvest occasion but a very close approximation would be obtained by examining the yield per unit length of row under each system of cropping (Fig. 10).

Considering first the g. dry matter yield per meter length of row, the mean yield of 7" spaced treatments were lower than that for 14" spaced treatments. In the 7" spaced treatments the yield of the control was higher than that of the mixed treatment at the last two harvest occasions. The 14" control treatment was higher than the mixed treatments, and where the pasture was mixed with the wheat on the same row the yield was higher than where the two crops grew in alternate rows. It is of interest

Fig. 10. Dry matter yield/m. row length of the three species at successive harvests.


WHEAT
GRASS
CLOVER
HARVEST 1
HARVEST 2
HARVEST 3
HARVEST 4
HARVEST 5
DRY WT (G/M ROW LENGTH)
TREATMENTS
TREATMENTS

to note that where the crops grew in alternate rows, the yield was the same in both 14 and 7" treatments till the third harvest occasion, while at the fourth occasion the 14" yielded more than the 7" treatment; at this harvest, as stated earlier, the 7" mixed treatment yielded singificantly lower than the 7" control. This relationship among these three treatments were maintained at the final harvest.

Yield of pasture

The yield of pasture in the control treatments was significantly higher ($P < 0.001$) than the mixed treatments at all harvests; and again the 7" spaced control yielded higher than the 14" on a per/m^2 basis. Among the mixed treatments, T_4 was significantly higher ($P < 0.01$) than T_3 and T_7 at all stages. T_3 was significantly higher than T_7 at the first two harvest occasions, but thereafter the difference was not significant. It is interesting to note that among the mixed treatments the yield of wheat in T_4 was the lowest while the yield of pasture was highest.

Considering yield per metre length of row, T_6 was higher than T_2 and the relationship between T_4 and T_7 was the same as for yield per unit area. The yield of T_3 dropped significantly below that of T_7. This difference increased with time. On the whole T_4 gave the highest pasture growth among the mixed treatments.

Yield of grass

Since all pastures in the experiment were grass dominant throughout, the yield and pattern of response of the various treatments were largely controlled by the grass fraction, so that any description would amount to repetition of the statements made in the last section.

Yield of clover

Yields of clover in this experiment were very low. The highest yield recorded was 124.4 g/m^2 at the fourth harvest, as compared to an yield of 728.2 g/m^2 of grass for the same treatment and harvest. Clover in this experiment was growing under severely reduced light intensities, being shaded by the grass or by both grass and wheat. However, even at this low level of growth there were interesting responses to the various treatments which were on the whole in accordance with the response already recorded for the pasture.

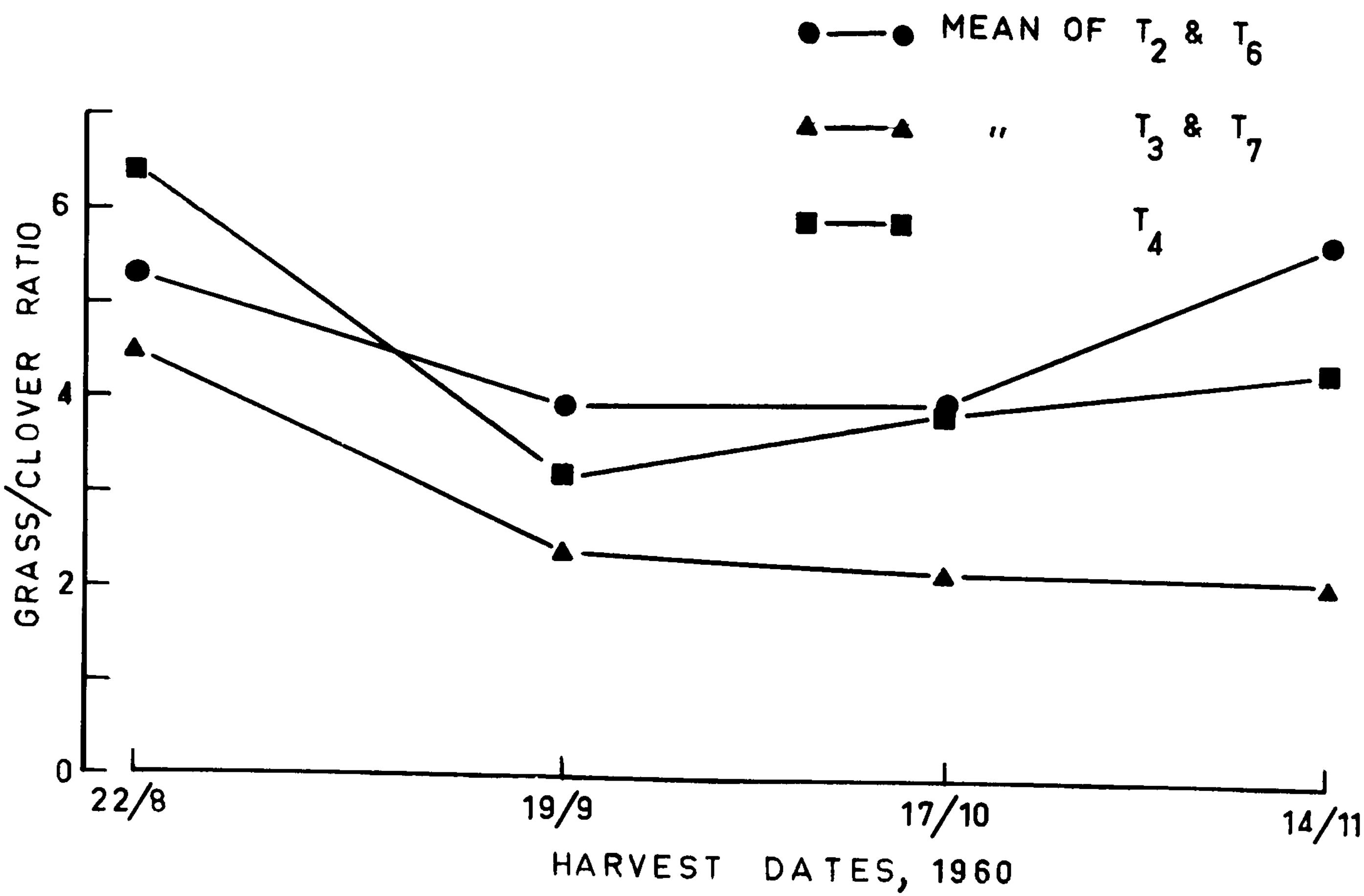
The control treatments (T_2 and T_6) yielded higher than the mixed treatments and again T_2 was higher than T_6. Among the mixed treatments there was no significant difference at the first harvest. While the lack of difference between T_4 and T_7 may have been due to the similar competitive effect of the associated species on clover and, that in T_3 was more severe, even though T_3 had double the number of clover plants/m^2 still the yield was not higher than T_4 or T_7. This relationship however was changed at the second harvest where there was no difference between T_3 and T_4 although the yield of T_7 was significantly lower, a relationship evident also at the third occasion. At the fourth occasion T_3, T_4 and T_7 yielded 72.3, 64.9 and 56.0 g/m^2 respectively.

In the yield per meter length of row the response of the clover was different to that of wheat and grass. Of the controls T_6 was very much higher than T_2; in fact T_2 was so low that except at the first harvest there was no significant difference between it and T_4. There was no difference between T_3 and T_7 at the first two occasions while at the next two T_7 was significantly greater than T_3 ($P < 0.05$). This difference was not significant at the last occasion.

Grass clover ratio

The proportion of grass to clover was lower when the pasture and the wheat were mixed in the same row than when the pasture rows were separated from the wheat rows (Fig. 11). At the second harvest the ratios of all treatments decreased considerably in comparison to that at the first occasion and remained more or less at that level at the third occasion. At the fourth occasion however T_2 and T_6 (controls) rose to a high level while T_4 was only slightly higher than the previous occasion. T_3 and T_7 did not vary appreciably.

Fig. 11. Grass-clover ratios at successive harvests.


MEAN OF T_2 & T_6
" T_3 & T_7
T_4
GRASS/CLOVER RATIO
0
2
4
6
22/8
19/9
17/10
14/11
HARVEST DATES, 1960

It would appear that in the presence of wheat clover grows relatively better than grass; in other words the grass is depressed to a greater extent than the clover by wheat. The trend of T_4 is not clear in this experiment though it appears to be intermediate between the controls and the mixed treatments.

5.1.3. Summary of yield data

In all treatments the yield at the last occasion was lower than at the fourth, as a result of the loss of leaves in all species and the shedding of seeds in the pasture.

While various changes occurred throughout the growth of the experiment, the response at the fourth harvest would adequately summarise the results of the experiment and elucidate the results of competition between the two crops.

(i) In total production the 7" mixed treatment was superior to the 14" mixed and the alternate treatments.

(ii) Wheat yields were also highest in the 7" mixed treatment.

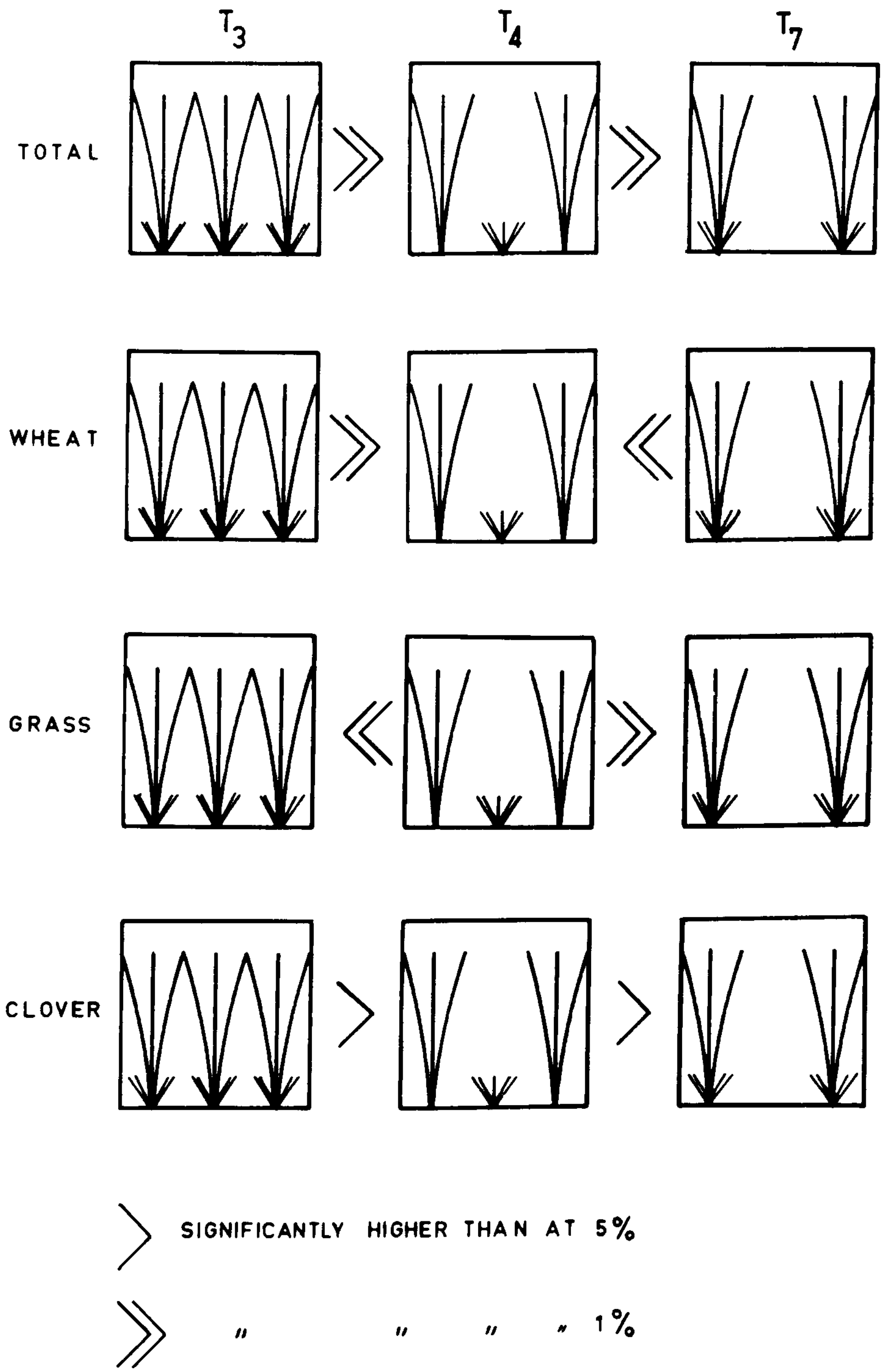
(iii) Pasture yields were highest in the alternate treatment and there was little difference between the other two.

(iv) The yield of grass was essentially similar to that of the pasture.

(v) Clover yields were highest in the 7" than in the alternate treatment and least in the 14" mixed treatment. These relationships are shown diagrammatically in Fig. 12.

Fig. 12. Diagram showing the difference between treatments in Dry matter yield/m^2 at the fourth harvest.

DRY WT (G/M²)


T3
T4
T7
TOTAL
WHEAT
GRASS
CLOVER
SIGNIFICANTLY HIGHER THAN AT 5%
" " " " 1%

5.1.4. Yield components

Wheat

Tiller numbers per plant

There were no significant differences between treatments at the first harvest, but the counts made at the final harvest showed significant differences between treatments (Table 5).

Table 5

Mean number of tillers per wheat plants

	T_1	T_3	T_4	T_5	T_7	L.S.D. 5%
H_1	3.87	4.36	3.62	5.05	4.68	1.13
H_5	5.15	4.48	6.12	8.48	6.47	0.64

In the presence of pasture there was a marked reduction in tiller numbers, a reduction which was greater in the 14" spaced treatments than in the 7". These data are in accordance with the dry matter production of wheat and would to a very great extent explain the difference in yield observed there. At the last count the number of sterile tillers were negligible.

Tiller weights

There was a steady increase in weight per tiller with time, but there was no significant differences between treatments at any harvest (Table 6). These data indicate that the difference in yield per meter length of row of wheat was not due to difference in weight per tiller.

Table 6

Mean weight per tiller of wheat at successive harvests

	H_1	H_2	H_3	H_4	H_5
T_1	0.76	2.14	3.42	3.98	4.20
T_3	0.74	1.97	3.67	4.16	4.49
T_4	0.65	2.02	3.67	4.38	4.37
T_5	0.69	1.87	4.19	4.51	4.05
T_7	0.69	1.86	3.42	4.44	4.28
L.S.D. 5%	ns	ns	ns	ns	ns

Leaf area index

The mean L for the various treatments are recorded in Table 7. Significant differences were observed between the 7" and

Table 7

Mean L of wheat at successive harvests

	H_1	H_2	H_3
T_1	1.09	1.76	0.78
T_3	1.08	1.44	0.91
T_4	0.58	0.82	0.44
T_5	0.92	1.20	0.58
T_7	0.74	1.08	0.47
L.S.D. 5%	0.28	0.52	0.32

14" spaced crops. The depression due to the presence of pasture was evident at all harvests and for all treatments except between the 7" control and mixed treatments at the third harvest. The depression was more marked in the 14" than in the 7" crops, and among the former more so in the alternate than the mixed treatment.

Grain yield

The 7" spaced control yielded higher than the 14" control. Within the 7" spaced treatments yields were significantly reduced by the presence of the pasture. Within the 14" spaced wheat crops the control was superior (not significantly) to the mixed treatment, but was significantly higher than the alternate row treatment (Table 8).

Table 8

Grain yield of wheat

	T_1	T_3	T_4	T_5	T_7	L.S.D. 5%
G/m^2	481.78	363.01	252.19	333.38	281.15	112.86
G/m row length	84.52	63.66	88.48	116.93	98.25	17.61

These yield figures are in accordance with the dry matter production recorded for wheat, showing a depression due to presence of pasture, which is higher in 14" spaced treatments when the pasture is between rather than beneath the rows of wheat. The extent of depression is clearly seen on the basis of yield per meter length of row. Since the increased yields of T_5 did not compensate for the reduction in the number of rows, the utilisation of the land must have been inefficient when wheat was planted in 14" spacing as compared to 7". The depression due to pasture was greater in 7" spaced crops (24.7%) than in 14" spaced crops (16.0%), and it is interesting to note that the yield of 7" control was not significantly different from the alternate row treatment. If both these two treatments were considered to be basically 14" spaced wheat crops, with another row of wheat alternating in T_1 and a row of pasture in T_4, then it would appear that the row of pasture was as effective as the row of wheat in competing with the basic rows of wheat; T_4 was 24.3% less than T_5.

Weight per grain

Significant differences were observed in 1000 grain weight between the control and mixed treatments with 7" spacing, but there was no difference between the corresponding 14" spaced treatments. The alternate row treatment gave the lowest weight and was significantly lower than either of the controls (Table 9)

Table 9

1000 grain weight of wheat

T_1	T_3	T_4	T_5	T_7	L.S.D. 5%
43.30	41.32	40.16	42.32	42.04	1.78

Grass

Tiller numbers per plant

At the first harvest, the only occasion where tiller numbers could be estimated with any accuracy, there were no significant differences between the two control treatments. The three mixed treatments were not different among themselves but were significantly lower than the controls. (Table 10).

Table 10

Mean number of tillers per grass plants at the first harvest

T_2	T_3	T_4	T_6	T_7	L.S.D. 5%
15.39	9.63	8.80	15.11	6.53	3.72

The reduction in tiller numbers due to the presence of wheat was quite evident. Earlier it was recorded that there was a large reduction in the numbers of grass plants due to the presence of wheat and with this reduction in tiller numbers the reduced yields recorded for grass in association with wheat could be largely explained.

Tiller weights

No significant differences were observed between treatments at the first harvest. At the fourth occasion, however, in the 7" spaced treatments the tillers from the mixed treatment weighed significantly less than ($P < 0.05$) the control. This difference was evident at the first two occasions also, though not significant. (Table 11); a similar trend between the control and mixed 14" spaced treatments was evident. No data were recorded at the

Table 11

Mean weight per tiller of grass at successive harvests

	H_1	H_2	H_3	H_4
T_2	0.079	0.212	0.524	0.774
T_3	0.058	0.176	0.555	0.616
T_4	0.083	0.225	0.509	0.718
T_6	0.062	0.185	0.554	0.634
T_7	0.075	0.168	0.464	0.576
L.S.D. 5%	ns	ns	ns	0.127

fifth harvest due to uneven shedding of seeds. Here again - as in the case of the wheat - the difference between tiller weights would not account for the big differences between treatments in herbage yields.

Leaf area index

The L of the mixed treatments were significantly lower than the corresponding control treatments. The depression due to the wheat was greater in the 7" spaced treatments than in the 14". Among the latter the mixed treatment was reduced much more than the alternating treatment (Table 12)

Table 12

Mean L of grass at successive harvests

	H_1	H_2	H_3
T_2	0.94	3.14	2.04
T_3	0.36	0.78	0.64
T_4	0.44	1.14	0.94
T_6	0.70	1.62	1.49
T_7	0.25	0.60	0.63
L.S.D. 5%	0.23	0.63	0.53

Seed yields (Grass)

The relationship between treatments in seed yields were similar to that obtained in herbage production (Table 13). Highest yield was obtained in7" control treatment.

Table 13

Mean Yield of Grass g/m^2

T_2	T_3	T_4	T_6	T_7	L.S.D. 5%
80.31	39.75	55.33	65.72	43.66	9.98

Of the mixed treatments the highest yield was obtained in T_4, establishing the superiority of this treatment in as much as growth of grass in undersowing is concerned.

Clover

Leaf area index

The effects here were similar to that observed with the grass (Table 14).

Table 14

Mean L of clover at successive harvests

	H_1	H_2
T_2	0.21	0.80
T_3	0.08	0.48
T_4	0.06	0.56
T_6	0.10	0.63
T_7	0.05	0.22
L.S.D. 5%	0.04	ns

Seed yield (Clover)

Trends similar to that observed with grass seed yields were evident though not significant in the case of the clover (Table 15).

Table 15

Mean Seed Yield of Clover g/m^2

T_2	T_3	T_4	T_6	T_7	
3.33	2.27	3.58	3.44	2.41	n.s.

5.1.5. Soil Moisture

Soil moisture determinations were made in all plots at two depths (0 - 9" and 9 -18") from the time of planting to maturity. (Fig. 13).

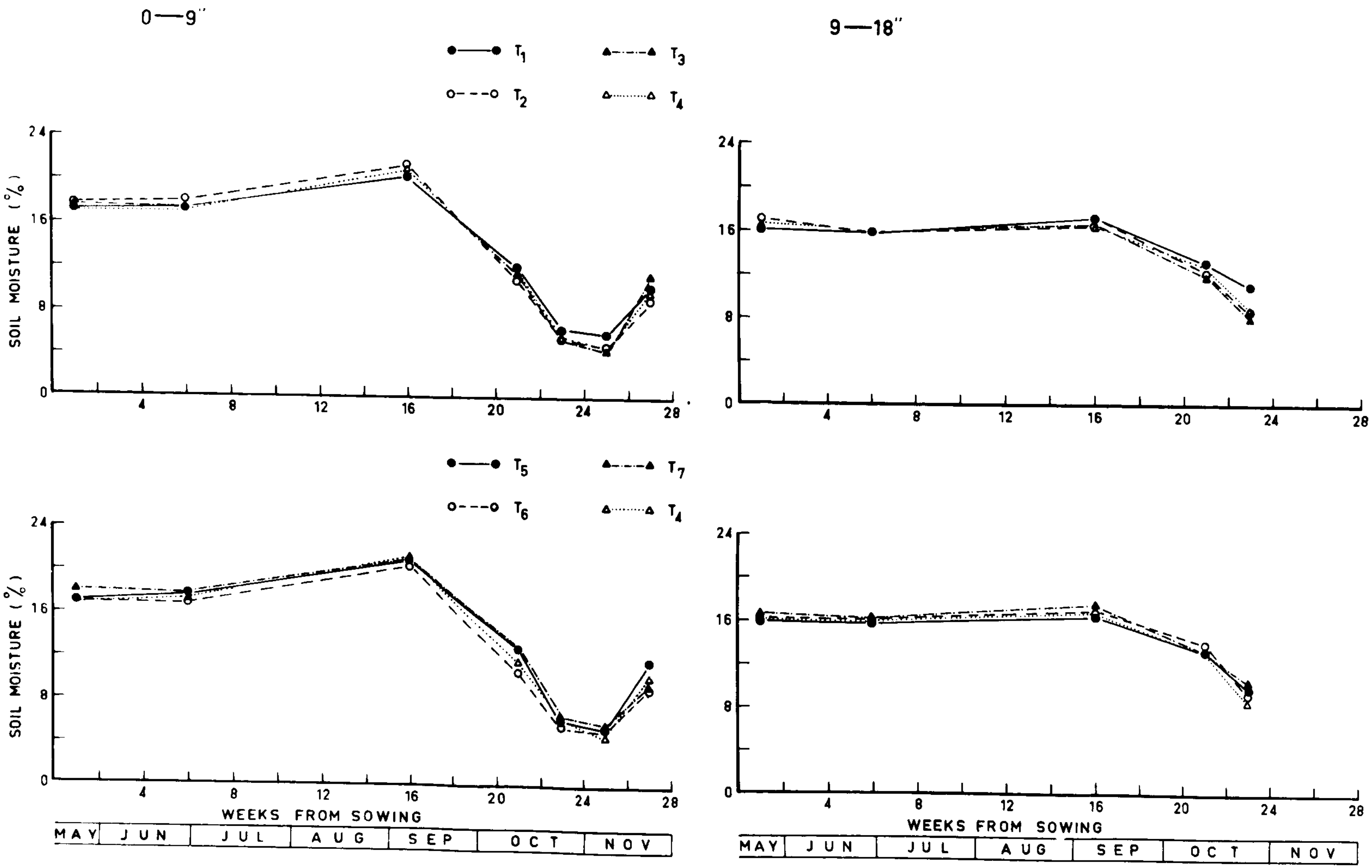
There were no significant differences in percentage soil moisture between treatments at either depths except at the last occasion (24/xi) where at 0 - 9" some differences were observed. On this occasion (Table 16) those plots with wheat were higher than the pasture controls. Prior to this determination there had been some rain, 2.75 inches from 12/xi to 23/xi, by which time a good

Table 16

Mean % soil moisture at 0 - 9" from 9/ix - 24/xi

Treatments	9/ix	12/x	9/ix	24/xi
T_1	20.47	12.10	6.00	10.26
T_2	21.41	10.87	4.83	9.05
T_3	20.48	11.71	4.33	11.28
T_4	20.90	11.94	4.70	10.41
T_5	20.83	12.83	5.63	11.70
T_6	20.46	11.57	5.16	9.12
T_7	20.38	12.95	5.95	9.38

Fig. 13. Percentage soil moisture at depths of 0-9"
and 9-18" in the various treatments throughout
the season (1960).


0—9''
9—18''
T1
T2
T3
T4
T5
T6
T7
T4
SOIL MOISTURE (%)
SOIL MOISTURE (%)
0
8
16
24
4
8
12
16
20
24
28
WEEKS FROM SOWING
WEEKS FROM SOWING
MAY
JUN
JUL
AUG
SEP
OCT
NOV

proportion of the wheat leaves were blown away while a thick mat of herbage covered the ground in the control pasture plots. This enabled more water to reach the soil in the plots with wheat than those of the control pastures, and hence the difference between these two groups of treatments.

5.1.6. Light intensity

Light intensity from ground level to above the crops at 3" intervals were measured weekly commencing 12 weeks from planting in all treatments of Block 2. On all occasions measurements were taken in the same order, commencing with Plot 8 and concluding with Plot 14. In all treatments 12 sets of measurements were made giving 6 and 3 replications in the 7" and 14" spaced treatments respectively. In 7" spaced crops measurements were made beneath the rows (P_0) and mid way between rows ($P_{3\frac{1}{2}}$) and in 14" spaced crops beneath the rows (P_0) and at $3\frac{1}{2}$" intervals giving three other sets of measurements ($P_{3\frac{1}{2}}$, P_7 and $P_{10\frac{1}{2}}$). Measurements were commenced at 12 noon (Local Standard Time) and completed by 1 p.m. at the early stages; later in the season a slightly longer time was taken due to the increase in the number of readings with increase in the height of the crops.

Light intensity at ground level in control wheat plots

In both the 7" and 14" wheat treatments the mean percentage light intensity reaching ground level decreased with time, attaining a low level and then, after heading of the crops, rose steadily (Fig. 14). It has been established by other workers (Stahler 1948; Black 1952 and Klebesadel and Smith 1959) that there are usually three distinct phases in the light reaching ground level in cereal crops. Firstly a stage of steady decline, then a stable low value, which after a time steadily increases. The first and the last stages were clearly evident in this experiment, but it could hardly be said that the stable stage existed for any appreciable length of time, particularly in the 7" crop.

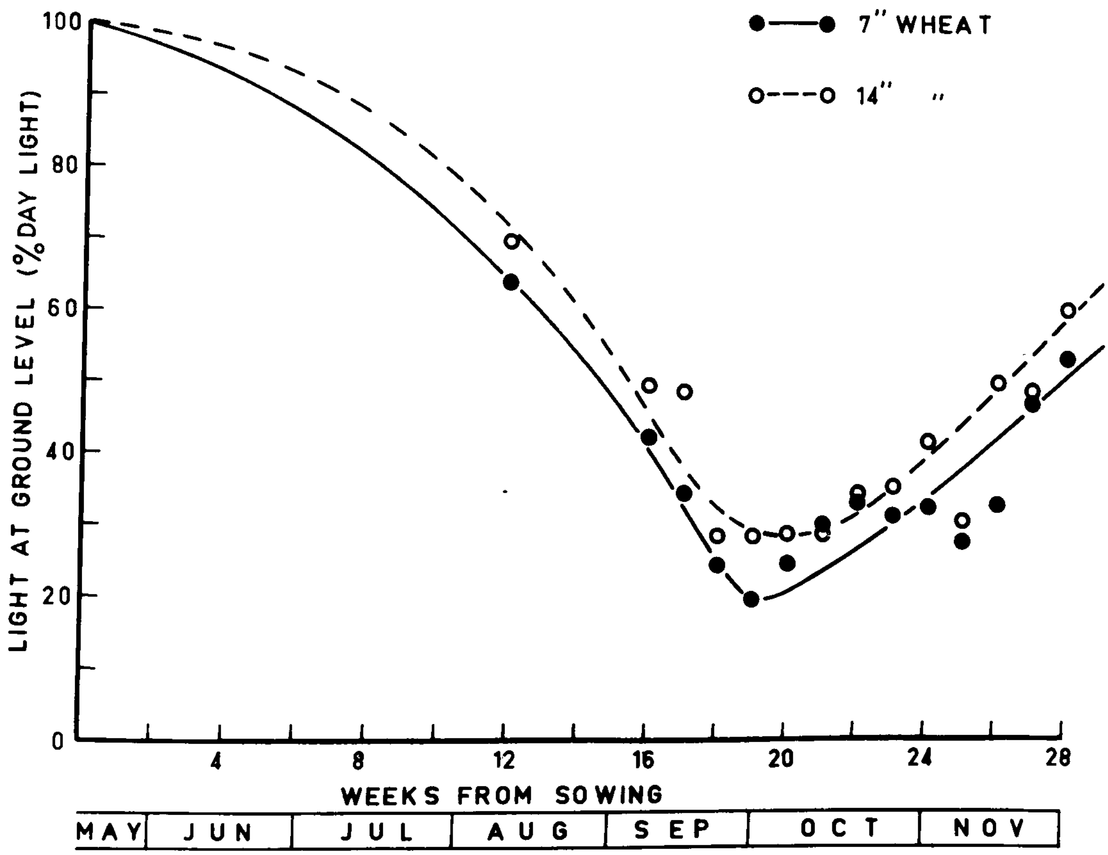
It should be noted from Fig. 14 that the 7" crop intercepted more light than the 14" crop at all times, although the difference between them was not very high. The leaves would be the main agents of light interception and a comparison of the leaf area and light reaching ground level would be of interest (Table 17). Within each spacing the light intensity followed an inverse

Table 17

L.A.I. of wheat and light intensity at ground level at the first three harvests.

		H_1	H_2	H_3
7"	L.A.I.	1.09	1.76	0.78
	% light	55	30	25
14"	L.A.I.	0.92	1.20	0.58
	% light	63	40	32

Fig. 14. Mean % daylight and ground level in wheat crops throughout the season (1960)

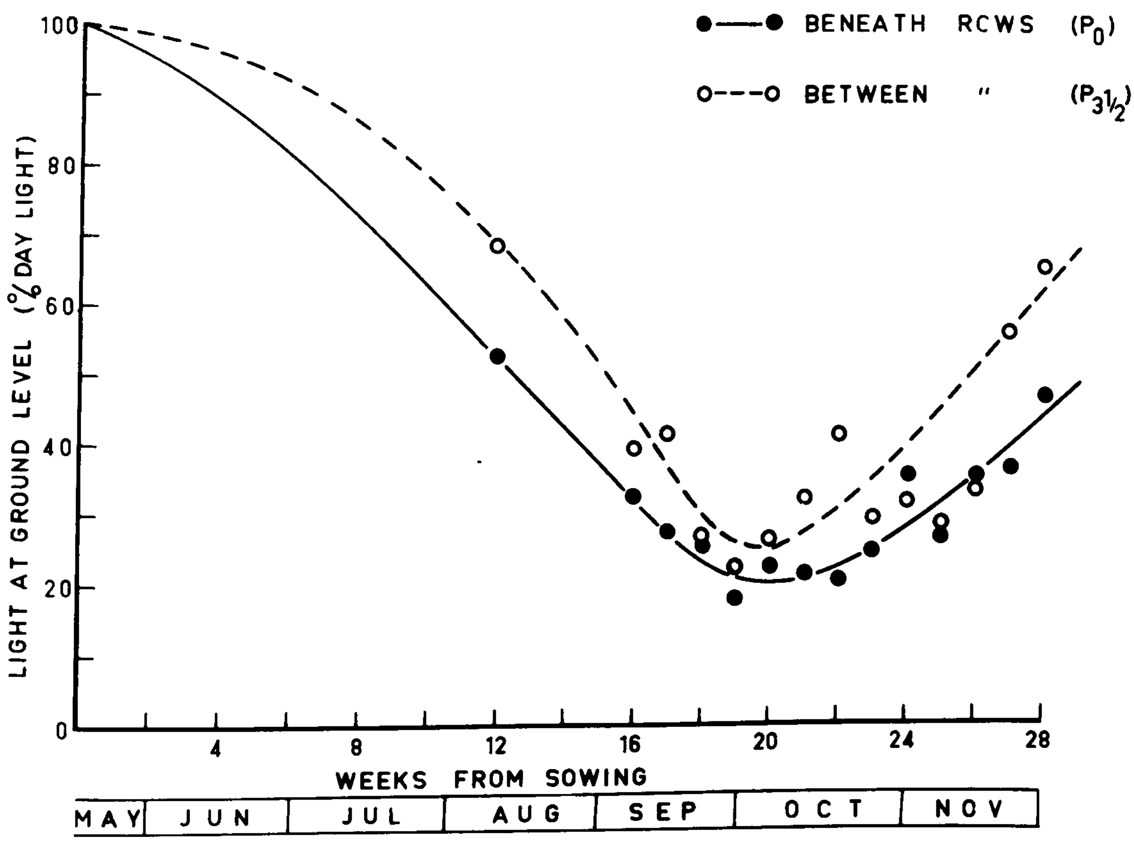


7" WHEAT
14" "
LIGHT AT GROUND LEVEL (% DAY LIGHT)
100
80
60
40
20
0
4
8
12
16
20
24
28
WEEKS FROM SOWING
MAY
JUN
JUL
AUG
SEP
OCT
NOV

relationship to the L.A.I. except at the third harvest. Here L.A.I. was a measure of the green leaves only, while the light was intercepted by the green leaves as well as by dead leaves and with decrease in total leaf area due to shrinkage and curling of dead leaves the relative amounts of light intercepted by stems would also become considerable. At the second harvest maximum L.A.I. and minimum light intensities were recorded.

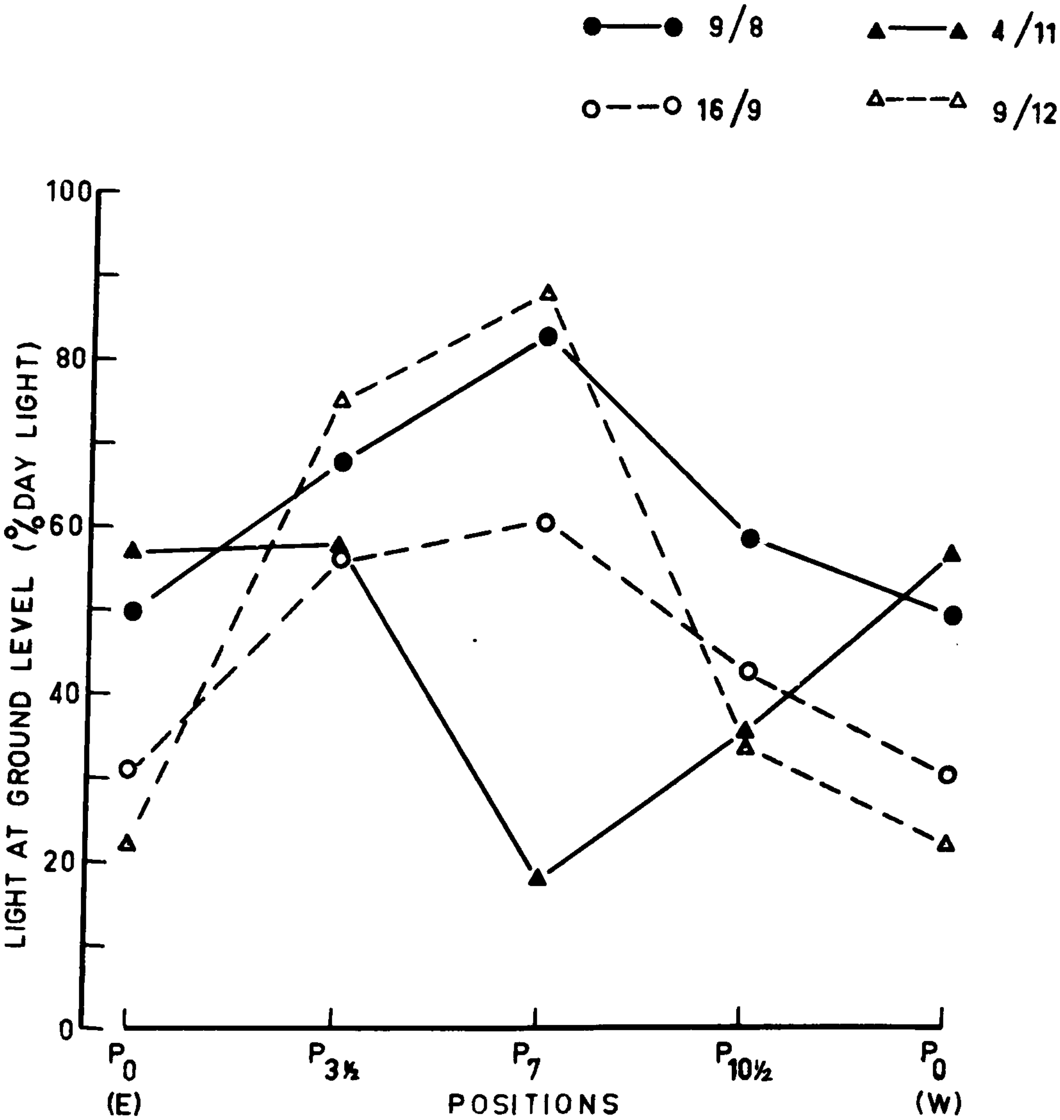
The spread of leaves across the rows suggested that there would be differences in the light intensity reaching the ground at the various positions between rows, and the mean values presented in Fig. 14 would not adequately describe the light environment. Examining the data for the various positions within rows (P_0 and $P_{3\frac{1}{2}}$ in 7" and P_0, $P_{3\frac{1}{2}}$, P_7 and $P_{10\frac{1}{2}}$ in 14" spaced crops) showed that in 7" spaced crop P_0 received less light than $P_{3\frac{1}{2}}$ throughout the growth of the crop (Fig. 15). The difference however was very small at the time of maximum interception. Similar examination of the data for the 14" crop where the differences between the various positions should be even more marked showed no pattern as expected. In Fig. 16 the % light at ground level at the various positions on four selected occasions are given for T_5. The point of maximum illumination moved eastward till the third occasion, and on the last returned to the position as at the second occasion. T_5 was the last treatment (Plot 14) to be measured on all occasions and the time was well past True Solar Noon; and the

Fig. 15. Percentage daylight at ground level beneath and midway between rows of wheat at 7" spacing.



BENEATH RCWS (P_0)
BETWEEN " ($P_{3\frac{1}{2}}$)
LIGHT AT GROUND LEVEL (% DAY LIGHT)
100
80
60
40
20
0
4
8
12
16
20
24
28
WEEKS FROM SOWING
MAY
JUN
JUL
AUG
SEP
OCT
NOV

Fig. 16. Percentage daylight at ground level at the various positions relative to the wheat rows in 14" spaced wheat crop on 4 selected dates.



9/8
4/11
16/9
9/12
LIGHT AT GROUND LEVEL (% DAY LIGHT)
100
80
60
40
20
0
P0 (E)
P3½
P7
P10½
P0 (W)
POSITIONS

pattern of light at ground level indicates that the sun was West of North. The change in the trend on the last occasion was due to change in T.S.N. whose deviation from Local Standard Time decreased to a minimum on the third occasion and then increased at the fourth and reached the same value as at the second. (see Fig. 52). Thus it can be concluded that small variations in time of sampling can have large effects on relative illumination within the crops.

Light profiles in wheat crops

while the intensity at ground level would give some information it would not describe the conditions under which an under-down pasture would grow. For this purpose three occasions were selected, one on the decending slope (16/9), one at maximum interception (30/9) and the other on the ascending slope (25/11) of the curves presented in Fig. 14. On these dates the % intensity of light at different heights of the crop in all the positions as described earlier were plotted and the 20, 40, 60 and 80% isopleths of light intensity were constructed and are shown in Fig. 17. The asymetry in the 14" spaced crop was due to the measurements being made after true solar noon.

The mean % light intensity for the various positions were plotted against the heights, The height along the y axis and the light along the x axis starting with 100% at the origin and decreasing away from it (Fig. 18). This was adopted to incorporate in the same diagram the shade cones as presented by Rademacher (1940).

Fig. 17. Isopleths of % daylight within 7" and 14" wheat crops on three selected dates.

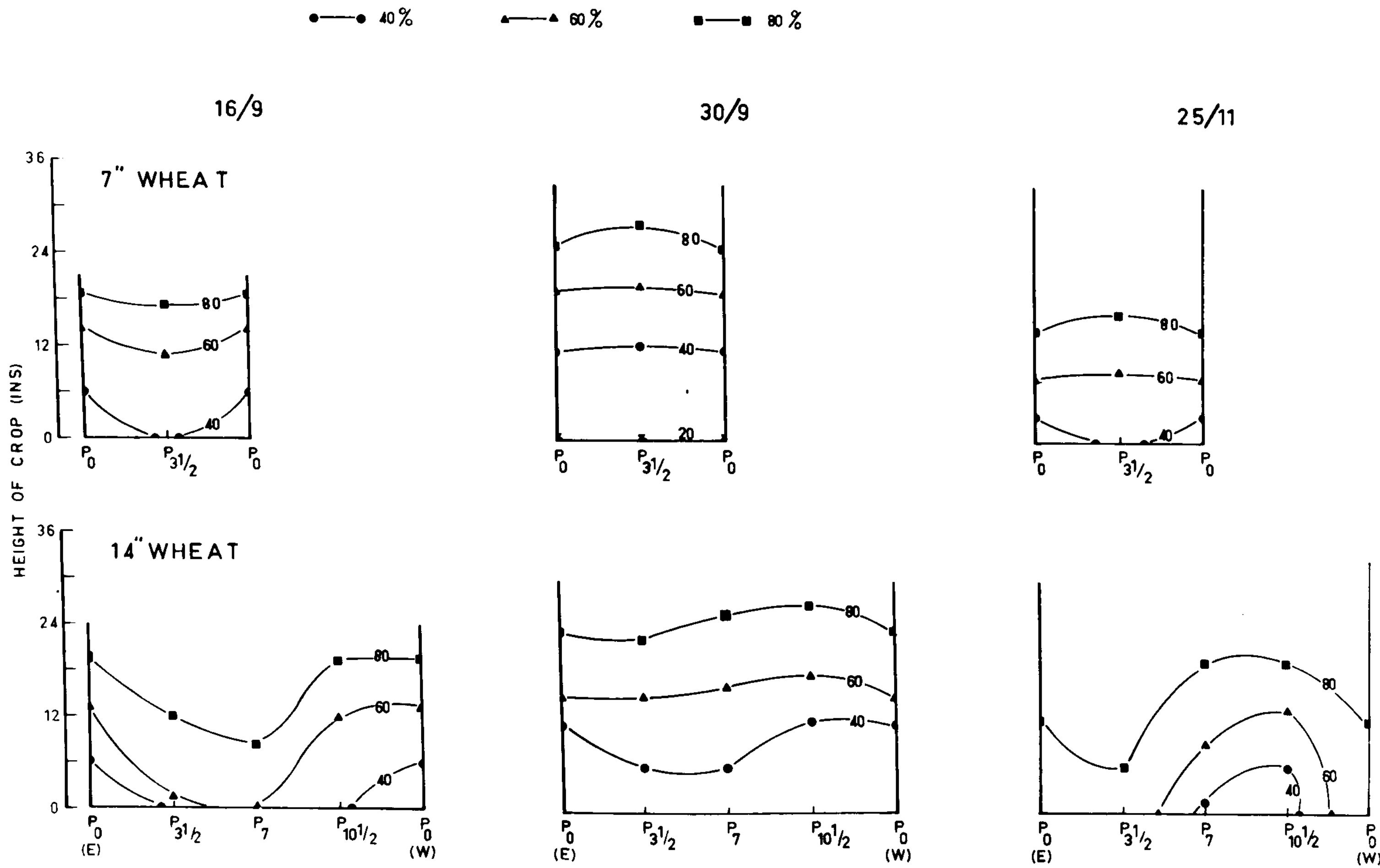
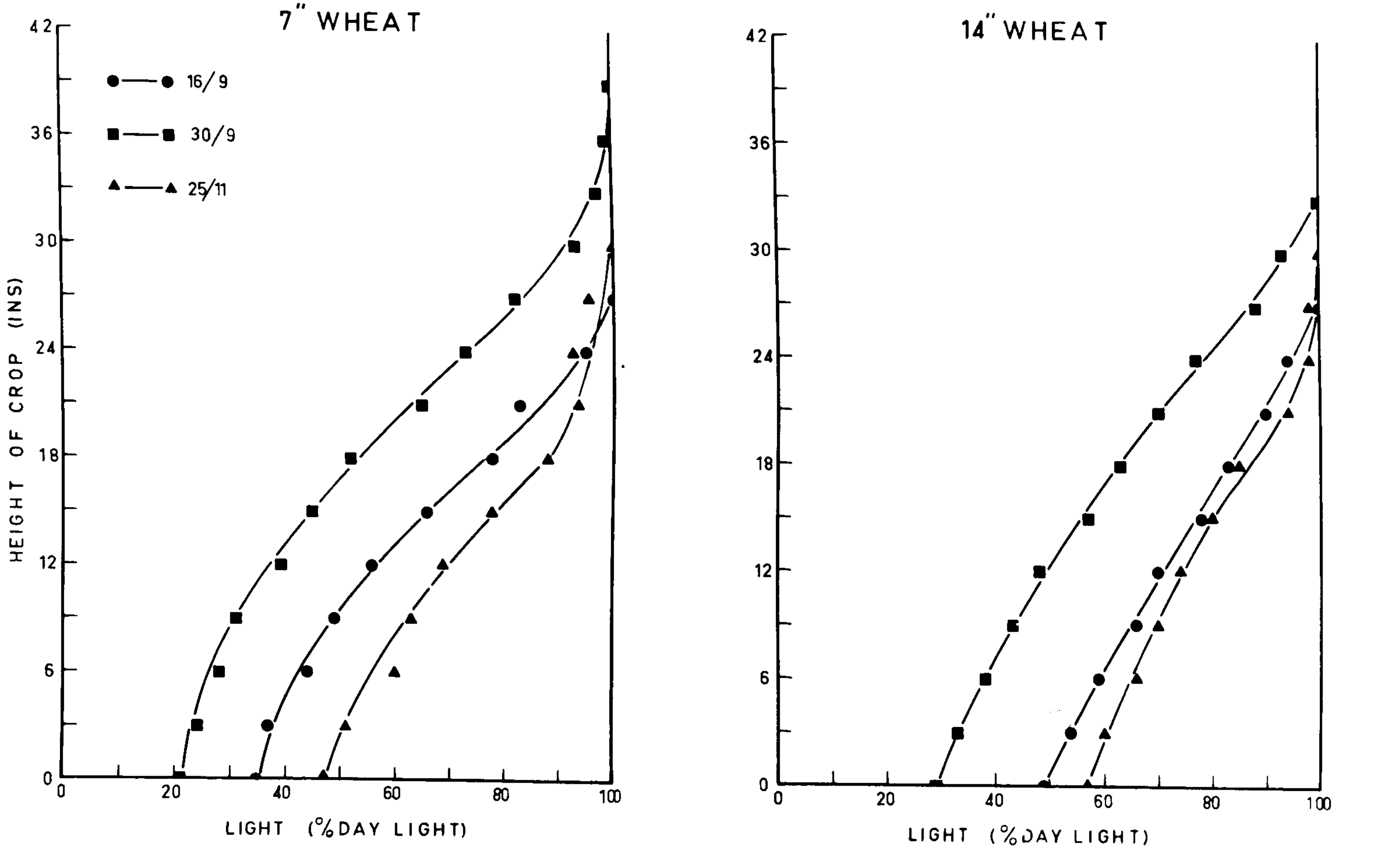

40 %
60 %
80 %
16/9
30/9
25/11
7" WHEAT
14" WHEAT
HEIGHT OF CROP (INS)
36
24
12
0
80
60
40
20
P_0
$P_{3\frac{1}{2}}$
P_7
$P_{10\frac{1}{2}}$
(E)
(W)

Fig. 18. Profiles of % daylight in 7" and 14" wheat crops on three selected dates.



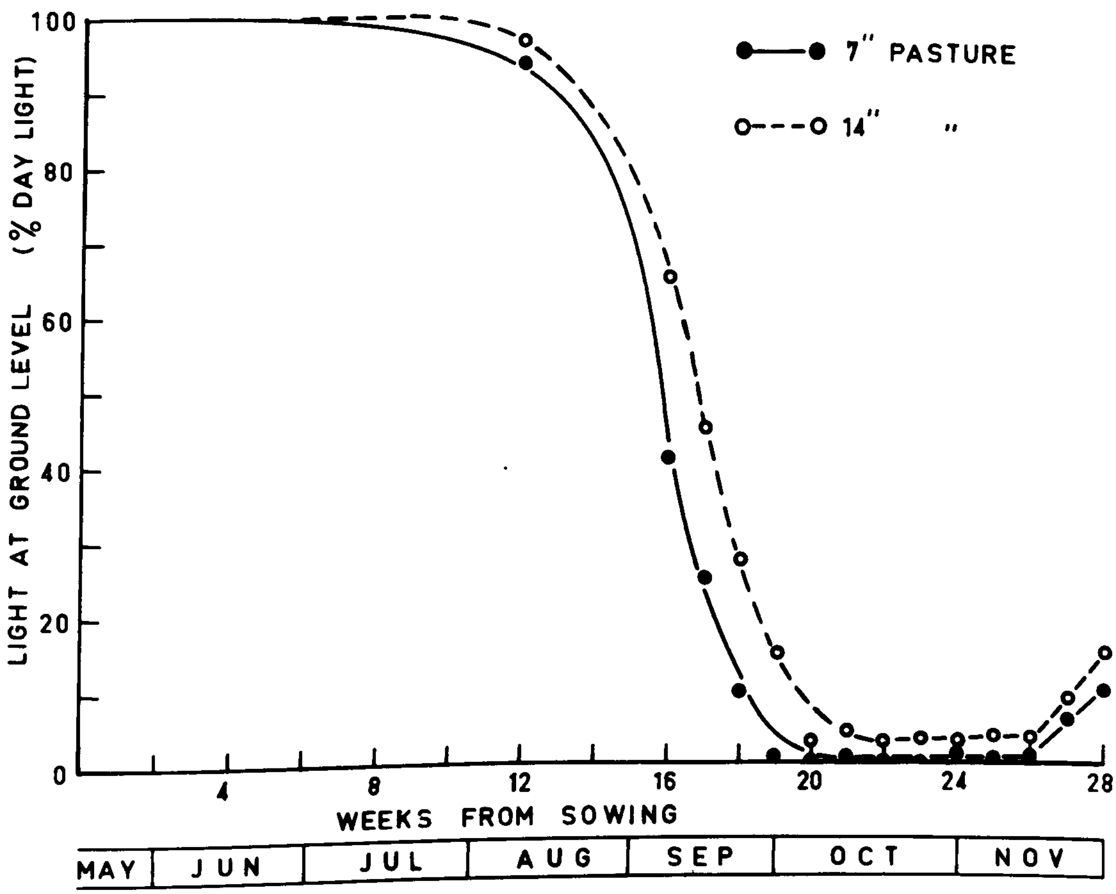
7" WHEAT
14" WHEAT
16/9
30/9
25/11
HEIGHT OF CROP (INS)
LIGHT (%DAY LIGHT)
0
6
12
18
24
30
36
42
20
40
60
80
100

The curves however would show only half the cones. In both crops the amount of light intercepted at each height increased appreciably at the second occasion and decreased at the third. The 7" crop intercepted more light at all heights and at all times than the 14". Rademacher (1940) considered that a crop with a shade cone with least interception and whose interception decreased steadily along its height would not be suitable for suppression of weed growth; the antithesis of his arguments would therefore be acceptable for the establishment of pasture undersown to cereal crops. On that basis the 14" wheat would allow a better growth of the pasture than the 7" wheat, as was the case in the yield of pasture in the 7" and 14" mixed cropping treatments. The shape of these curves were similar to those described by Mitchell and Calder (1956) for pure grass swards. The light intensity decreased steadily with the depth of the crop, suggesting an even distribution of the intercepting agents along the height of the crops.

Light intensity in control pasture swards

As in the pure wheat plots the light intensity at ground level in the control pasture plots decreased steadily with time, reached a low value which was stable for an appreciable length of time (6 weeks) and then increased steadily. In contrast to the wheat plots, interception in pasture plots was almost complete. The 14" plot intercepted slightly less than the 7" plot (Fig. 19). Except for the first three occasions there were no appreciable

Fig. 19. Mean % daylight at ground level in 7" and 14" pastures throughout the season (1960).



7" PASTURE
14" "
LIGHT AT GROUND LEVEL (% DAY LIGHT)
100
80
60
40
20
0
4
8
12
16
20
24
28
WEEKS FROM SOWING
MAY
JUN
JUL
AUG
SEP
OCT
NOV

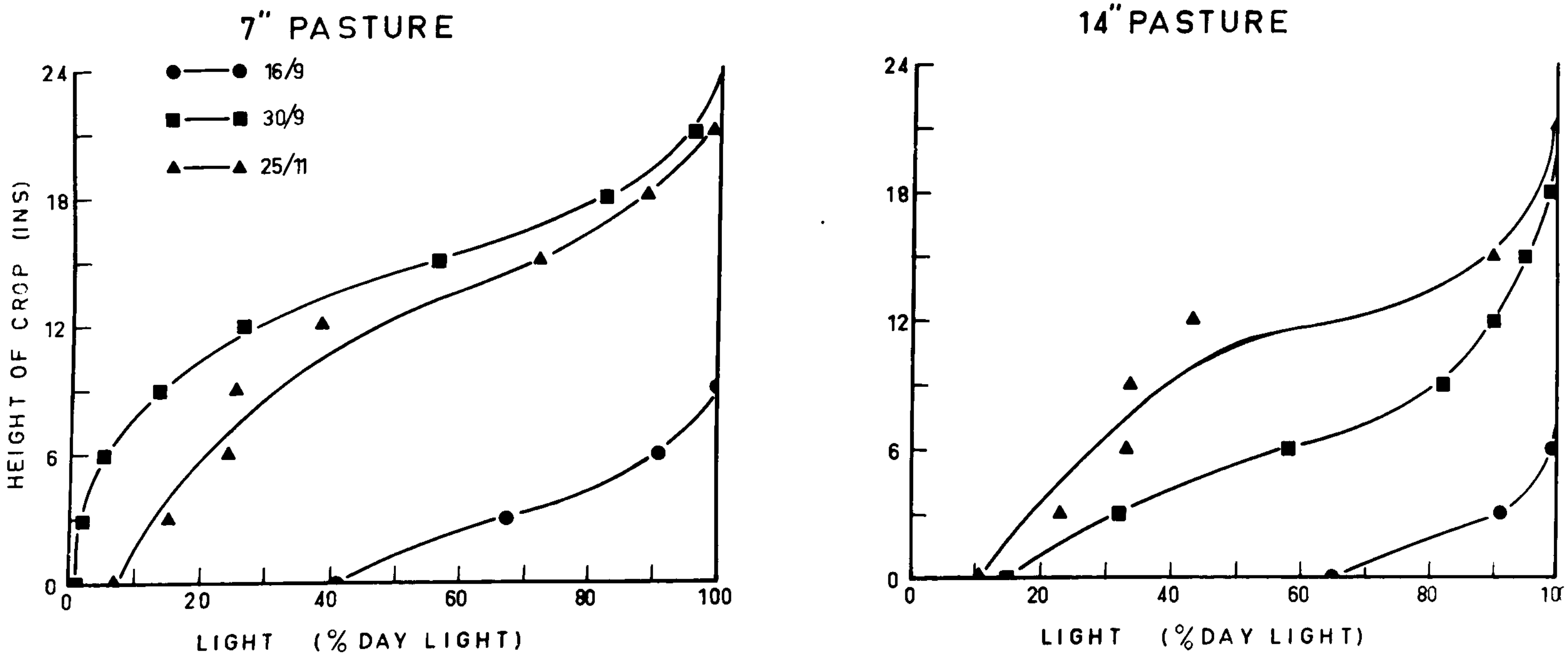
differences between the various positions. This was due to greater tillering of the grass and spreading growth of clover, both of which covered the inter row space almost completely.

Light profile curves for the pasture are presented in Fig. 20. On the first occasion the curves followed a pattern similar to that expected in a pure grass plot (Mitchell and Calder 1956). On the second occasion the pattern was unchanged in the 14" plot, while in the 7" plot there was a low rate of increase in light intensity from ground level to about 6" and then a higher rate of increase. The low rate of increase in the first 6" of the sward may have been due to the presence of the majority of the clover leaves at about that height, the rest of the sward being grass. The absence of a pronounced region of low interception as might have been expected in a grass/clover mixture may be due to the very small amounts of clover in the pastures. On the third occasion both treatments showed three regions in the light profiles. From the top of the pastures there was a steady decrease in light intensity till 9" from the ground, then a region of 3" depth where there was little or no change in interception, and then steady interception to ground level.

Light intensity in mixed treatments

The pattern of light interception in these treatments closely followed that of the corresponding control wheat treatments. Interception was however greater, as would be expected from the presence of the pasture species. The pattern of light interception is shown

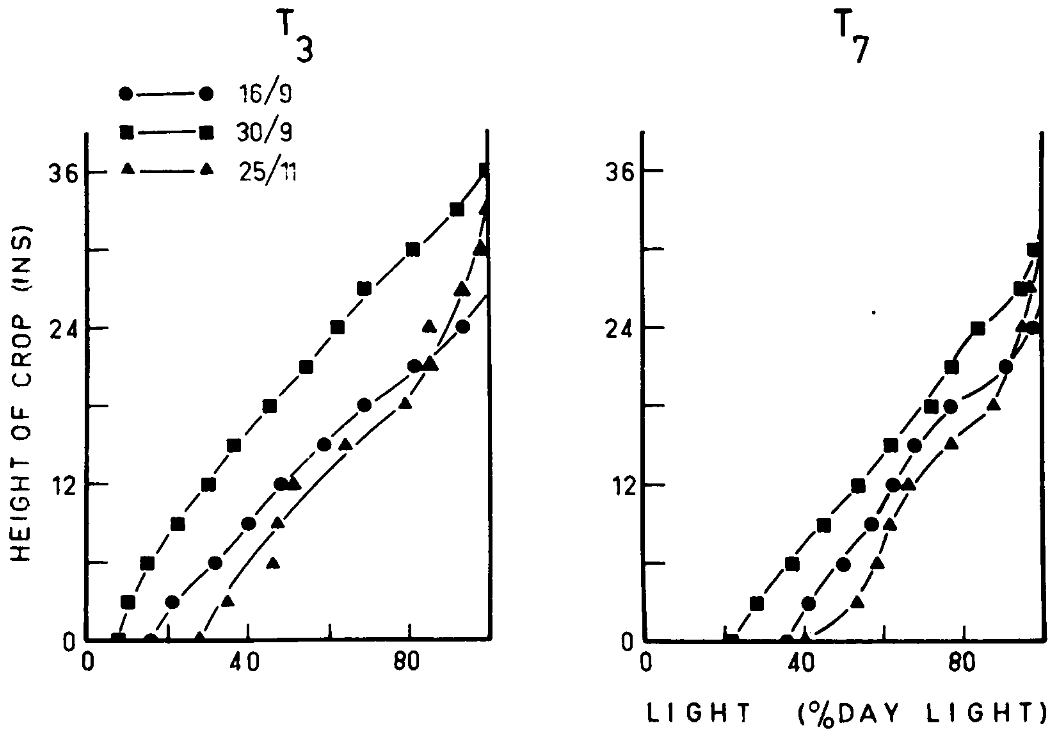
Fig. 20. Profiles of % daylight in 7" and 14" spaced pasture rows on three selected dates.


7" PASTURE
14" PASTURE
16/9
30/9
25/11
HEIGHT OF CROP (INS)
LIGHT (% DAY LIGHT)
0
6
12
18
24
20
40
60
80
100

in the profiles for the three treatments at the three selected occasions in Fig. 21. On all occasions the 7" wheat and pasture mixed treatment intercepted more light than the corresponding control wheat, but in the other two mixed treatments (T_4 and T_7) the interception was greater at the base of the crops, although above the height of the clover the interception was less than the corresponding control wheat treatment; and more so in the wheat and pasture alternating treatment than in the wheat and pasture mixed on the same row.

In the 7" spaced treatments the greater interception by the mixed treatment over the control may be explained by the presence of a greater amount of plant material and hence leaf area. It should be noted that there was only a very small reduction in wheat yield and L.A.I. in T_3 as compared to T_1. Similarly in the 14" mixed treatment there was greater reduction of yield and L.A.I. of wheat and hence less light interception at the $3\frac{1}{2}$", 7" and $10\frac{1}{2}$" positions. The pasture which was present at the 0" position would have affected the illumination only in that position where the wheat itself would have caused a large regulation. In the treatment with wheat and pasture in alternate rows, the yield and L.A.I. of wheat were more reduced by the pasture, but, since the pasture occupied the 7" position it would have intercepted a very high proportion of the light in that position even if it did not affect the adjacent $3\frac{1}{2}$" and $10\frac{1}{2}$" positions. The situation however could be explained if it is assumed that the points of maximum illumination

Fig. 21. Profiles of % daylight in the mixed treatments on three selected dates.



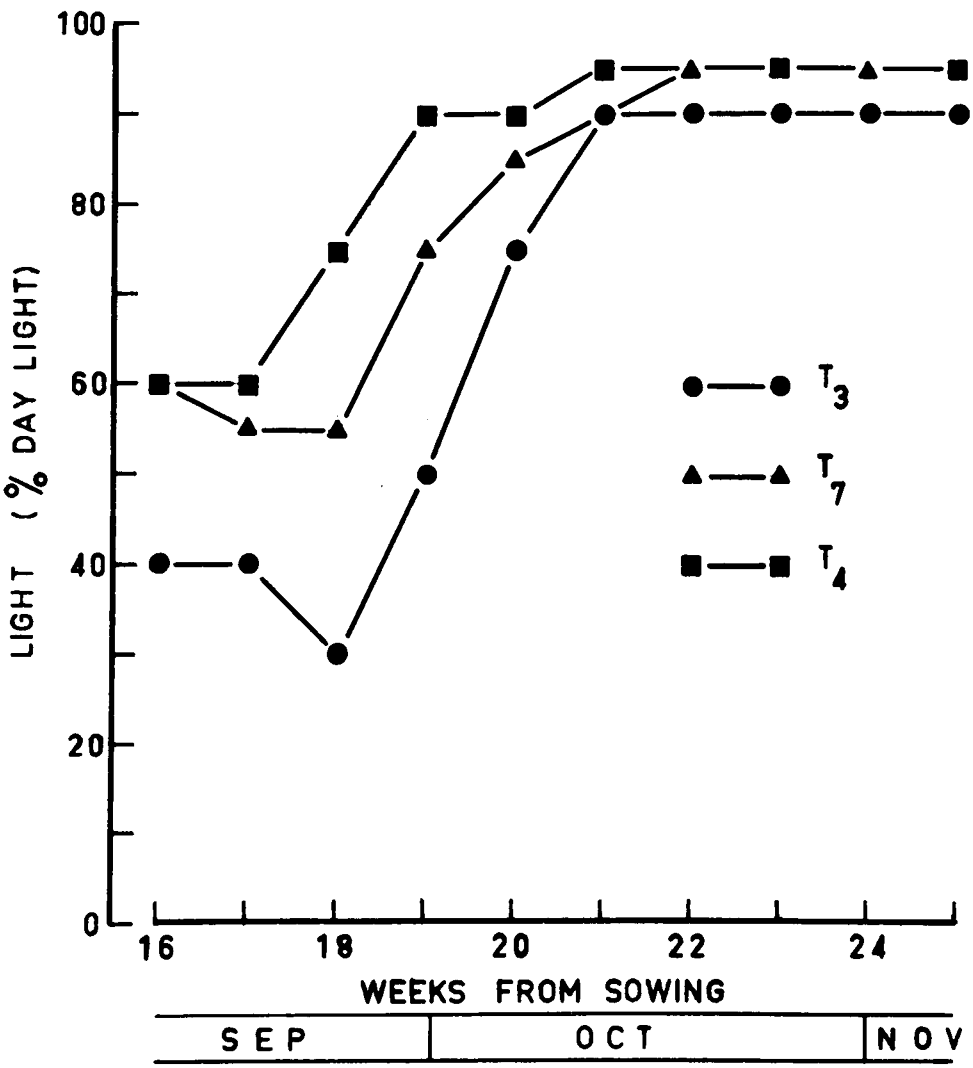
T_3
T_7
T_4
16/9
30/9
25/11
HEIGHT OF CROP (INS)
0
12
24
36
0
40
80
LIGHT (%DAY LIGHT)

were at some distance away from the position of the pasture rows. It has already been stated that the light measurements in this experiment were made sometime after true solar noon and the point of maximum illumination had shifted towards East and in most occasions had reached the $10\frac{1}{2}$" position. On this basis the pattern of light profiles can be understood.

Percentage light at the surface of the pasture in mixed treatments.

These values were obtained by calculating the mean % light immediately above the pasture species (grass) and are shown in Fig. 22 for the measurements from 16/9 onwards. It is evident that very much less light reached the pasture surface in the 7" mixed treatment than in the 14". These curves follow the same pattern as that of the light intensity at ground level for the control wheat treatments and it would therefore be reasonable to assume that from the time of planting to 16/9 there had been a progressive decrease in light at the pasture surface. It will be noted that from about mid October onwards the amount of light at the pasture surface was only 10% less than full day light, but by this time the crops have attained near maturity and would not have utilised the radiation. At no stage of growth would the % light at the surface of the pasture indicate the amount actually available or utilised by the pasture. A very considerable portion of the radiation would presumably have been absorbed by the wheat beneath the pasture surface. It was alse

Fig. 22. Percentage daylight immediately above the pasture in the mixed treatment (1960).


100
80
60
40
20
0
LIGHT (% DAY LIGHT)
16
18
20
22
24
WEEKS FROM SOWING
SEP
OCT
NOV
T_3
T_7
T_4

noticed from light measurements at ground level that while in the pure pasture swards there was almost complete interception during most of the growing period, there was a considerable amount of light reaching ground level in the mixed treatments. Hence the amounts available and utilised by the pastures would have been much less.

5.1.7. Regrowth of pasture in the following season (1961)

During the 1961 season the regrowth of the pastures in the five treatments (2 controls and 3 undersown) were followed to study the effect of undersowing.

Seedling population

The pasture seeds germinated with good autumn rains in late March, 1961 and on April 11, 3" core samples were taken to estimate seedling populations in the various treatments. Each species (rye grass and subterranean clover) were counted separately. There were no significant differences between treatments in clover population, and the mean number of clover seedlings was 28 per m^2. In the grass the differences were of the same order as obtained with seed yields. The weight of seeds and number of seedlings per m^2 are given in Table 18.

Table 18

Mean weight of seeds and seedling number of grass per m^2

	T_2	T_3	T_4	T_6	T_7	L.S.D. 5%
Seeds (g/m^2)	80.08	39.38	54.78	60.01	43.45	9.98
Seedlings/m^2	37700	11400	19600	29400	18200	3650

Following these counts each plot was divided and one half received a dressing of urea at 1 cwt./acre on 18 May. The first harvest was made on 30 May, and thereafter three other harvests were made on 22 June, 28 August and 25 September.

Total dry matter yield of pasture

At the first harvest there was no significant difference between the two control pastures, and they yielded significantly higher than those which had been sown with wheat, among which there was no difference (Fig. 23). In each treatment the applied nitrogen increased yields significantly. A similar response was observed at the second harvest. At the third harvest there were significant differences between treatments, and a small response to applied nitrogen. At the last harvest all differences had disappeared.

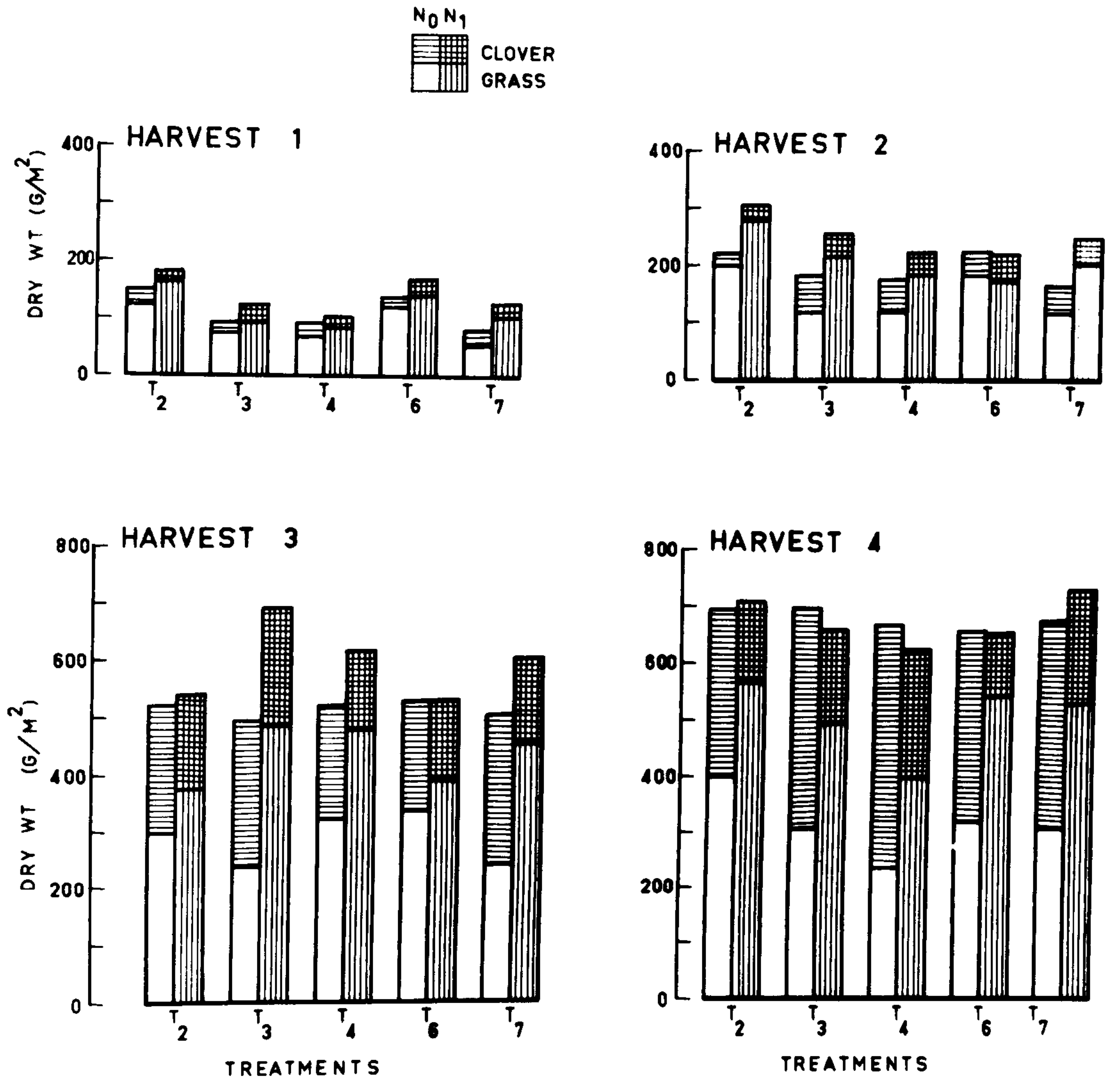
Yield of grass

At the first two harvests the yield of grass followed the same pattern as the total yield of pasture. At the third harvest the response to applied nitrogen was much greater than that recorded for the total yield and this was maintained at the final harvest.

Clover

At no stage were significant differences between treatments recorded, although a trend towards higher yields was evident in the

Fig. 23. Dry matter yield/m^2 of grass and clover at successive harvests in the year following establishment (1961).

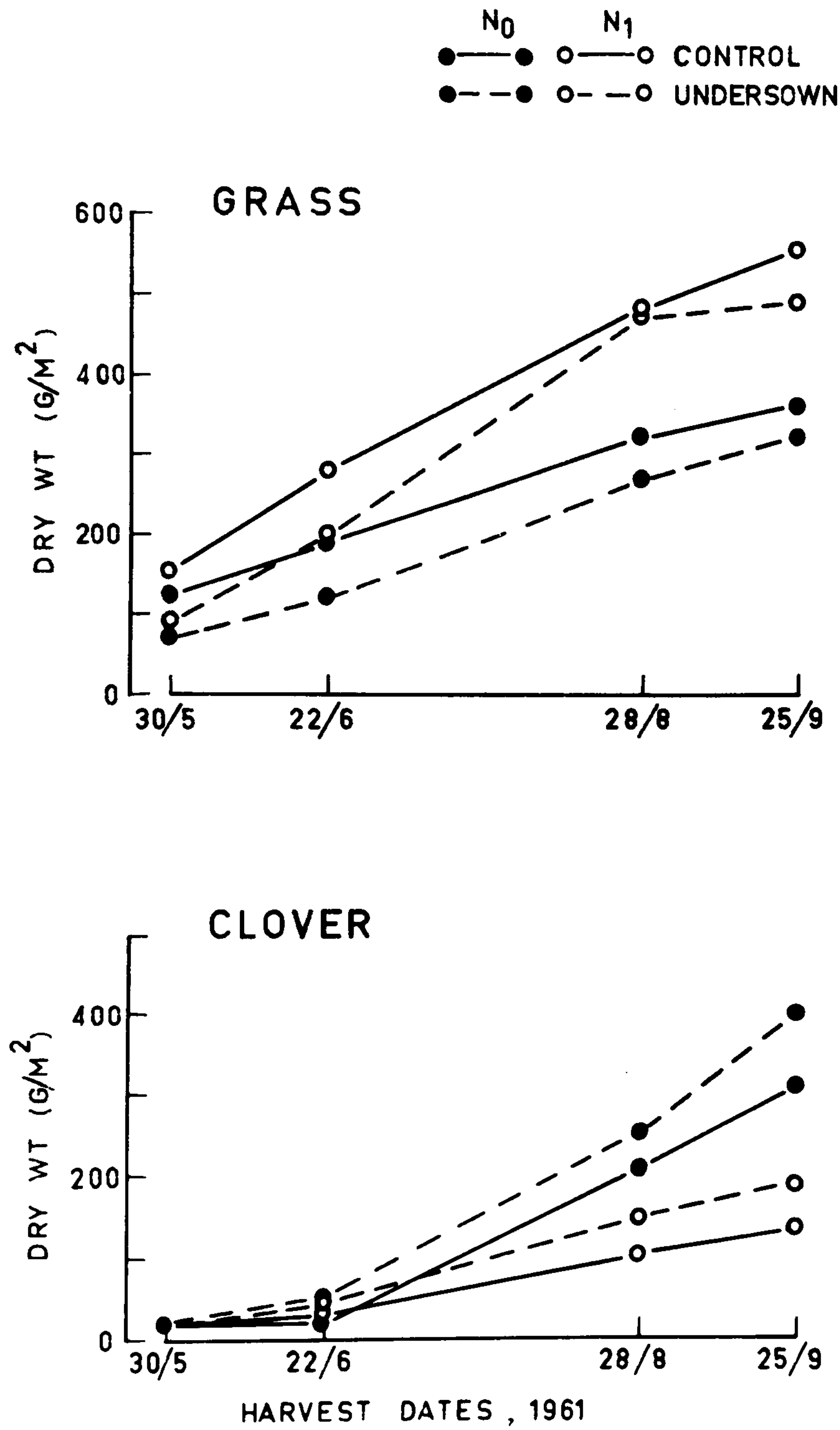


N_0 N_1
CLOVER
GRASS
HARVEST 1
HARVEST 2
HARVEST 3
HARVEST 4
DRY WT (G/M^2)
0
200
400
600
800
T_2
T_3
T_4
T_6
T_7
TREATMENTS

mixed treatments, particularly in T_3 and T_7 as compared with the controls. A similar situation was observed in 1960 also. Nitrogen had no effect on the yield of clover at the first two harvests, but significantly decreased yields at the next two harvests. It is interesting to note that while there was no response to added nitrogen at the final harvest in total production, there was increased yields of grass and decreased yields of clover. This may almost certainly be attributed to a suppression of clover growth as a result of the greater shade cast by the grass when given additional nitrogen (Stern 1960)

Since among the treatments the only difference demonstrated was that between the controls on the one hand and the mixed treatments on the other, mean yields of these two groups of treatments both in presence and absence of nitrogen were plotted against time and are presented in Fig. 24 for grass and clover. The effect of nitrogen on grass yield at all times is evident and a trend towards higher yields in the control plots as compared to the mixed treatments is also evident both in presence and absence of nitrogen. In the clover however there were no significant differences at the first two harvests, but a separation into low yields in the controls as against high yields in the mixed treatments regardless of nitrogen is evident. The relationship between grass and clover growth in presence and absence of nitrogen is shown in Plate 3 which was taken prior to the third harvest in one of the mixed treatments.

Fig. 24. Dry matter yield/m^2 of control and undersown pastures at successive harvests in the year following establishment (1961).



N0
N1
CONTROL
UNDERSOWN
GRASS
DRY WT (G/M²)
600
400
200
0
30/5
22/6
28/8
25/9
CLOVER
DRY WT (G/M²)
400
200
0
30/5
22/6
28/8
25/9
HARVEST DATES, 1961

Plate 3. A pasture plot in 1961. Left half did not receive nitrogen and the right half received urea at 1 cwt/acre.

5.1.8. Interim discussion on Experiment 1

The results obtained during the year of planting showed that the growth of pasture was better in the 14" than in the 7" spaced wheat, and within the wider spacing when the pasture was between rows than beneath the rows of wheat. There was no difference in soil moisture under any of the treatments and it is considered highly unlikely that there was any shortage of soil nutrients. On the other hand light measurements showed that there was greater interception by the wheat in 7" than in 14" spaced crops, and had the measurements been made at true solar noon it might have been possible to establish that the mid position in the 14" spaced wheat received a much higher percentage of day light than beneath the rows. It was also noticed that during the major portion of the growing season (up to heading) the pasture species were much shorter than the wheat and it is therefore reasonable to assume that they were receiving much less light energy than the corresponding control swards of pasture. This reduced light alone would be sufficient to reduce the growth of pasture species regardless of competition for other factors. Further, Donald (1958) stressed that a plant growing under reduced light is not able to exploit to the full other factors such as soil moisture and nutrients.

Since light would always be at a reduced level under a cover crop it is necessary to understand the shade cast by cereal crops planted at different row spacing, rate of sowing and row direction. To this end Experiments 2 and 2A were planted.

5.2.0. Experiments 2 and 2A

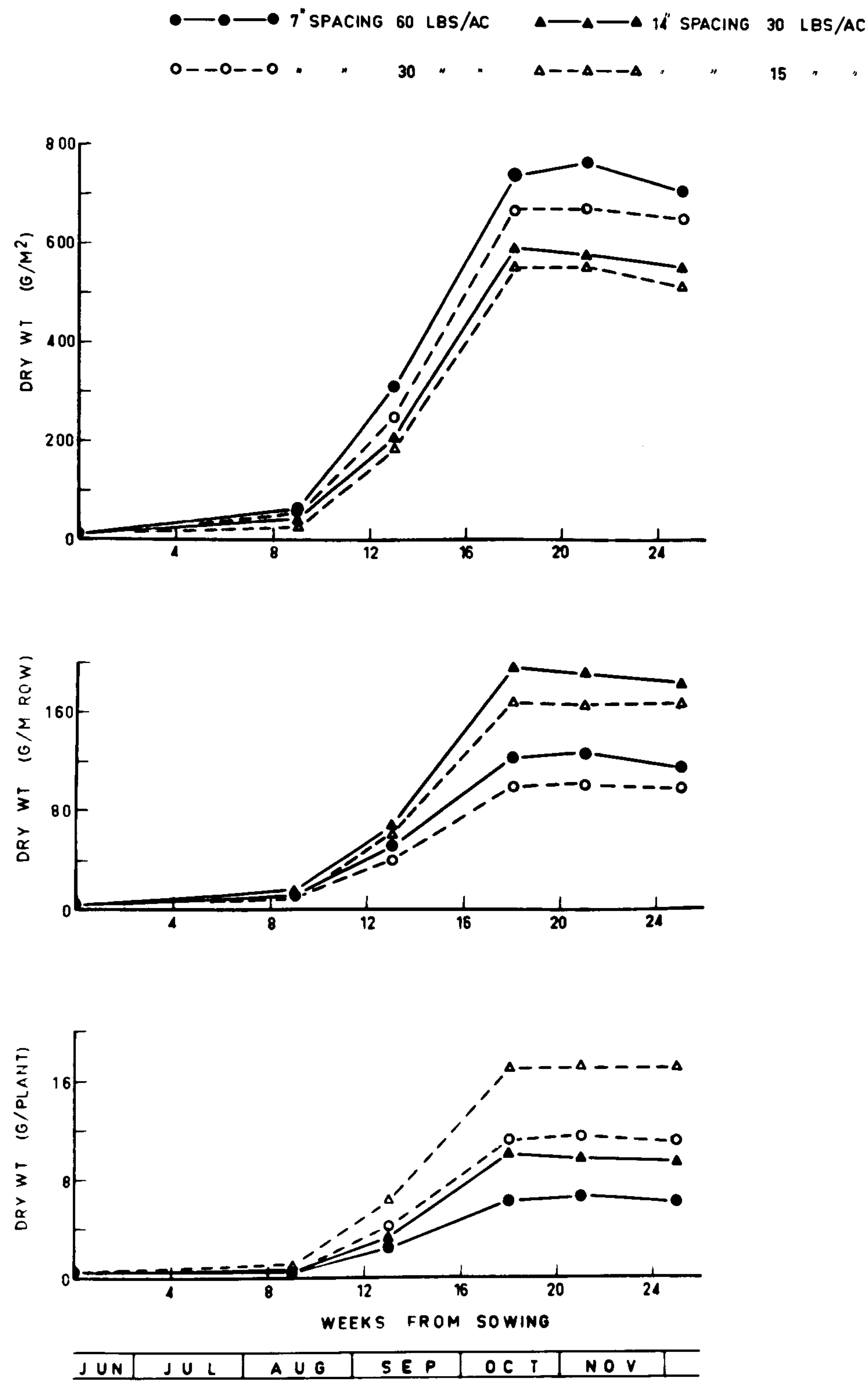
These were planted to study the light microclimate within wheat crops of differing row directions, row spacing and rate of sowing; and incidentally the leaf area distribution and the growth and yield of wheat. The four spacing X rate treatments are designated as follows for ease of reference:-

60	lbs/acre	7"	spacing	as	D_1
30	"	"	7"	"	"	D_2
30	"	"	14"	"	"	D_3
15	"	"	14"	"	"	D_4

5.2.1. Dry matter yield, Experiment 2.

The dry matter produced may be studied in terms of yield per unit area (g/m^2), yield per unit length of row (g/m length of row) and finally yield per plant (g/plant). These three aspects of yield are presented in Fig. 25 as mean of N-S and E-W rows. There were no significant differences between the two row directions even though from the second harvest onwards the yield from N-S rows were consistently higher than that from the E-W rows as the mean yield per plot would show (Table 19). Though the differences were small they were consistent and the lack of significance may have been due to the very low degrees of freedom of the "error term" (1:4). Another factor may be the high variation between blocks.

Fig. 25. Dry matter yield of the four rate x spacing treatments (Experiment 2).



7" SPACING 60 LBS/AC
" " 30 " "
14" SPACING 30 LBS/AC
" " 15 " "
DRY WT (G/M2)
DRY WT (G/M ROW)
DRY WT (G/PLANT)
WEEKS FROM SOWING
JUN
JUL
AUG
SEP
OCT
NOV

Table 19

Mean dry matter yield per plot (g/m^2)

	H_1	H_2	H_3	H_4	H_5
N - S	46.8	243.9	639.9	646.9	625.5
E - W	48.2	233.2	614.8	612.5	587.2
% increase of N-S over E-W	-2.8	4.6	3.8	5.7	6.5

Yield per m^2

There were very highly significant differences ($P < 0.001$) between spacing, with 7" yielding better than 14". Rate of sowing was very effective at the first harvest but differences decreased steadily at subsequent harvests. A point of interest was the higher yield from D_2 compared to D_3. Both these treatments had the same number of plants per acre but differently arranged.

Yield per meter length of row

Here again the effect of rate of sowing was essentially the same as per m^2. Spacing was without effect at the first harvest, but thereafter was highly significant with 14" spacing being far superior to 7".

Yield per plant

In contrast to the first experiment where the number of plants per unit length of row in all treatments was the same, here, due to differences in the rate of sowing within each spacing the number of plants per unit length of row in the high rate would be double that in the low rate. Unfortunately no plant counts were made in this experiment except at 3 weeks from sowing, but it would be reasonable to assume that the mortality of plants at the rates of sowing adopted in this experiment would be negligible except perhaps in the 60 lbs/acre 7" spaced treatment. Puckridge (1962) studying competition among spaced wheat plants (var. Insignia) did not observe any mortality at the lower densities. There was however, 18% reduction over the whole growing season in the fourth density, which was equivalent to the 60 lbs/acre 7" spacing treatment (D_1) in this experiment. Wassermann (personal communication) also working with Insignia wheat at a comparable density found 15% mortality up to the time of flowering, but practically no reduction in plots sown at 20 lbs/acre. At the time plant counts were made in this experiment there were 29.4 and 15.5 plants per meter length of row in the 60 and 30 lbs/acre drill set rates of sowing. While appreciating the possibility of plant mortality and hence its consequence on the effect on the yield of surviving plants, the weight per plant throughout the experiment is calculated from the number of plants/m row length at the time of emergence.

At the first harvest there was no significant difference between spacing but the low rate of sowing yielded higher than the high rate, a difference that was maintained throughout. A point of interest was the superiority of the 30 lbs/acre 7" spacing over the 30 lbs/acre 14" spacing.

In this experiment there was no increase in dry matter produced after the third harvest, 19 weeks from sowing. This was probably due to the dry conditions experienced from early October onwards, which would also explain the low levels of yield and the lack of the yield-density relationship with time.

5.2.2. Tiller production

Number of tillers per m^2

At the first harvest there was no significant differences due to row direction, but both spacing and rate of sowing were highly significant ($P < 0.001$). The differences due to spacing and rate of sowing were maintained at subsequent harvests. Row direction was significant ($P < 0.05$) at the second and fourth harvests when the N-S rows were higher than the E-W rows. In the 60 lbs/acre 7" spaced treatment there was a steady decrease in the number of tillers up to the third harvest. In the 30 lbs/acre both 7" and 14" spacing there was very little change with time, while in the 15 lbs/acre 14" spaced treatment a large increase from the first to the second harvest was noted, after which tiller numbers were maintained constant.

Number of tillers per m length of row

Here the relationship with spacing was opposite to that in the previous section but was similar as far as rate of sowing was concerned.

Number of tillers per plant

Higher tiller numbers were recorded in the low rate of sowing than in the high rate and within each rate the 14" spacing was better than the 7" spacing.

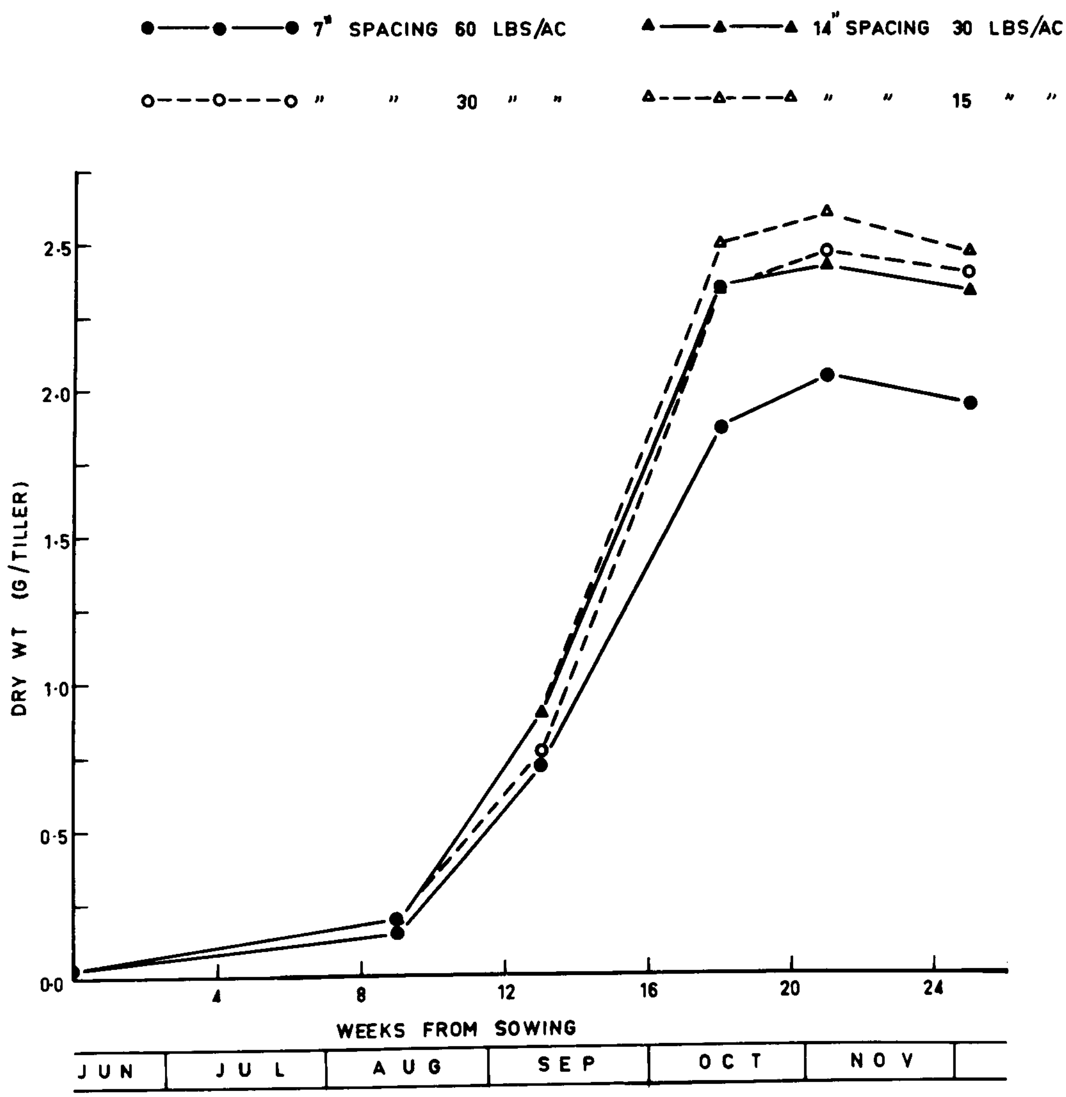
Tiller numbers followed the same relationship as did the dry matter production.

Weight per tiller

There was no significant difference at any stage due to row direction, and mean weights are presented in Fig. 26. At the first harvest there was no significant difference between treatments. At the second harvest the 14" spaced treatment produced heavier tillers than the 7" spaced and the 30 lbs/acre treatments had heavier tillers than the 60 lbs/acre treatments. At the third harvest D_4 recorded the highest weight and D_1 the lowest. D_2 and D_3, both of which had the same number of plants per acre, recorded similar weights. The relationships at this harvest was maintained at the fourth and fifth harvests.

D_1 had the highest number of tillers per m^2 but the mean weight per tiller was lowest, and the reverse was true of D_4. In spite of this the former recorded the highest yield and the latter the lowest, since the reduction in tiller numbers was not compensated by a sufficient increase in tiller weights. The high yield from D_2 compared to D_3 was due to higher number of tillers in that treatment as there was no difference between the tiller weights from the two treatments.

Fig. 26. Dry wt/tiller in the four Rate x spacing treatments at successive harvests (Experiment 2).



7" SPACING 60 LBS/AC
" " 30 " "
14" SPACING 30 LBS/AC
" " 15 " "
DRY WT (G/TILLER)
0·0
0·5
1·0
1·5
2·0
2·5
4
8
12
16
20
24
WEEKS FROM SOWING
JUN
JUL
AUG
SEP
OCT
NOV

5.2.3. Grain yield

There was no significant difference due to row directions, and mean values are presented in Table 20.

Table 20

Yield of grain

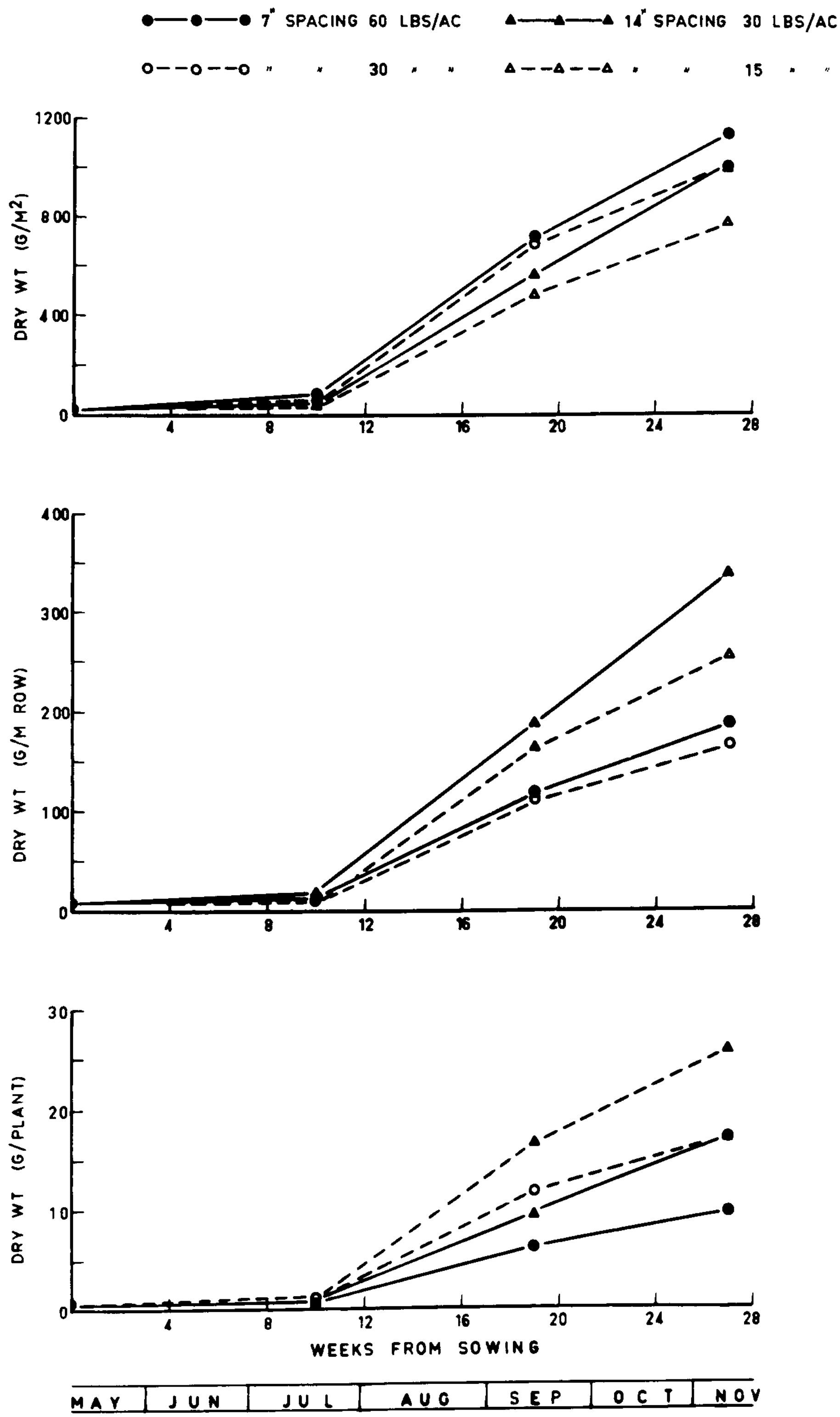
	D_1	D_2	D_3	D_4
g/m^2	278.34	278.18	210.64	196.95
g/m row length	46.74	46.27	35.10	65.65
g/plant	2.92	5.78	4.40	8.20

These follow the same pattern as the dry matter yield except that the rate of sowing had no effect on yield/m^2 and meter row length; and because of this the yield/plant was highly significant.

5.2.4. Dry matter yield of Experiment 2A

This experiment, which was planted four weeks before Experiment 2, was harvested on three occasions and produced some data which supplemented those of Experiment 2. Firstly, there was a larger difference between the N-S and E-W rows which assumed significance ($P < 0.05$) at the second and third harvests. Secondly there was no difference between D_2 and D_3 at the final harvest. The mean dry matter yield of N-S and E-W rows for the various treatments are presented in Fig. 27.

Fig. 27. Dry matter yield of the four Rate x Spacing treatments at successive harvests. (Experiment 2A)



7" SPACING 60 LBS/AC
" " 30 " "
14" SPACING 30 LBS/AC
" " 15 " "
DRY WT (G/M2)
DRY WT (G/M ROW)
DRY WT (G/PLANT)
WEEKS FROM SOWING
MAY
JUN
JUL
AUG
SEP
OCT
NOV

Yield per m^2

At the first harvest there was no significant difference between row directions even though the N-S rows yielded 13.3% higher than the E-W rows. The relationship between spacings and rates of sowing were as those recorded in the previous experiment. At the final harvest the difference due to row direction was significant at the 5% level, the N-S rows yielding 10.5% more than the E-W rows, and the 7" spacing yielding higher than the 14". Within each the higher rate yielded more than the low rate, so much so that there was no difference between D_2 and D_3. Even though row direction was significant there was no interaction with spacing or rate of sowing.

Yield per m row length

On the first occasion neither row direction nor spacing had any significant effect and yield was directly related to rate of sowing. At the second harvest, there was an overall increase in N-S rows, significant at the 5% level, 14" spacing yielded higher than the 7" and within each spacing there was some advantage from the high rate of sowing. At the final harvest essentially the same relationship between treatments were observed.

Yield per plant

At the first harvest no significant differences were observed, but at the second occasion the low rate and wider spacing yielded higher. While this was maintained at the final harvest D_2 and D_3

yielded the same amounts, showing that regardless of arrangement the same number of plants finally approach similar yields.

5.2.5. Grain yield

The grain yield followed a slightly different pattern to the dry matter produced at the final harvest. The three aspects are presented in Table 21. The N-S rows yielded higher than

Table 21

Yield of grain.

	D_1	D_2	D_3	D_4
g/m^2	351.12	336.66	349.58	279.61
g/m row length	56.11	56.11	116.52	93.20
g/plant	2.93	5.61	5.83	9.32

the E-W rows. In the yield/m^2 there was significant difference between spacing in the dry matter produced with 7" spacing yielding higher than 14" but this was not significant in the grain yield; and the difference between rate of sowing was significant at the 0.1% level for dry matter yield but grain yield was significant only at the 5% level. Other aspects of grain yield however followed the same relationship as did the dry matter.

5.2.6. Leaf area index Experiment 2

At the first two harvests leaf area measurements were made to study the vertical and lateral distributions along the rows. It was the original intention to study the distribution throughout the growth of the crops, but due to early and sudden death of the leaves between the second and third harvests the programme was discontinued.

Total L.

For any harvest total L. was calculated by adding the various fractions. There was no significant difference between row directions, and mean values for the treatments are presented in Table 22. These figures follow the dry matter yield at both harvests. At the first harvest there were big differences between

Table 22

Mean L at the first two harvests

	D_1	D_2	D_3	D_4	L.S.D. 5%
Harvest 1	1.49	1.04	0.65	0.43	0.19
Harvest 2	2.69	2.05	1.69	1.51	0.36

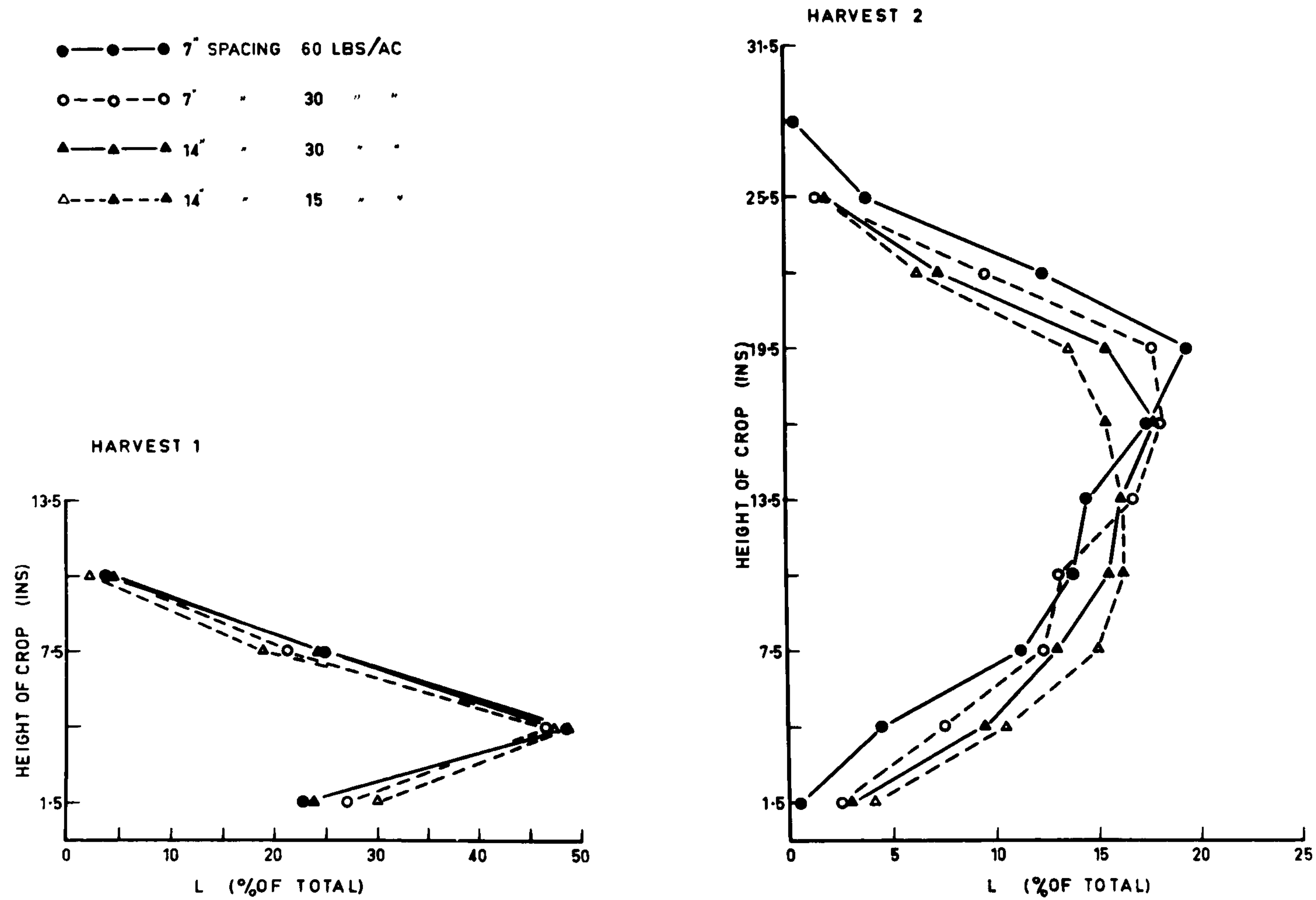
spacings and within each spacing the rates; but at the second harvest while the difference between spacing was highly significant ($P < 0.001$) the rates within the 14" spacing were not significantly different compared to 7" spacing, though the trend was evident.

Vertical distribution of leaf area

As for total L there were no significant differences between row directions, and the mean values for the four treatments are presented in Fig. 28. At the first harvest the leaf area increased with height reaching a maximum between 3 and 6" from the ground and then decreased steadily in all treatments. At the second harvest this tendency was evident though less pronounced, and the leaf tissue was spread over a greater height of the crop (6-21"). In the 7" spaced crops the maximum was attained between 18 and 21" while there was no defined maximum region in the 14" spaced crops, where the leaf area was spread evenly from 6 to 21". At the first harvest the high rate of sowing had less leaf area in the lower layers than the low rates, and within each rate of sowing the 7" spaced rows were less than the 14" spaced rows. This relationship was completely reversed above the height of maximum leaf area. A similar trend existed at the second harvest also.

In Table 23 the dead leaves are shown as % of the total of dead and green leaves. There was greater mortality in the closely spaced treatments than in the widely spaced ones, and within each spacing more in the high rate of sowing than in the low. There was higher mortality in the E-W than in N-S rows though this did not reach significance.

Fig. 28. Vertical distribution of leaf area at the first two harvests.



7" SPACING 60 LBS/AC
7" " 30 " "
14" " 30 " "
14" " 15 " "
HARVEST 1
HEIGHT OF CROP (INS)
13·5
7·5
1·5
0
10
20
30
40
50
L (% OF TOTAL)
HARVEST 2
HEIGHT OF CROP (INS)
31·5
25·5
19·5
13·5
7·5
1·5
0
5
10
15
20
25
L (% OF TOTAL)

Table 23

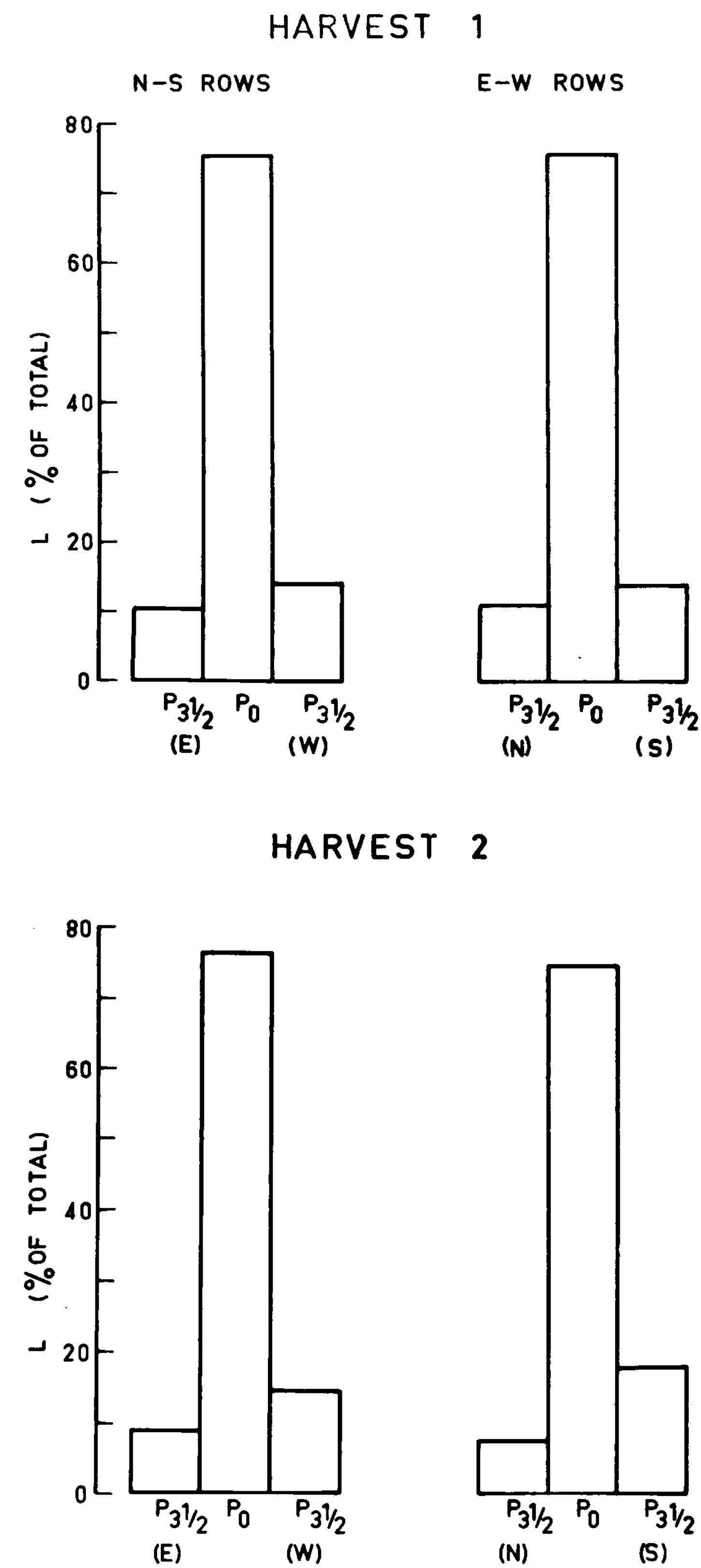
Dead leaves as % of total weight of leaves at the second harvest

	D_1	D_2	D_3	D_4	L.S.D. 5%
N-S rows	9.53	7.33	4.93	2.50	
E-W rows	11.33	8.13	6.23	3.66	
Mean	10.43	7.73	5.59	3.08	2.42

Lateral distribution of leaf area

75% of the total leaf area was accounted for in the centre strip which covered 1.75" on either side of the rows. This was true of all treatments at both harvests (Fig. 29). There was little difference between the leaf area on either side of the rows in N-S and E-W rows. At the second harvest however while the difference in the N-S rows was of the same order and direction as at the first harvest, the southern side had considerably higher amounts than the northern side in the E-W rows. The lateral distribution of leaf tissue is shown in Plate 4 for D_1 and D_3 one week before heading. This consistently higher amounts of leaf tissue on the western side of N-S and southern side of E-W rows would suggest that there was greater growth on those sides. While this could be real the wind direction at the time of sampling could influence the results. In the field the leaves and even whole plants could be blown to one

Fig. 29. Lateral distribution of Leaf area at the first two harvests.



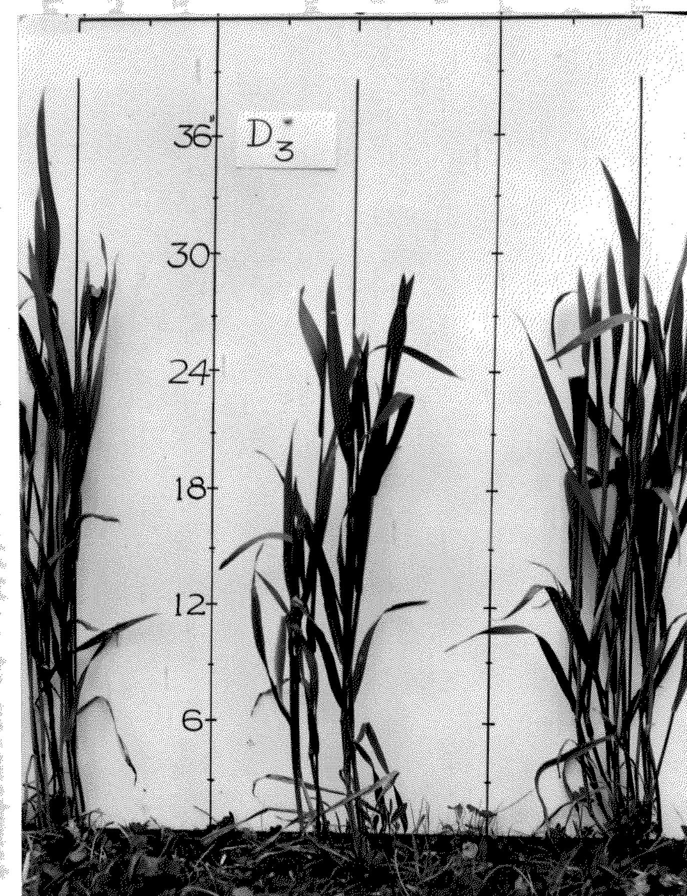
HARVEST 1
N-S ROWS
E-W ROWS
L (% OF TOTAL)
0
20
40
60
80
$P_{3\frac{1}{2}}$ (E)
P_0
$P_{3\frac{1}{2}}$ (W)
$P_{3\frac{1}{2}}$ (N)
P_0
$P_{3\frac{1}{2}}$ (S)
HARVEST 2
L (%OF TOTAL)
0
20
40
60
80
$P_{3\frac{1}{2}}$ (E)
P_0
$P_{3\frac{1}{2}}$ (W)
$P_{3\frac{1}{2}}$ (N)
P_0
$P_{3\frac{1}{2}}$ (S)

Plate 4. Showing lateral spread of the plants in Experiment 2 prior to the second harvest.

(a) D_1 60 lbs/acre 7" spacing

(b) D_3 30 lbs/acre 14" spacing.


36"
D_1


36"
D_3
30
24
18
12
6

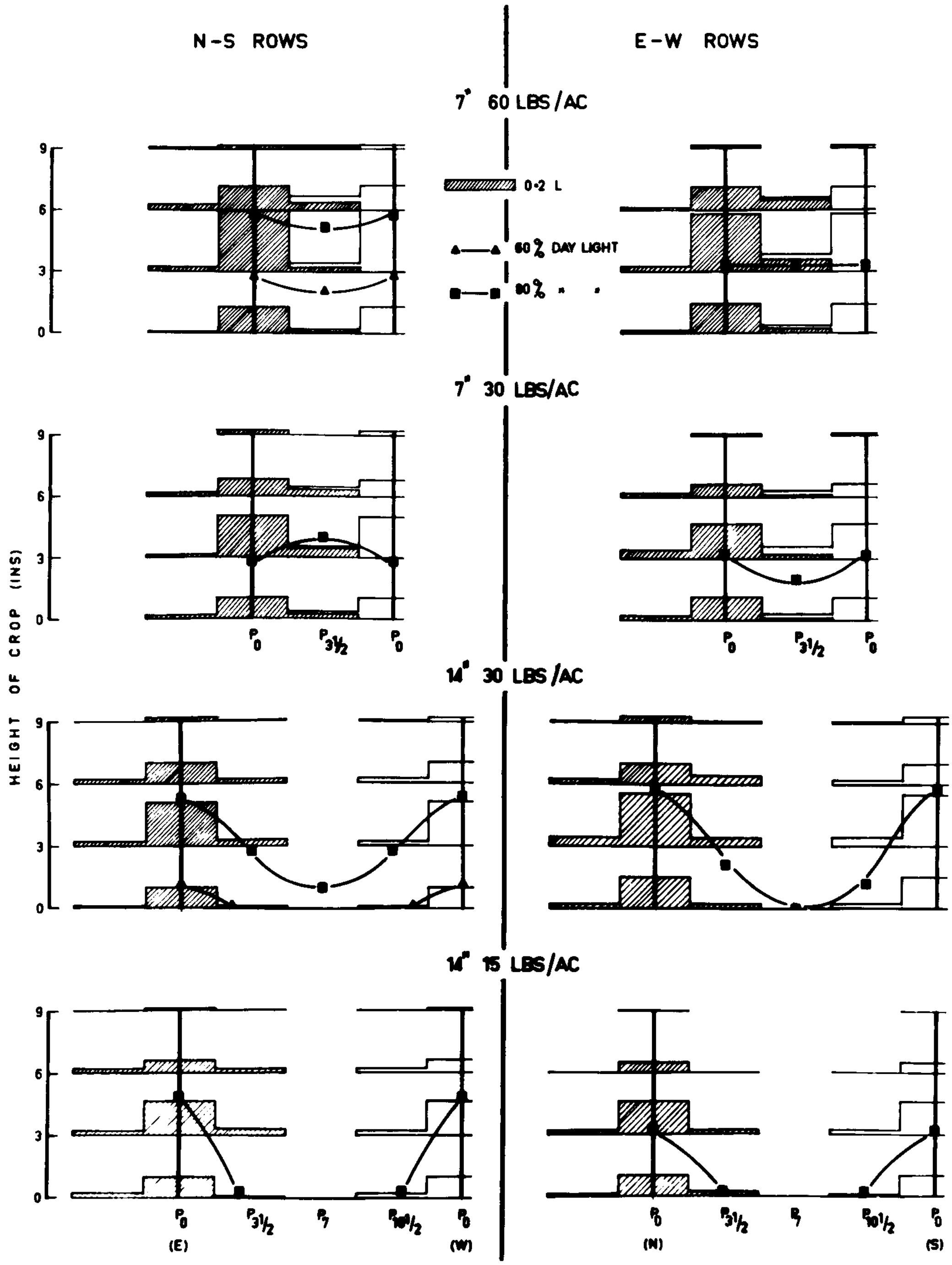
side or the other by the wind. On both harvest occasions the wind was northerly varying between north east and north west, with an average speed of 13 m.p.h. The wind at the time of sampling would be particularly effective in the E-W rows, where more plant material would be found on the southern side than on the northern. Furthermore the effect of the wind would be greater the taller the plants; hence the bigger difference at the second harvest than at the first.

Both the vertical and lateral distribution for the various treatments at the two times of samplings are presented in Fig. 30 and 31, where L. in each position is shown as histogram covering the entire lateral distance of the particular position. The adjacent unhatched row in each treatment is a repetition to reconstruct the L. distribution in the crop. There was very little leaf beyond 5.25" from the row on either side, giving a maximum spread of 10.5", even in the 14" spaced crops. This would leave a central region 3.5" wide between the rows in 14" spaced treatments where the light would be virtually unintercepted at noon in N-S rows. No such region would exist in the E-W rows as the plants would be at right angles to the sun's rays at noon.

5.2.7. Light intensity, Experiment 2

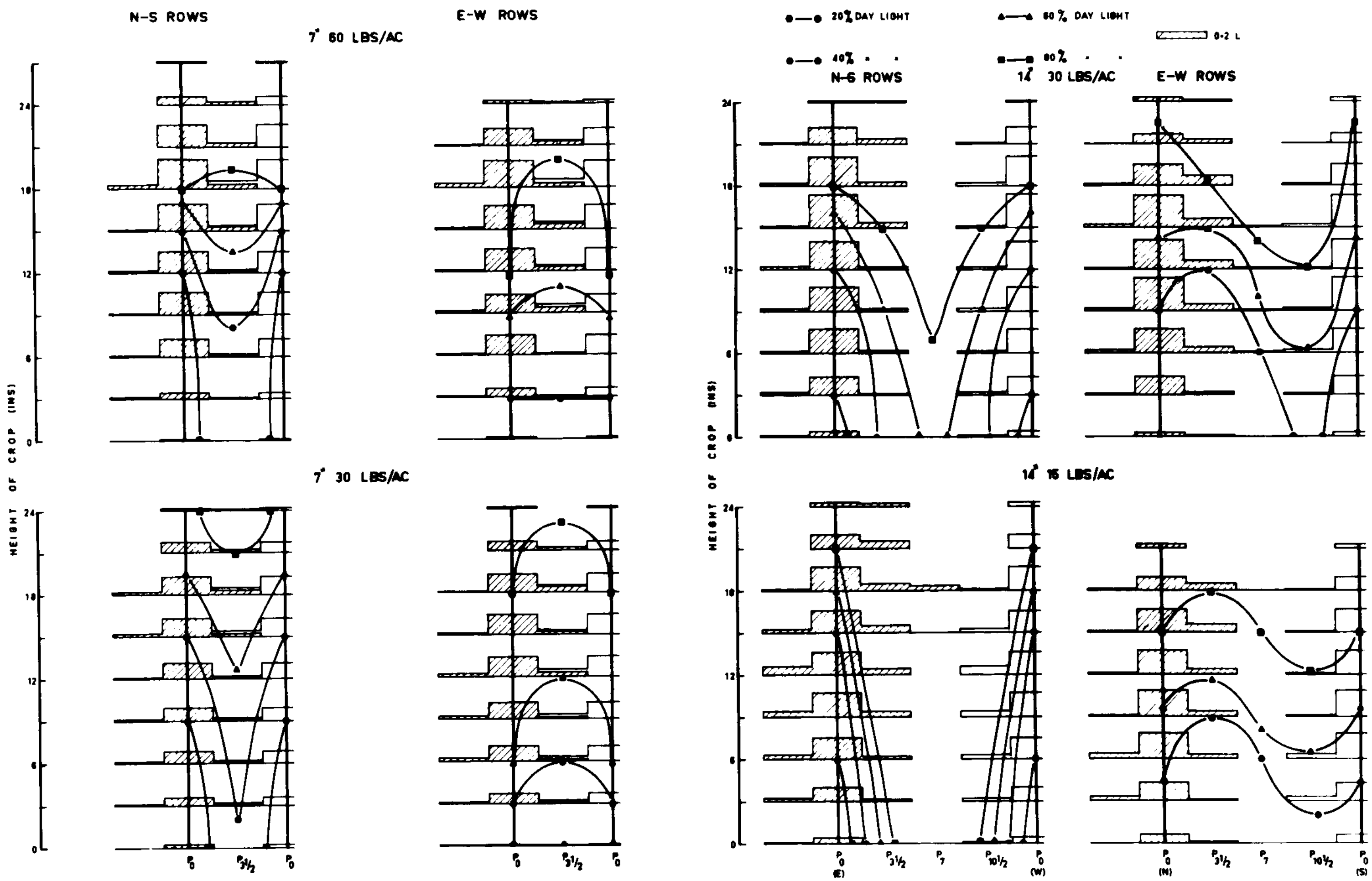
Detailed light measurements were made at weekly intervals in Block 3 commencing eight weeks from planting. On each occasion measurements were made at True Solar Noon and four hours before and after. In addition fortnightly measurements were made at

Fig. 30. Leaf area distribution and isopleths of % daylight at the first harvest.



N-S ROWS
E-W ROWS
7" 60 LBS/AC
0·2 L
60 % DAY LIGHT
80 % " "
7" 30 LBS/AC
14" 30 LBS/AC
14" 15 LBS/AC
HEIGHT OF CROP (INS)
9
6
3
0
P0
P3½
P7
P10½
(E)
(W)
(N)
(S)

Fig. 31. Leaf area distribution and isopleths of % daylight at the second harvest.


N-S ROWS
E-W ROWS
7" 60 LBS/AC
7" 30 LBS/AC
14" 30 LBS/AC
14" 15 LBS/AC
20% DAY LIGHT
40% " "
60% DAY LIGHT
80% " "
0-2 L
HEIGHT OF CROP (INS)
0
6
12
18
24
P0
P3½
P7
P10½
(E)
(W)
(N)
(S)

noon beneath and between rows at ground level in all plots of the Experiment.

Mean light intensity at ground level

In all treatments the % daylight reaching the ground at noon was higher than at 8 a.m. and 4 p.m. except in the E-W 14" spaced treatments at the end of the experiment. There was no difference between the morning and afternoon measurements. The change in % light with time is shown in Fig. 32. The various points were scattered and the curves were fitted by eye and smoothed to eliminate irregularities caused by unevenness of the crops, changes in cloudiness, wind etc. Since there was no difference between the morning and afternoon, only the morning measurements are presented in the figure. In the morning and afternoon the rate of decrease of light was faster than at noon and reached minimum value approximately two weeks before the noon measurements. The % light reaching ground at the time of maximum interception in the various treatments are shown in Table 24. There was more light reaching ground in the 14" spaced treatments than in the 7", and within each spacing the low rate of sowing was slightly higher than the high rate. On the whole there was very little difference between row direction, particularly in the 7" spaced treatments. In the 14" spaced treatments the N-S rows were higher than the E-W at noon and lower in the morning and afternoon.

Fig. 32. Mean % daylight at ground level throughout the season at the solar noon and four hours before. The curves were fitted with eye and the actual readings are not shown. (Data in Appendix 10.3.7. (a) - (b)).

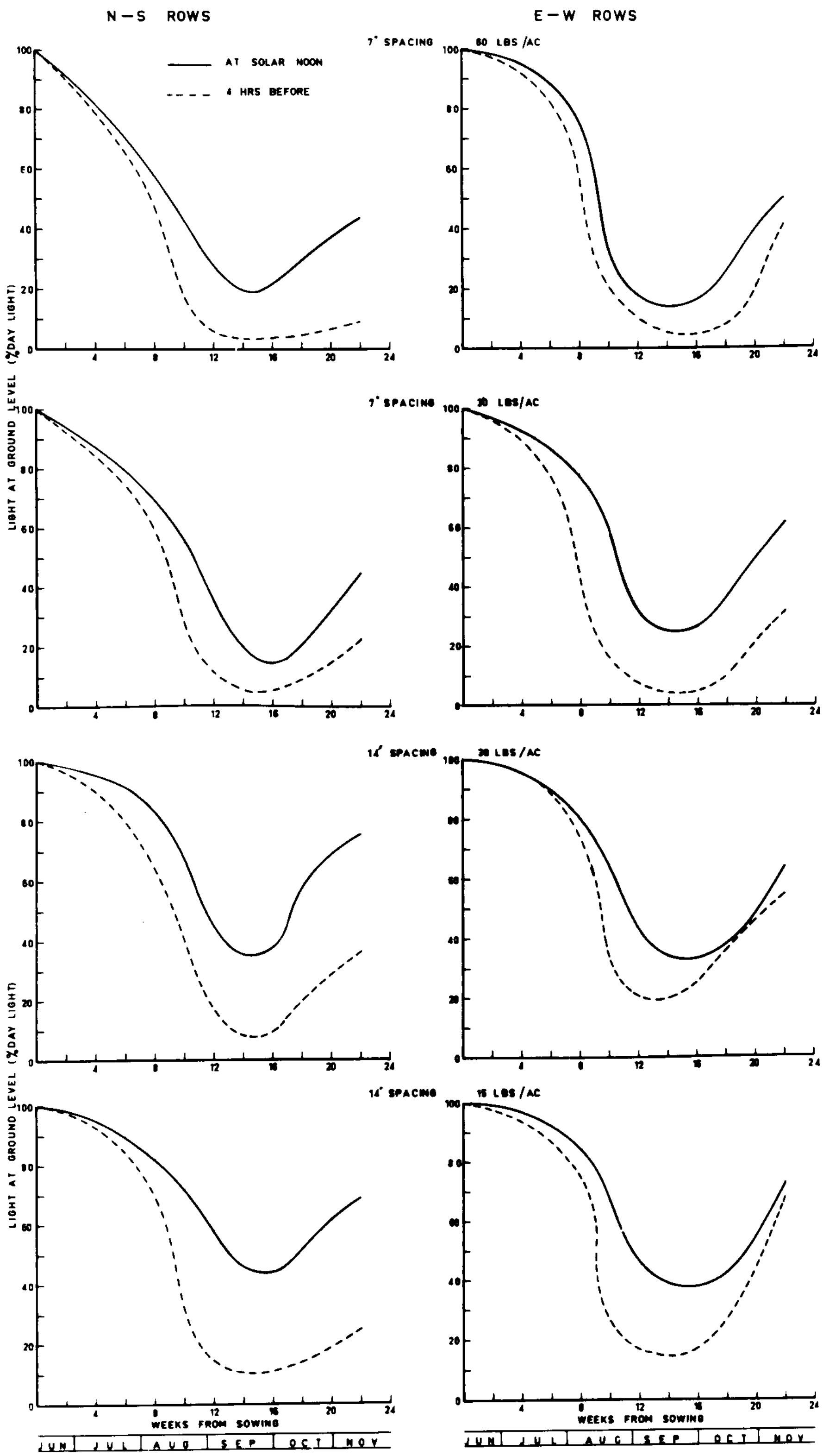

N — S ROWS
E — W ROWS
AT SOLAR NOON
4 HRS BEFORE
7" SPACING
60 LBS/AC
30 LBS/AC
14" SPACING
30 LBS/AC
15 LBS/AC
LIGHT AT GROUND LEVEL (% DAY LIGHT)
WEEKS FROM SOWING
JUN JUL AUG SEP OCT NOV

Table 24

Mean % light reaching ground level at time of maximum interception

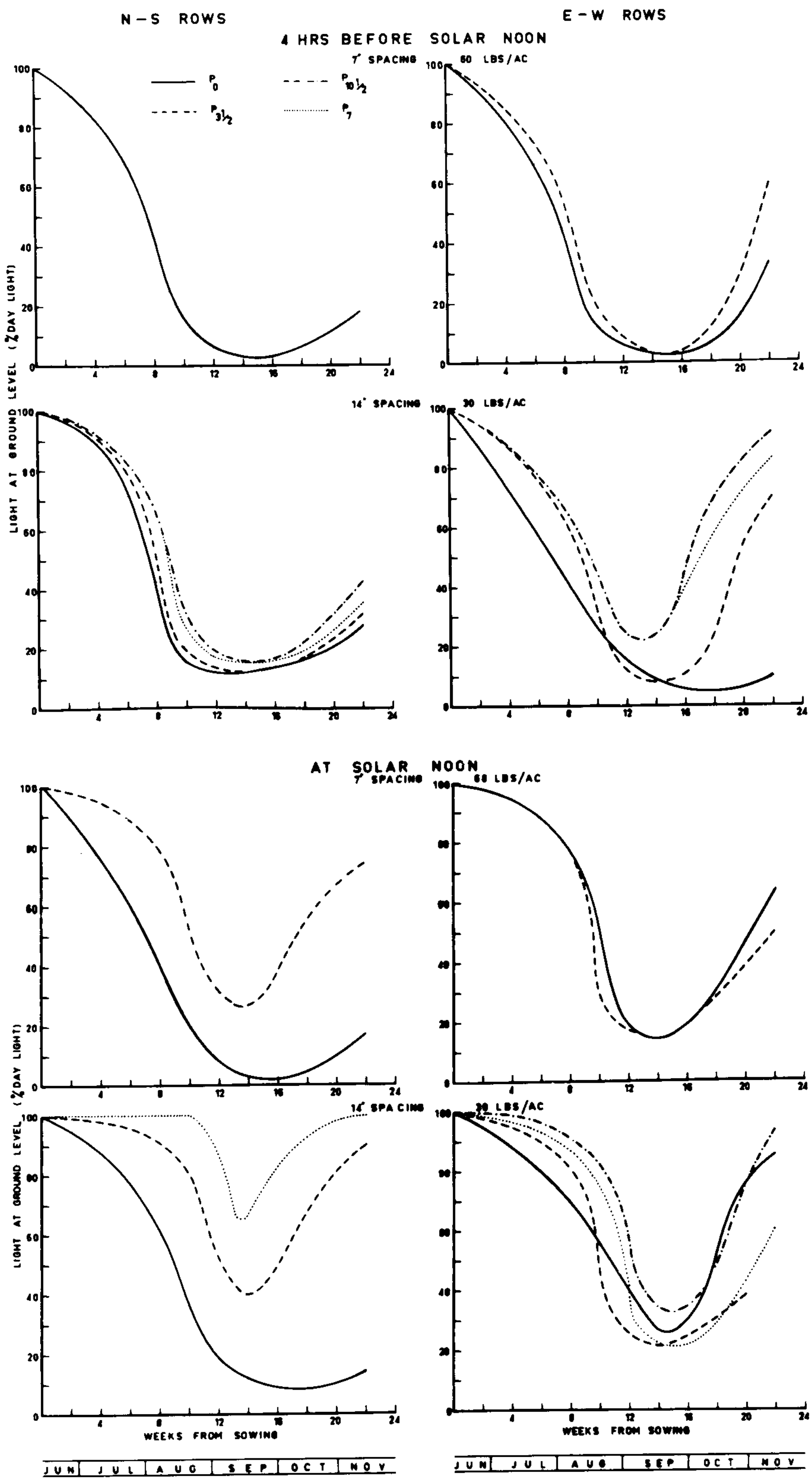
		Noon	(a.m. & p.m.) Mean
N-S	D_1	15.0	2.5
	D_2	20.0	5.0
	D_3	35.0	7.5
	D_4	42.5	10.0
E-W	D_1	15.0	2.5
	D_2	25.0	5.0
	D_3	32.5	17.5
	D_4	37.5	20.0

% light at various positions at ground level

North - South rows

There was very little difference between the rates of sowing within each spacing in the pattern of the light received at the various positions and in Fig. 33 the higher rates at the two spacings are shown. Again there was little difference between the morning and afternoon measurements, except in the 14" spaced treatments of N-S direction where $P_{3\frac{1}{2}}$ and $P_{10\frac{1}{2}}$ were in the morning the reverse of that in the afternoon, purely due to the change in the direction of the sun from East to West. In the 14" spaced

Fig. 33. Percentage daylight at the various positions at ground level in the high rate of sowing in each spacing throughout the season at solar noon and four hours before. The curves were fitted with eye and the actual readings are not shown. (Data in Appendix 10.3.7. (a) - (b)).


N – S ROWS
E – W ROWS
4 HRS BEFORE SOLAR NOON
7" SPACING
60 LBS/AC
14" SPACING
30 LBS/AC
AT SOLAR NOON
7" SPACING
60 LBS/AC
14" SPACING
30 LBS/AC
LIGHT AT GROUND LEVEL (% DAY LIGHT)
WEEKS FROM SOWING
JUN
JUL
AUG
SEP
OCT
NOV

treatment there was very little difference between $P_{3\frac{1}{2}}$ and $P_{10\frac{1}{2}}$ at noon, the mean curve of which was intermediate to P_0 and P_7.

East - West rows

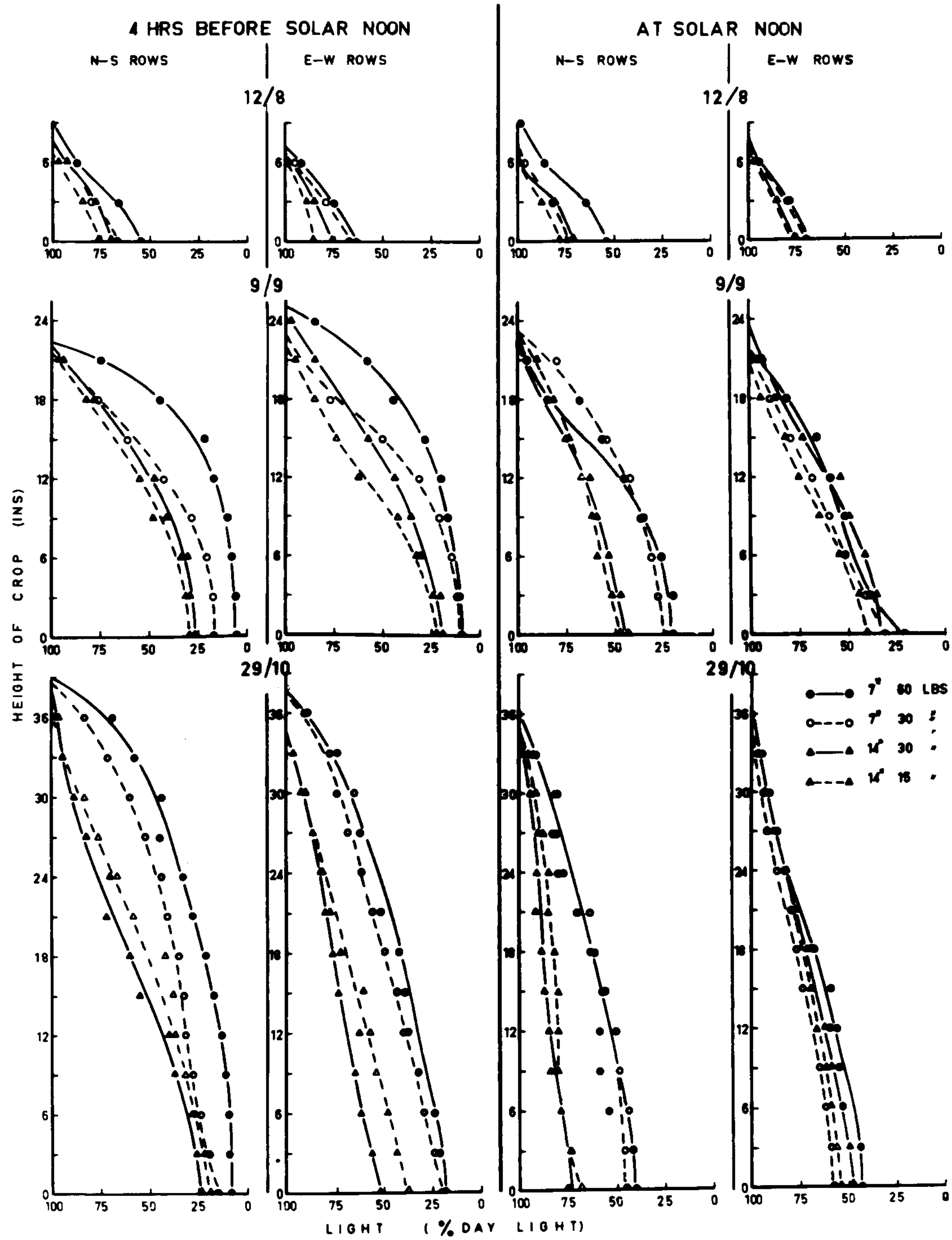
Here again the pattern of light received at the various positions were different only between the spacings; the morning measurements were not different from the afternoon measurements, and in Fig. 33 the higher rates of sowing at each spacing are shown. In the 7" spaced treatment $P_{3\frac{1}{2}}$ received more light than P_0 at the early and late stages of growth in the morning. At noon there was very little difference up to the time of the ascending slope, when $P_{3\frac{1}{2}}$ received less light than P_0. In the 14" spaced treatment, in the morning P_0 received less light than the rest of the positions followed by $P_{3\frac{1}{2}}$, P_7 and $P_{10\frac{1}{2}}$. At noon the relationship between the various positions were inconsistent and the range of values between the lowest and the highest was very narrow compared to the corresponding N-S row. At the early stages the relationship between the various positions were similar to that recorded for the morning.

There was very little difference between N-S and E-W rows in the various treatments in the pattern of light recorded in the morning and afternoon but very large differences were recorded at noon. In the N-S Rows the light at P_0 steadily reached a low level and remained at that level for a considerable length of time and later rose very little, while in the E-W rows the values rose sharply. The light at other positions followed a similar pattern to that of P_0 in E-W rows while in the N-S rows there ~~was~~ were very large differences between the various positions.

<u>Light profiles</u>

Light profiles on three selected occasions representing dates on the descending slope (12/8), time of maximum interception (9/9) and the ascending slope (29/10) are presented in Fig. 34 for solar noon and four hours before. On the first occasion the light decreased steadily with increasing depth from the top of the crops, more light reaching the ground in 14" than in 7" spaced crops; and within each slightly more in the case of the low than the high rate of sowing. On the second occasion and in the morning a similar difference between treatments were observed, but instead of a steady rate of decrease with depth, after about 2/3 the way down there was very little further interception. This was very marked in the N-S rows. At noon the N-S rows showed a rather steady decline in light with depth, and treatment differences were of the same order as at the first occasion. There was very little difference among the treatments in E-W rows. The situation at the third occasion was essentially similar to that at the second except that interception was uniform through the depth of the crops. Light profiles for the various positions in 14" spaced 30 lbs/acre (D_3) treatment at the time of maximum interception (9/9) are given in Fig. 35. for the two directions and at solar noon and four hours after. Any

Fig. 34. Profiles of mean % daylight on three selected dates.



4 HRS BEFORE SOLAR NOON
AT SOLAR NOON
N-S ROWS
E-W ROWS
N-S ROWS
E-W ROWS
12/8
12/8
9/9
9/9
29/10
29/10
HEIGHT OF CROP (INS)
LIGHT (% DAY LIGHT)
7" 60 LBS
7" 30
14" 30
14" 15

differences between directions and positions were mainly at noon.

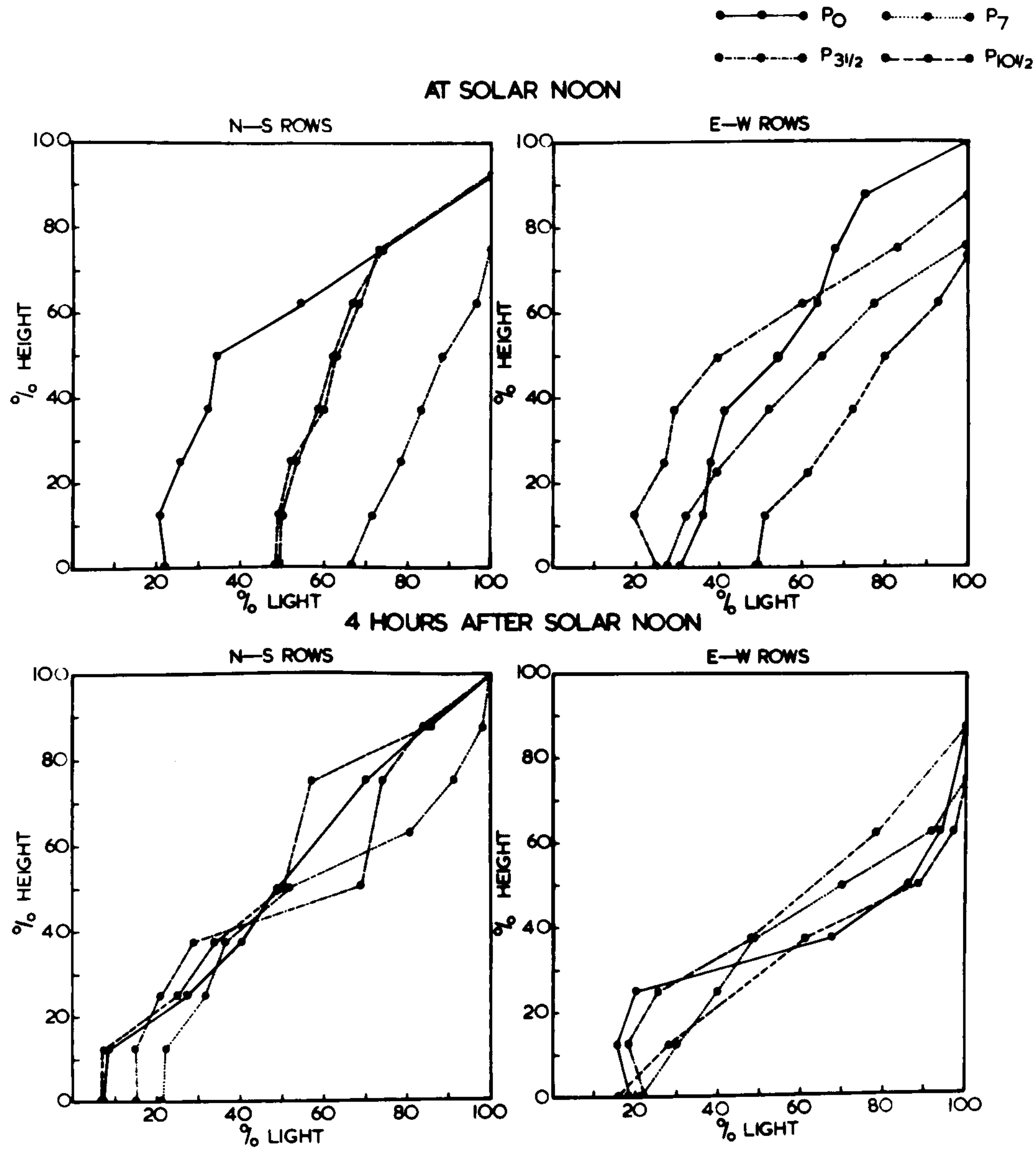
Isopleths of light intensity

Isopleths of light intensity across the rows for the three occasions were constructed and are presented in Fig. 36 for morning and noon. Generally speaking the isopleths in the N-S rows at mornings were similar to the E-W rows at noon and the pattern at morning in the E-W rows being similar to those at noon in N-S rows. As might be expected, the isopleths are related to the angle of the sun and the direction of the rows, the point of maximum illumination being decided both by the angle of the sun and height and row spacing of the crops. From these curves it may be concluded that for the 14" spaced crops in the E-W rows - particularly during the growing period - more light would be received at $P_{10\frac{1}{2}}$ than at any other and would decrease as P_0 was approached; in the N-S rows P_7 would receive the highest, $P_{3\frac{1}{2}}$ and $P_{10\frac{1}{2}}$ being equal to each other and less than P_7 with least illumination at P_0. It would also appear that P_0 would receive more light in E-W rows than in N-S rows, all other positions in N-S rows would receive more than E-W rows, since at no time did direct light reach the inter row space. The pattern of shadow movement in D_3 were photographed from noon onwards one week before heading and are shown in Plate 5.

Light and leaf area distribution

In Figs. 30 and 31 along with the distribution of L. iso-

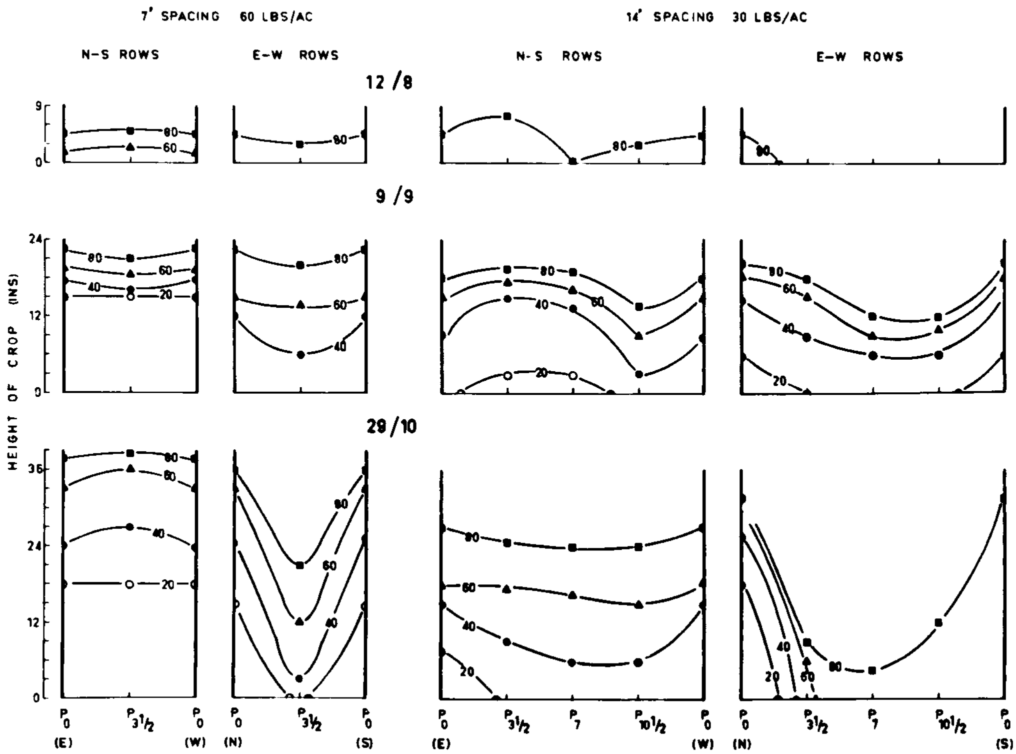
Fig. 35. Profiles of % daylight at the various positions in 30 lbs/acre 14" spaced wheat crops, at the time of maximum interception.



P0
P7
P3½
P10½
AT SOLAR NOON
N—S ROWS
E—W ROWS
% HEIGHT
% LIGHT
4 HOURS AFTER SOLAR NOON

Fig. 36. Isopleths of % daylight on three selected dates.

4 HRS BEFORE SOLAR NOON



AT SOLAR NOON

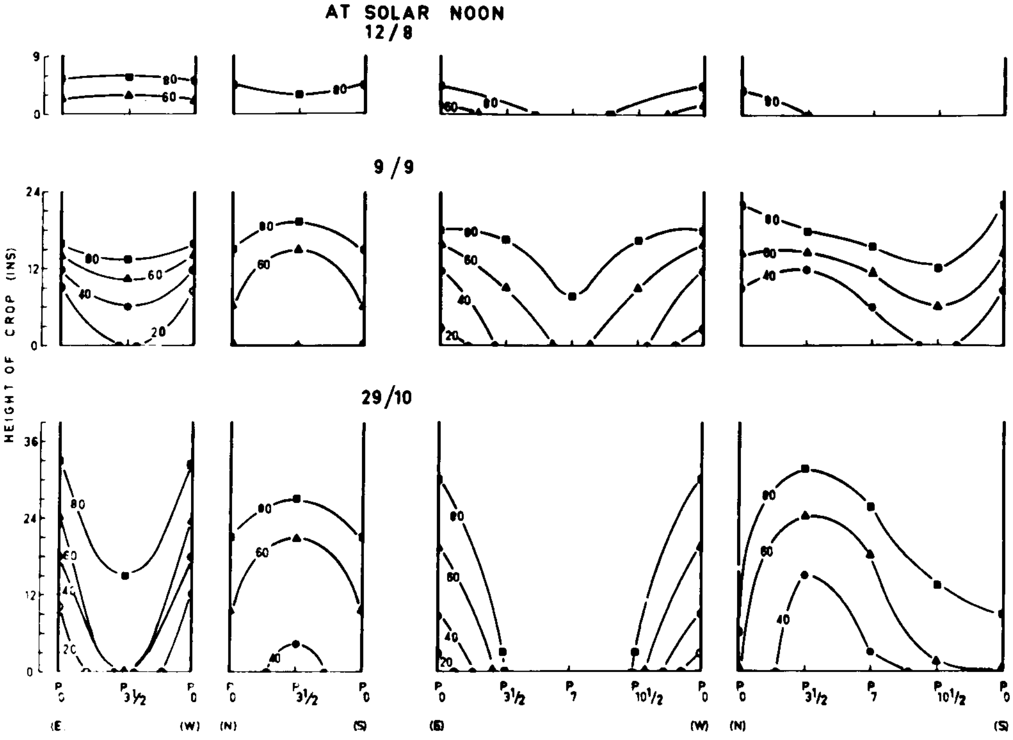
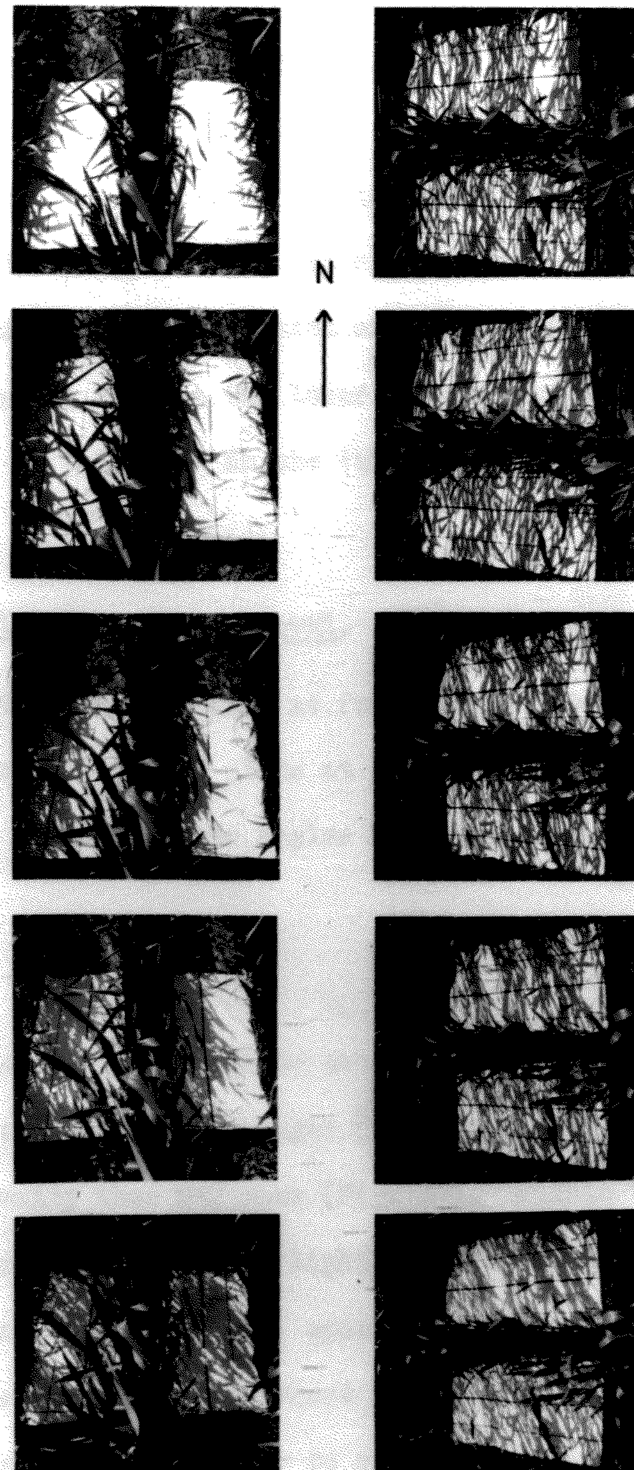


Plate 5. Movement of shadow between rows from solar noon onwards in 30 lbs/acre 14" spaced wheat a week prior to heading in Experiment 2.

(a) N-S rows

(b) E-W rows



AT T.S.N.

0·5 HR. AFTER "

1·0 HR. " "

1·5 HRS. " "

2·0 HRS. " "

pleths of light intensity measured at T.S.N. two days prior to the date of harvest are presented. As mentioned when leaf distribution was discussed there was no difference in total L. or its distribution due to row direction. The isopleths of light intensity, however, varied with row direction. At the second harvest in 7" spaced crops there was a more even distribution of illumination in N-S than in E-W rows indicating that at the lower layers the leaves of the crops would receive more light. In the 14" spaced crops this was less marked.

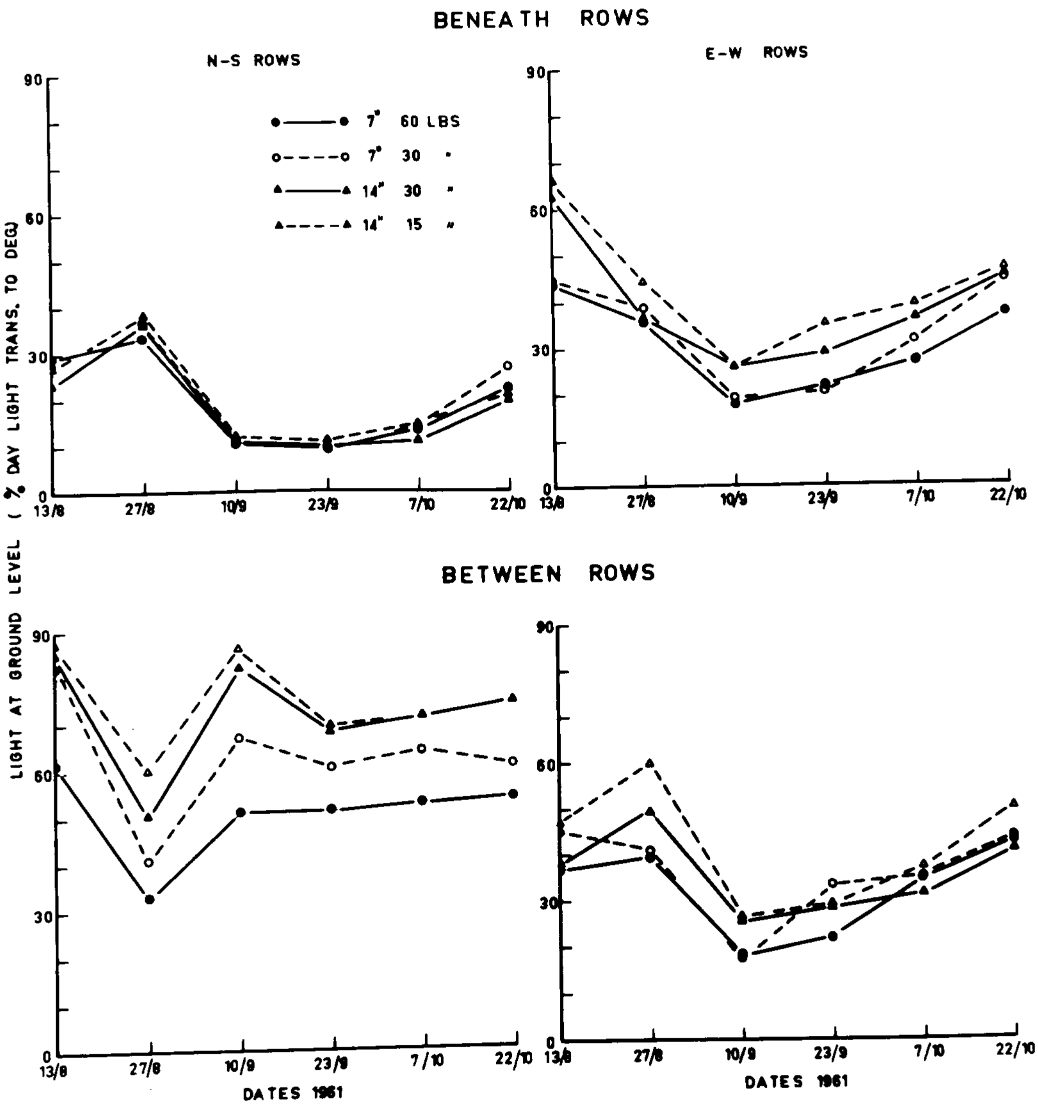
Detained analysis of % daylight at ground level.

Light measurements were also made at fortnightly intervals at noon beneath and between rows in all plots at ground level, and the percentage values were transformed to angles for statistical analysis.

Beneath rows

This would represent P_0 referred to earlier. On the first occasion (13/8), when there was direct sunlight (6000 F.C.) E-W rows recorded higher light intensity than N-S rows (Fig. 37). Within the E-W rows, 14" spaced rows recorded higher % light than 7", while there was no difference among the different spacings in N-S rows. On the second occasion when the sky was overcast (2200 F.C.) there was no difference either to row direction or to row spacing. On subsequent occasions the relationship between row direction and spacing were as at the first occasion.

Fig. 37. Percentage daylight (transformed to angles) at ground level beneath and between rows at solar noon.



BENEATH ROWS
N-S ROWS
E-W ROWS
7" 60 LBS
7" 30 "
14" 30 "
14" 15 "
LIGHT AT GROUND LEVEL (% DAY LIGHT TRANS. TO DEG)
BETWEEN ROWS
90
60
30
0
13/8
27/8
10/9
23/9
7/10
22/10
DATES 1961

Between rows

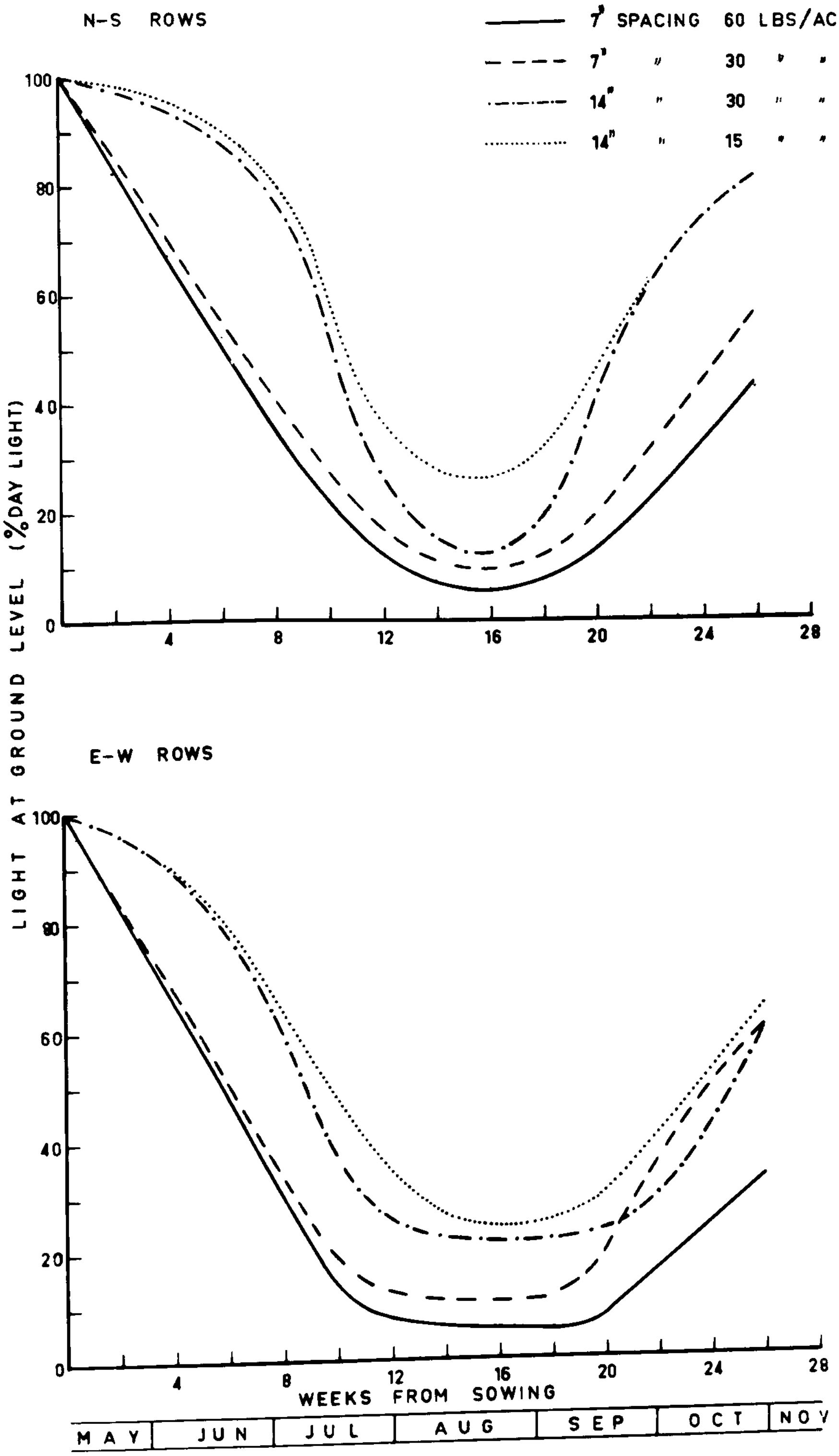
These would represent $P_{3\frac{1}{2}}$ and P_7 in 7" and 14" spaced crops respectively. On the first occasion higher light intensities were recorded in N-S than E-W rows. Within the N-S rows the 60 lbs/acre 7" spaced crop was much lower than the rest, among which there was no difference. In the E-W rows the high rate of sowing recorded less light than the low rate of sowing. At the second occasion there was no difference due to row direction, and higher light intensities were recorded in the 14" than in 7" spaced crops. Within each spacing the low rate was better illuminated than the high rate. On subsequent occasions the situation encountered at the first date was generally repeated.

These data showed firstly that E-W rows received more light than N-S rows at P_0 and the N-S rows received more in mid positions than the E-W rows and secondly that 14" were superior to 7" spaced rows. There was no difference between row direction under cloudy conditions. Even though E-W rows recorded more light than N-S rows at P_0 the differences were much smaller than between N-S and E-W rows in the mid positions. On this findings it could be said that undersown species at P_7 would receive more light in N-S than in E-W rows of cereals.

5.2.8. Light intensity, Experiment 2A

Fortnightly measurements were made at noon in this experiment. The % light reaching ground level followed the same

Fig. 38. Mean % daylight at ground level in the various treatments throughout the season (Experiment 2A).


N-S ROWS
E-W ROWS
7" SPACING 60 LBS/AC
7" " 30 " "
14" " 30 " "
14" " 15 " "
LIGHT AT GROUND LEVEL (% DAY LIGHT)
WEEKS FROM SOWING
MAY
JUN
JUL
AUG
SEP
OCT
NOV

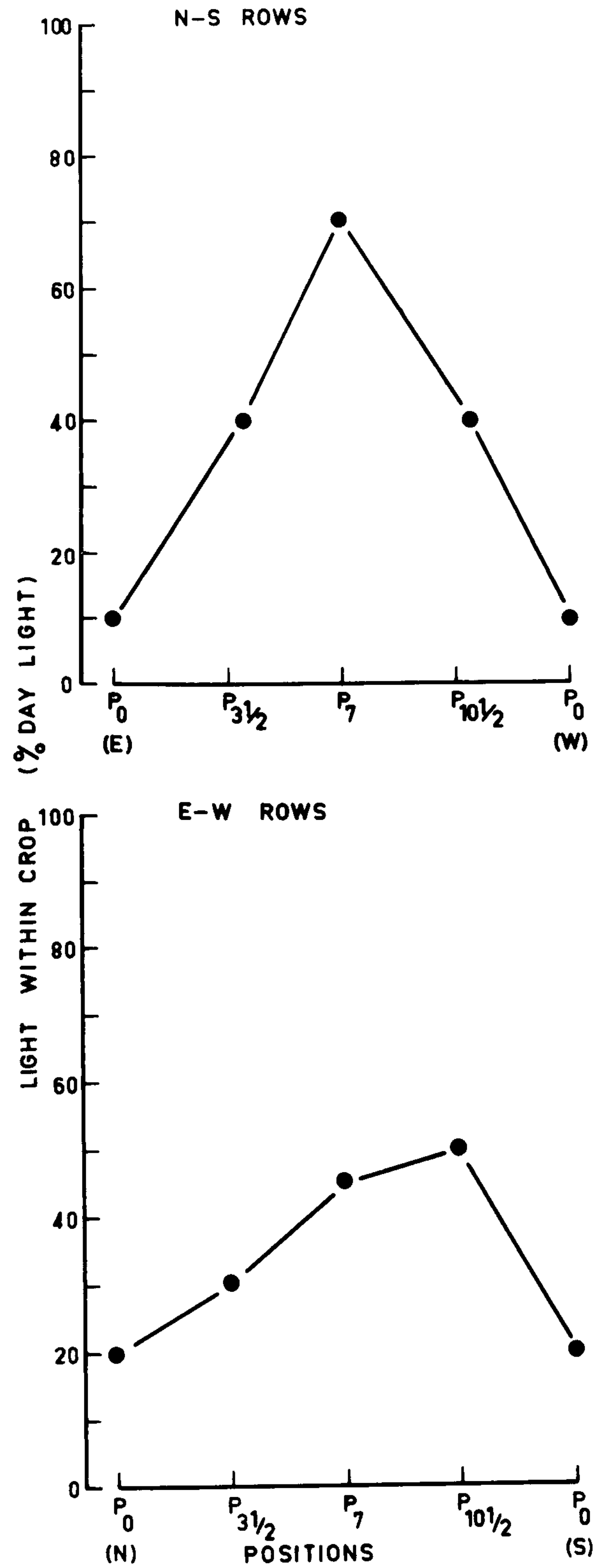
pattern as in the previous experiment except that at maximum interception less light reached ground level and that low level was maintained for a considerable period (6 weeks in E-W rows) see Fig. 38.

5.2.9. <u>Interim discussion on the light measurements of Experiments 2 and 2A.</u>

These experiments in the main established the difference in the light microclimate within N-S and E-W rows of wheat. In 14" spaced N-S rows P_0 would receive the least amount of light followed by $P_{3\frac{1}{2}}$ and $P_{10\frac{1}{2}}$; P_7 would receive the highest amounts throughout the growth of the crops. In similarly spaced E-W rows the pattern depended on the height of the crop, altitude of the sun and the height above ground under consideration. In the early stages of growth, when the crop was short and the altitude of the sun was low, P_0 and $P_{3\frac{1}{2}}$ would be mostly shaded while $P_{10\frac{1}{2}}$ would be virtually unshaded. As the height of the crop increases, shade will extend beyond the width of the rows and all positions will be shaded. This would maintain for most part of the growing season. The two patterns are shown diagrammatically in Fig. 39.

Undersown pasture species will always be shaded by the cereal and regardless of competition for other factors the undersown species will be at a disadvantage in that they have to grow under light microclimates which are substantially less than full daylight. It is now well known that the growth of plants will be

Fig. 39. Percentage daylight at ground level at the various positions in 14" wheat in N-S and E-W row directions over the growing season.


N-S ROWS
E-W ROWS
LIGHT WITHIN CROP (% DAY LIGHT)
POSITIONS
P0 (E)
P3½
P7
P10½
P0 (W)
P0 (N)
P0 (S)
0
20
40
60
80
100

reduced when the light available is reduced. The growth of the undersown species would depend on the amount of light available. The amount of light received in E-W and N-S rows were different and in them there were differences between the various positions. Hence the growth of the pasture species would vary when undersown in cereals of differing row direction and to the relative positions the pasture species occupy. To this end Experiments 3 and 3A were planted to study to what extent the difference in light received at the various positions in the two row directions would affect the growth of pasture species.

5.3.0. Experiments 3 and 3A

These experiments were carried out to study the growth of subterranean clover planted in rows at the four positions referred to in the last two experiments in relation to rows of wheat, both in the N-S and E-W directions. Experiment 3A was planted on 12 May, 1961 with wheat at 15 lbs./acre 14" spacing and clover at 7.5 lbs./acre also at the same spacing. Experiment 3 was planted on 9 June 1961 with wheat at 30 lbs./acre and clover at 11 lbs./acre, both at 14" spacing. In addition to the effect of wheat on clover the effect of clover on wheat was followed. Experiment 3A was harvested on three occasions; on the first occasion both species were harvested while at the second only clover and on the third only wheat was harvested. Experiment 3 was harvested on five occasions and on the final occasion only wheat was sampled.

5.3.1. Experiment 3

(a) Dry matter and grain yield of wheat

Clover had no significant effect on the yield of wheat at any stage, nor was there any consistent trends. It may also be noted that there was no effect of direction of row on the yield.

(b) Dry matter yield of clover

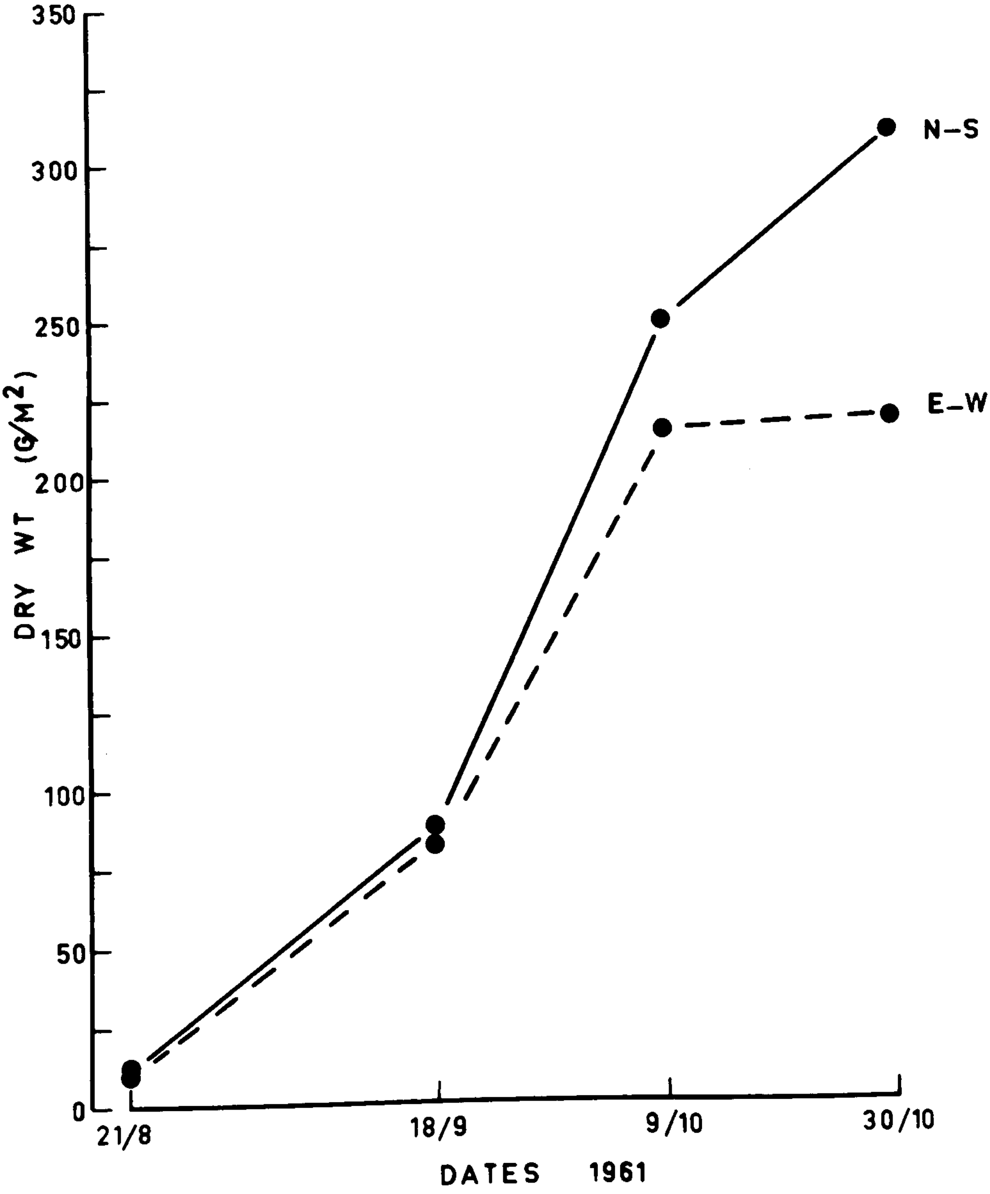
The control treatments yielded very much more than the mixed treatments, showing the effect of wheat on clover. Within the control treatments the clover in N-S plots yielded more than in the E-W, a difference which was significant at the last two harvests (Fig. 40). Because of the big difference (Table 25) between the control and mixed treatments the former was omitted and the yield of clover was analysed to study the effect of row directions and positions more precisely.

Table 25

Mean yield of clover of control and mixed treatments at successive harvests (g/m^2)

	H_1	H_2	H_3	H_3
Control treats.	11.46	79.64	231.70	165.00
Mixed treats.	8.56	38.43	62.52	52.82

Fig. 4C. Dry matter yield/m^2 of pure clover swards (T_2) at successive harvests.



350
300
250
200
150
100
50
0
DRY WT (G/M²)
N-S
E-W
21/8
18/9
9/10
30/10
DATES 1961

From the second harvest onwards the mean yield from the N-S row direction was higher than the E-W, though significant ($P < 0.05$) only on the third occasion. The yield data for the various positions in the two directions are presented in Fig. 41 for the four harvests.

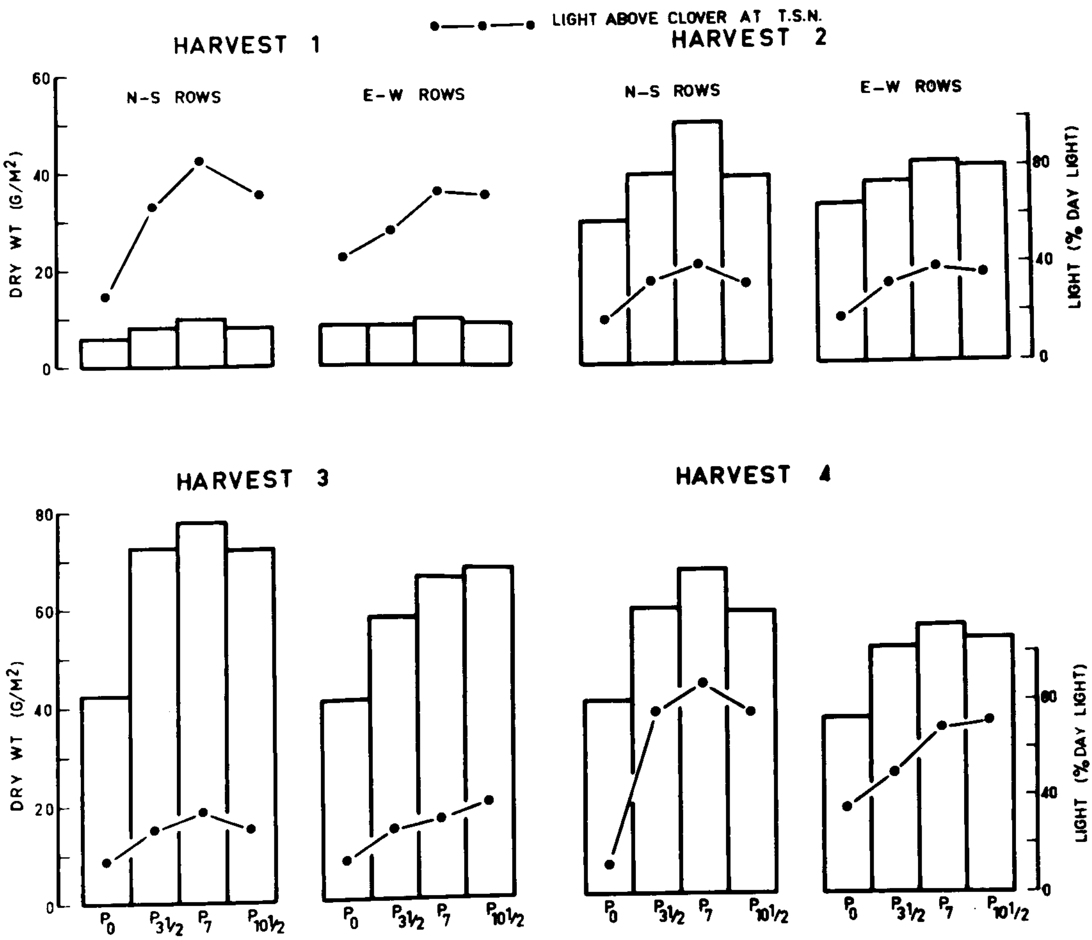
Harvest 1

On this occasion all the positions were significantly different ($P < 0.001$) from one another and the Position X Direction interaction was also significant ($P < 0.05$). The interaction was associated with the marked increase in P_0 at E-W over N-S. P_0 recorded lowest yields. In the N-S rows there was very little difference between $P_{3\frac{1}{2}}$ and $P_{10\frac{1}{2}}$ and they were much higher than P_0 and were similar to the corresponding positions in the E-W direction. P_7 in both directions was much higher than the other positions.

Harvest 2

Similar results to the previous harvest were recorded. The difference between the N-S and E-W direction in P_0 was not significant at this harvest. The difference between positions within N-S direction was of the same pattern as at the previous harvest. Within the E-W direction there was no difference between P_7 and $P_{10\frac{1}{2}}$ and the difference between these positions in the N-S direction was not sufficiently large to bring about a significant Position X Direction interaction.

Fig. 41. Dry matter yield/m^2 of clover at the various positions and percentage daylight above the clover, at successive harvests.


LIGHT ABOVE CLOVER AT T.S.N.
HARVEST 1
HARVEST 2
HARVEST 3
HARVEST 4
N-S ROWS
E-W ROWS
DRY WT (G/M2)
LIGHT (% DAY LIGHT)
P0
P3½
P7
P10½

Harvest 3

The yields in the N-S direction on the whole were significantly higher ($P < 0.05$) than in the E-W in all positions, the difference being greatest in $P_{3\frac{1}{2}}$. In the N-S direction P_7 yielded higher than $P_{10\frac{1}{2}}$ while in the E-W the reverse was the case, but in neither case was the differences significant.

Harvest 4

The yield from the various positions at this harvest was less than at the third showing not only a cessation of growth but also loss of material due to senescence. The N-S direction was in all positions yielded higher than the E-W although the differences were not significant. Here again there was no significant difference between P_7 and $P_{10\frac{1}{2}}$ even though in both directions P_7 was higher than $P_{10\frac{1}{2}}$.

The data were reanalysed treating the two directions as separate experiments to assess more precisely the difference between the various positions in each direction at successive harvests. The analysis took the form of a split plot design with harvests as main plots and the four positions as sub plots.

In both directions, harvests and positions were significant ($P < 0.001$). In the N-S direction yield of P_0 was significantly less ($P < 0.01$) than others. $P_{3\frac{1}{2}}$ and $P_{10\frac{1}{2}}$ were equal and significantly less ($P < 0.05$) than P_7. In the E-W direction P_0 was significantly less ($P < 0.05$) than all the others. Among the others there was no significant difference but $P_{3\frac{1}{2}}$ was less than P_7 and $P_{10\frac{1}{2}}$, between which there was no difference. Comparing the two directions, P_7 in N-S yielded higher than the corresponding position in the E-W.

(c) Light intensity

Light intensity was measured immediately above the clover and the crops in all treatments at fortnightly intervals commencing from 20/8 (first harvest) to 29/10 (fourth harvest). In Fig. 41 the mean percentage light above the clover in each position a day previous to the harvest is shown. In the N-S rows there was a very close relationship between the percentage light received at noon and the growth of clover in the various positions. At the first harvest in E-W rows there was significant difference in the light between P_0 and $P_{3\frac{1}{2}}$ but there was no difference in the yield of clover. This was probably due to the fact that while the growth response was to light available at the two positions from planting to first harvest, the light measurement was made at the time of harvest. It should be noted that the height at which the light was measured in relation to the wheat at successive harvests would be different due to an increase in height of the clover plants with time.

5.3.2. Experiment 3A

(a) Dry matter and grain yield of wheat

As in Experiment 3 there was no significant difference between directions and positions in the dry matter yield of wheat but there was considerable effect of the clover on the grain yield. The control treatment yielded higher than the mixed treatments. (Table 26).

Table 26

Mean grain yield of wheat per treatment (g/m^2)

Con	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	L.S.D. 5%
237.90	208.26	207.78	196.94	203.77	21.26

(b) Dry matter yield of clover

Here again the control yielded higher than the mixed treatments, and within the controls the N-S was better than the E-W, though not significant as Table 27.shows. For this reason the control treatments were eliminated from the analysis. The dry matter yield recorded at the two harvests are shown in Table 28.

Table 27

Mean yield of clover (g/m^2)

	H_1		H_2	
	N-S	E-W	N-S	E-W
Control treat.	29.49	28.98	234.10	211.60
Mixed treat.	7.62	7.98	48.76	50.88

Table 28

Mean yield of clover (g/m^2) at the various positions at the two harvests

		P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	L.S.D. 5%
H_1	N-S	9.54	14.76	20.66	15.75	
	E-W	11.90	17.98	19.28	14.77	
Mean		10.87	16.36	19.97	15.26	4.35
H_2	N-S	46.80	95.80	143.60	104.30	
	E-W	64.40	100.40	131.60	110.20	
Mean		55.60	98.10	137.30	107.25	22.06

At the first harvest the pattern of yields followed that already established in Experiment 3. At the second harvest the N-S direction followed the expected pattern but in the E-W direction the $P_{10\frac{1}{2}}$ yield was very much less than that of P_7 and was not appreciably different to that of $P_{3\frac{1}{2}}$. In other words there was no great difference in the pattern in the yield between the two row directions.

5.3.3. Interim discussion

There was very little effect of the clover on the wheat but the presence of the wheat decreased the yield of the clover considerably both in the N-S and E-W rows. Within the mixed treatments there was considerable difference between positions. In both directions when the clover was mixed on the same row as the wheat (P_0) the yield was very much less than at any other position. Among the other positions P_7 was superior to $P_{3\frac{1}{2}}$ and $P_{10\frac{1}{2}}$ in N-S rows, and in E-W rows there was no difference between P_7 and $P_{10\frac{1}{2}}$ both of which were higher than $P_{3\frac{1}{2}}$. This difference however was not significant but was consistent. It is worth noting that these patterns closely follow the light pattern shown in Fig. 39.

From the point of view of maximum light available and least competition for soil factors P_7 would be the most suitable position for the growth of pasture species in companion cropping. In N-S rows P_7 would receive more light than in E-W rows, while competition for other factors would be similar in both directions. On that basis the yield of clover in P_7 should be higher for N-S than E-W rows. This again was quite evident though not significant.

It may then be assumed that clover yields highest in the midway position (P_7) in N-S rows. It now remains to decide what would be the optimum rate of wheat for satisfactory growth of clover. Experiment 4 was undertaken to study this particular problem.

5.4.0. Experiment 4

This experiment was undertaken to determine the optimum rate of sowing of wheat in N-S rows at 14" spacing when undersown with pasture species, and to confirm if possible the relationship between positions recorded in the previous experiments for the growth of clover, and the effect of clover on the growth and yield of wheat at the various rates of sowing.

5.4.1. Dry matter and grain yield of wheat

In the absence of clover there was an almost linear relationship between yield and rate of sowing at all harvests (Fig. 42), and a levelling off of yield was noticed only between R_3 and R_4 at the last harvest. The presence of clover had no effect on any of the rates of sowing at the first two harvests. At the third harvest there was a significant depression ($P < 0.05$) at the first rate due to presence of clover, but there was no effect at the higher rates. The grain yield followed the same pattern, except that the difference between rates was less marked.

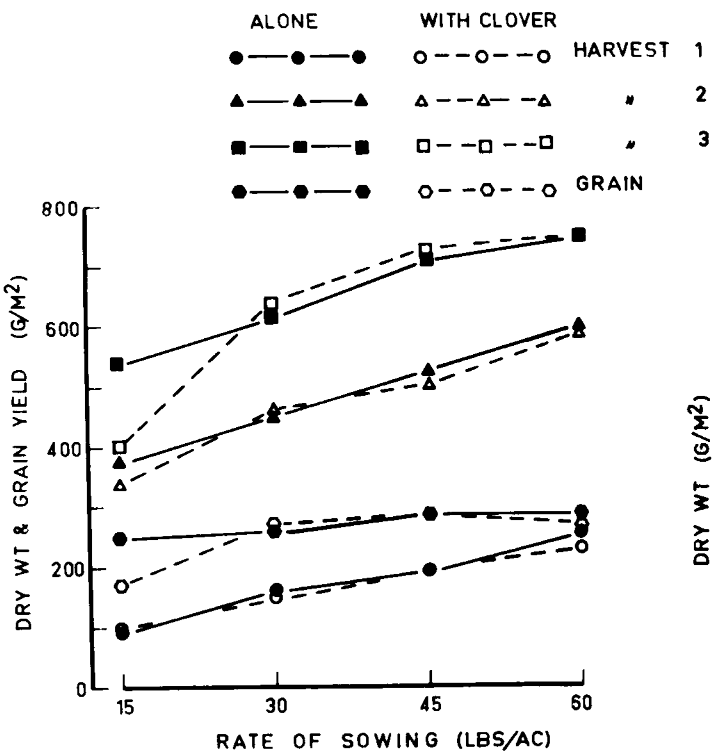
5.4.2. Number of tillers per m^2

With increase in rate of sowing there was an increase in the number of tillers, and this difference was maintained at all harvests. The presence of clover generally reduced the number of tillers at all rates of sowing.

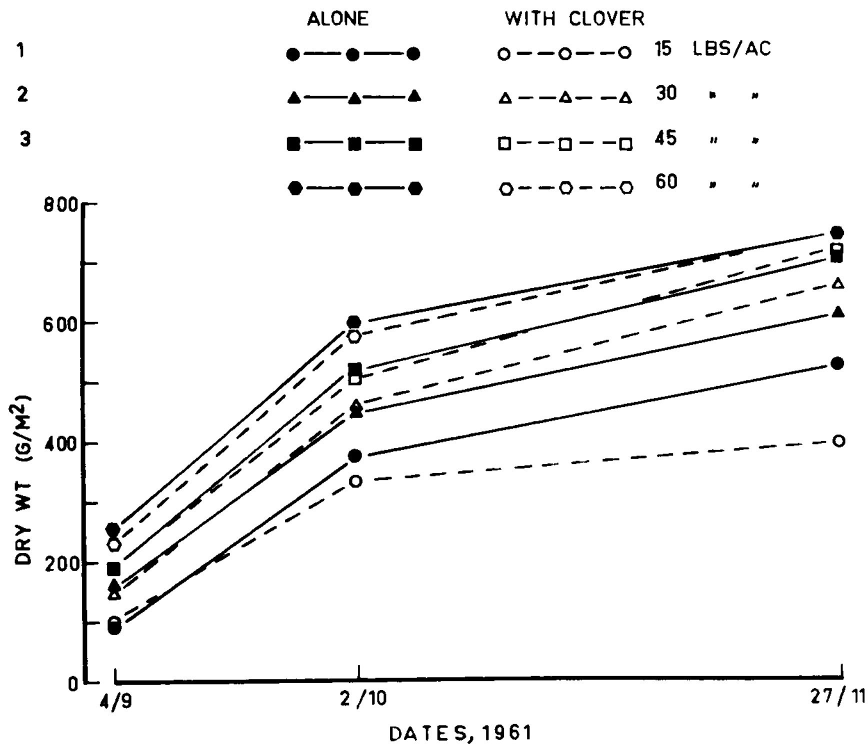
5.4.3. Mean weight per tiller

At the first harvest weight per tiller increased with rate of sowing but differences were not significant. At the subsequent harvests however, the weight per tiller decreased significantly ($P < 0.001$) with increase in rate of sowing. The presence of clover significantly increased the weight per tiller at the first harvest but was without effect at the second. At the third occasion, at the lowest rate of sowing, the mean weight in the presence of clover was significantly lower ($P < 0.005$) than in its absence.

Fig. 42. Dry matter and grain yield/m^2 of wheat, alone and when sown with clover.



ALONE
WITH CLOVER
HARVEST 1
" 2
" 3
GRAIN
800
600
400
200
0
DRY WT & GRAIN YIELD (G/M2)
15
30
45
60
RATE OF SOWING (LBS/AC)



ALONE
WITH CLOVER
15 LBS/AC
30 " "
45 " "
60 " "
800
600
400
200
0
DRY WT (G/M2)
4/9
2/10
27/11
DATES, 1961

5.4.4. Total L.

On the first occasion L increased with increase in rate of sowing while on the second occasion there was an overall reduction due to death of leaves, but the relationship between the rates was maintained (Table 29).

Table 29

Mean L at the two harvests

	R_1	R_2	R_3	R_4	L.S.D. 5%
H_1	0.646	1.188	1.400	2.034	0.203
H_2	0.483	0.720	0.896	0.964	0.156

5.4.5. Percentage dead leaves

The weight of dead leaves were calculated as % of the total of dead plus green leaves at the second harvest. A trend towards increasing mortality with increasing rate of sowing was evident (Table 30).

Table 30

Dead leaves as % of total leaf weight

R_1	R_2	R_3	R_4
17.2	17.1	19.1	27.1

5.4.6. Leaf area distribution

At the first harvest the percentage of the total leaf area found at the base of the crops decreased with increase in rate of sowing, and the leaf area was distributed over a greater height (Fig. 43). At the second, this was even more marked so that at the base there were no green leaves in R_3 and R_4 and very few in R_2. There was no difference in lateral distribution due to rate of sowing and on the average 70 and 67% of the total leaf area at the first and second harvests respectively were in the $3\frac{1}{2}$" along the row (P_0) with very little beyond $5\frac{1}{4}$" on either side of the rows.

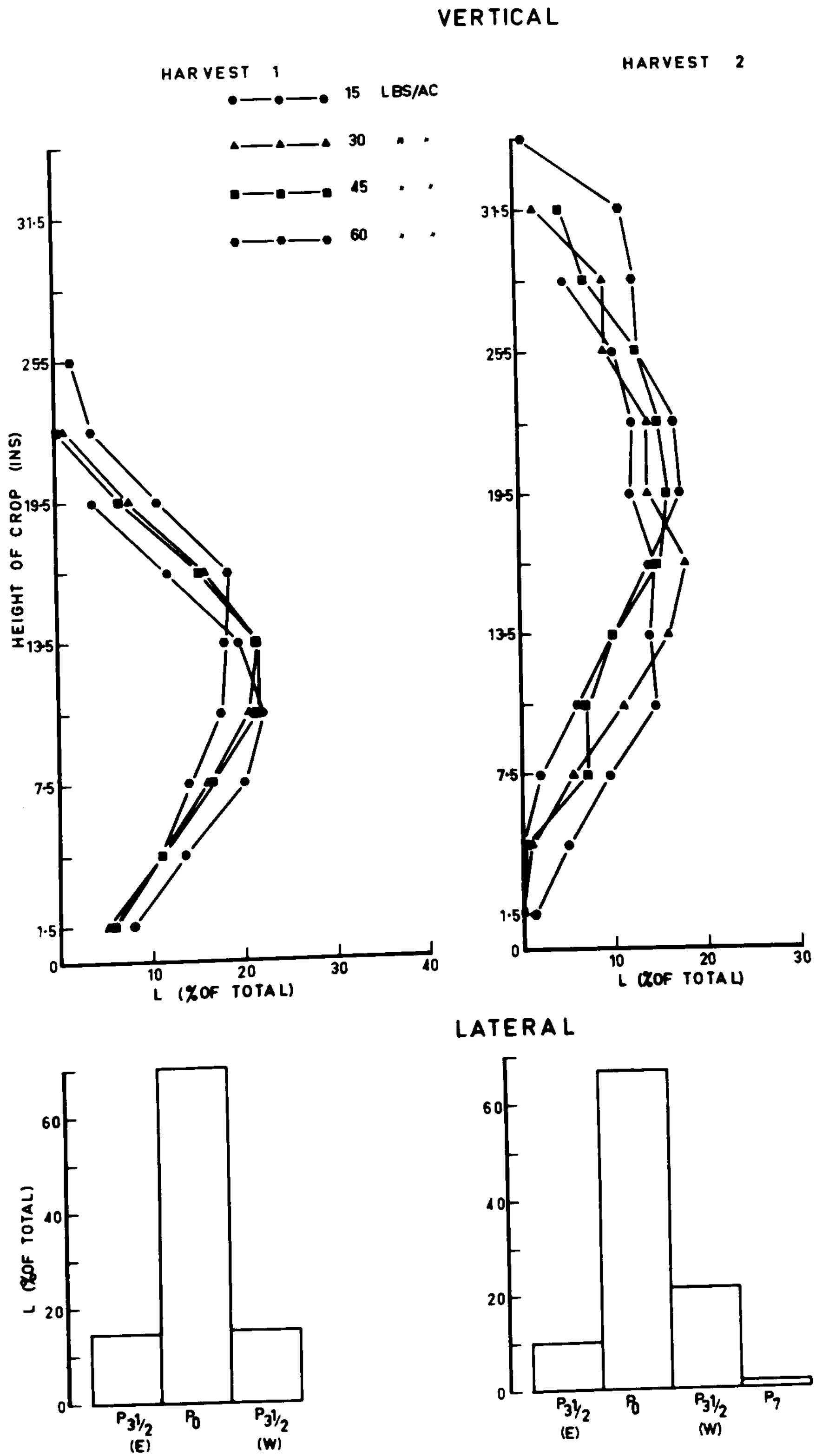
5.4.7. Dry matter and seed yields of clover

Clover was harvested for dry matter yield at the first two occasions and for seed yield at the third. On all occasions there was a big drop in yield from the control clover swards to those sown in the presence of wheat. (Fig. 44). Among the various rates of sowing of wheat there was an approximately linear relationship, with the dry matter and seed yield of clover decreasing with increasing rate of wheat.

5.4.8. Yield at the various positions

At the first harvest yield at P_0 was significantly less ($P < 0.01$) than at the other positions, among which there was no difference. On the second occasion, however, the yield at P_7 was

Fig. 43. Vertical and lateral distribution of leaf area at the first two harvests.



VERTICAL
HARVEST 1
HARVEST 2
15 LBS/AC
30 " "
45 " "
60 " "
HEIGHT OF CROP (INS)
31·5
25·5
19·5
13·5
7·5
1·5
0
10
20
30
40
L (%OF TOTAL)
LATERAL
L (%OF TOTAL)
0
20
40
60
P3½ (E)
P0
P3½ (W)
P7

significantly ($P < 0.001$) higher than at $P_{3\frac{1}{2}}$ and $P_{10\frac{1}{2}}$, between which there was no difference (Fig. 45). In each position the yield decreased with increase in the rate of sowing of wheat. In P_7 no difference was evident in the first three rates, but in the fourth rate the yield of clover was much less than in others. There was no difference between positions in seed yields.

5.4.9. Light intensity

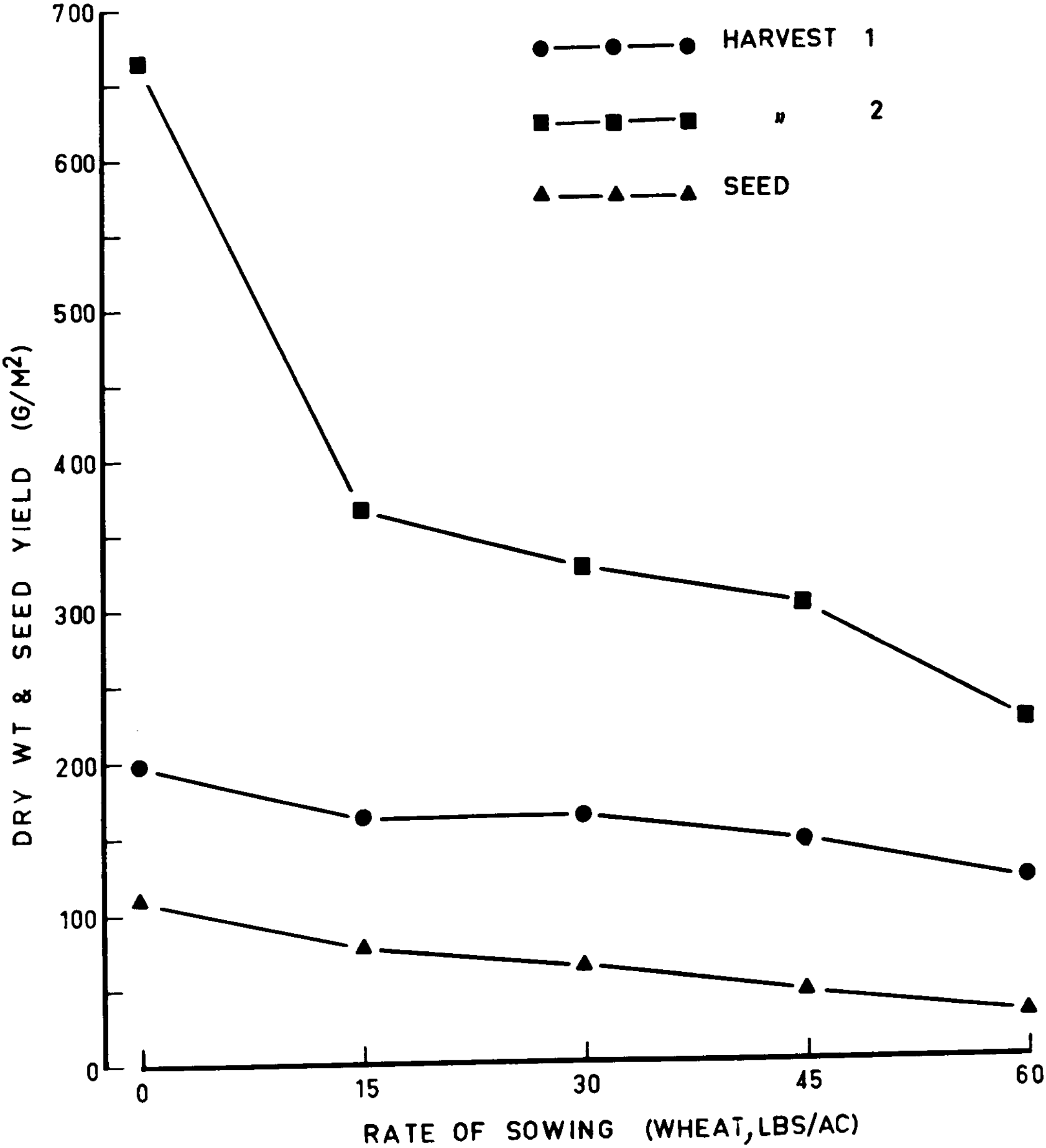
Fortnightly measurements were made at noon, and from the first to the second harvests hourly measurements at ground level were made from noon onwards.

5.4.10. % light at ground level

The amount of light reaching ground level decreased with increasing rate of sowing till the period of maximum interception. Thereafter on the ascending phase there was very little difference among the rates (Fig. 46). Similar trends were noticed at the various positions. At P_0 the light decreased very rapidly and remained at the low level. There was no difference in illumination between $P_{3\frac{1}{2}}$ and $P_{10\frac{1}{2}}$. At P_7 light was never below 75% daylight in any of the rates of sowing and for the most part was at or about 100%.

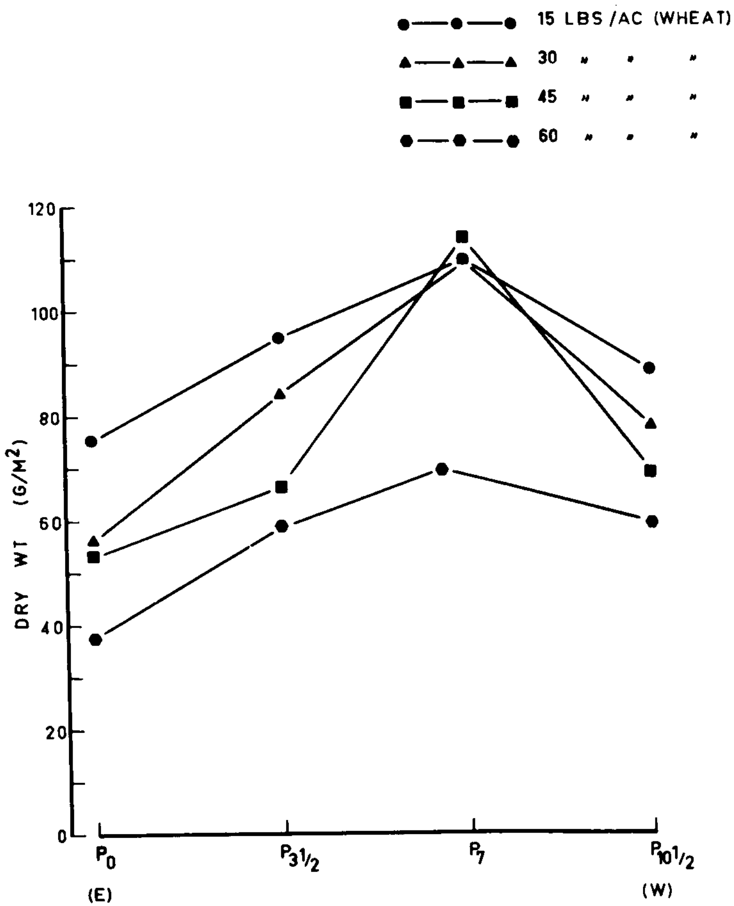
The measurements made at hourly intervals at ground level showed that the point of maximum illumination shifted towards East as the sun moved West. The percentage light received at the various positions with time is given in Fig. 47 for R_3 on four occasions. It will be noted that at each position there was a peak at some time of

Fig. 44. Mean dry matter and seed yield/m^2 of clover at the five densities of wheat. (In the absence of wheat and the 4 rates of sowing).

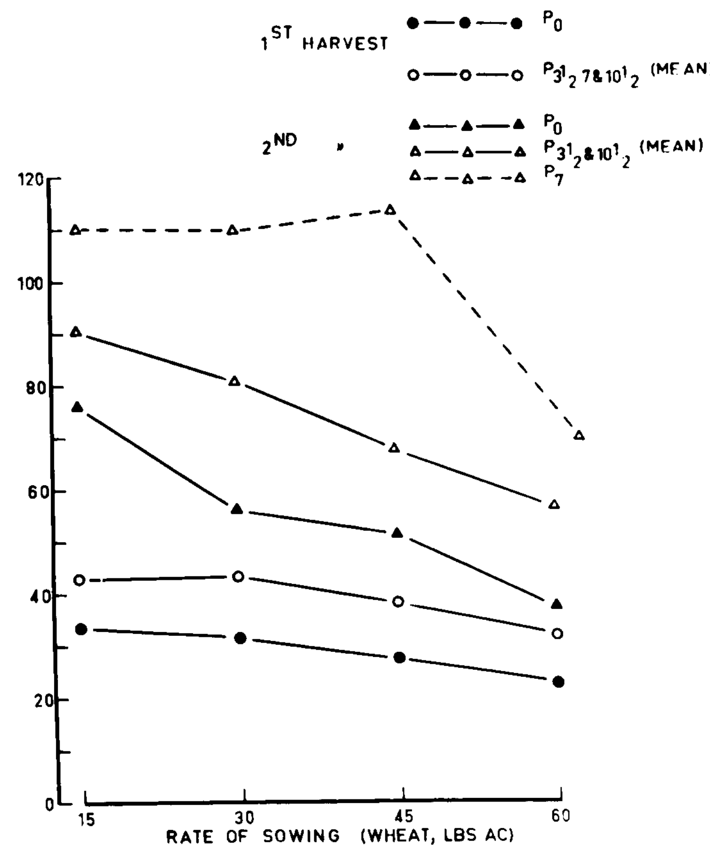


HARVEST 1
" 2
SEED
DRY WT & SEED YIELD (G/M2)
700
600
500
400
300
200
100
0
0
15
30
45
60
RATE OF SOWING (WHEAT, LBS/AC)

Fig. 45. Dry matter yield/m^2 of clover at the four positions at the first two harvests



15 LBS /AC (WHEAT)
30 " " "
45 " " "
60 " " "
DRY WT (G/M2)
120
100
80
60
40
20
0
P0
(E)
P3 1/2
P7
P10 1/2
(W)



1ST HARVEST
P0
P3 1/2 7 & 10 1/2 (MEAN)
2ND "
P0
P3 1/2 & 10 1/2 (MEAN)
P7
120
100
80
60
40
20
0
15
30
45
60
RATE OF SOWING (WHEAT, LBS AC)

Fig. 46 (a) Percentage daylight at ground level at solar noon in the four rates of sowing (mean of all positions)

(b) Percentage daylight at ground level at solar noon at the various positions (mean of the 4 rates of sowing).

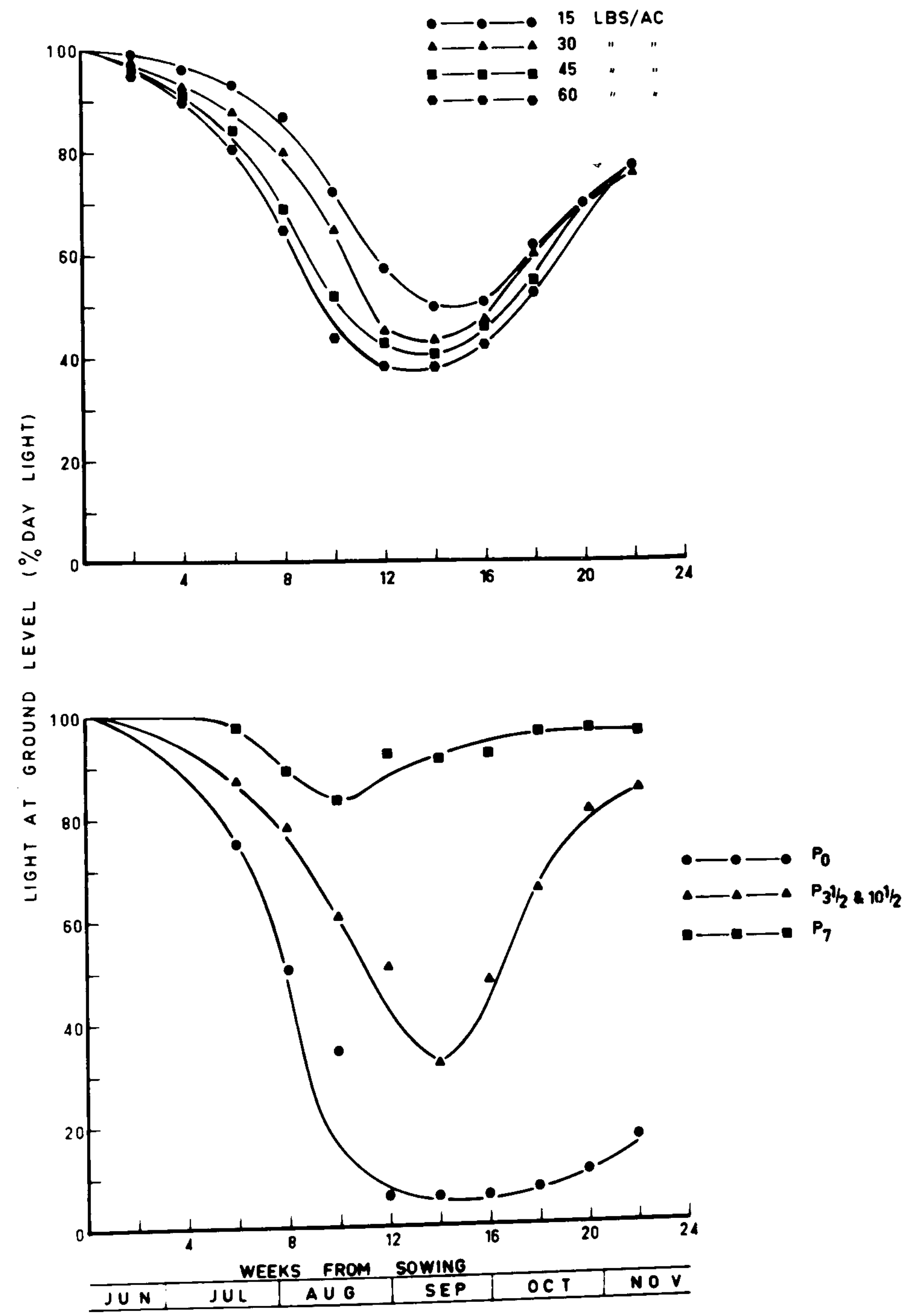
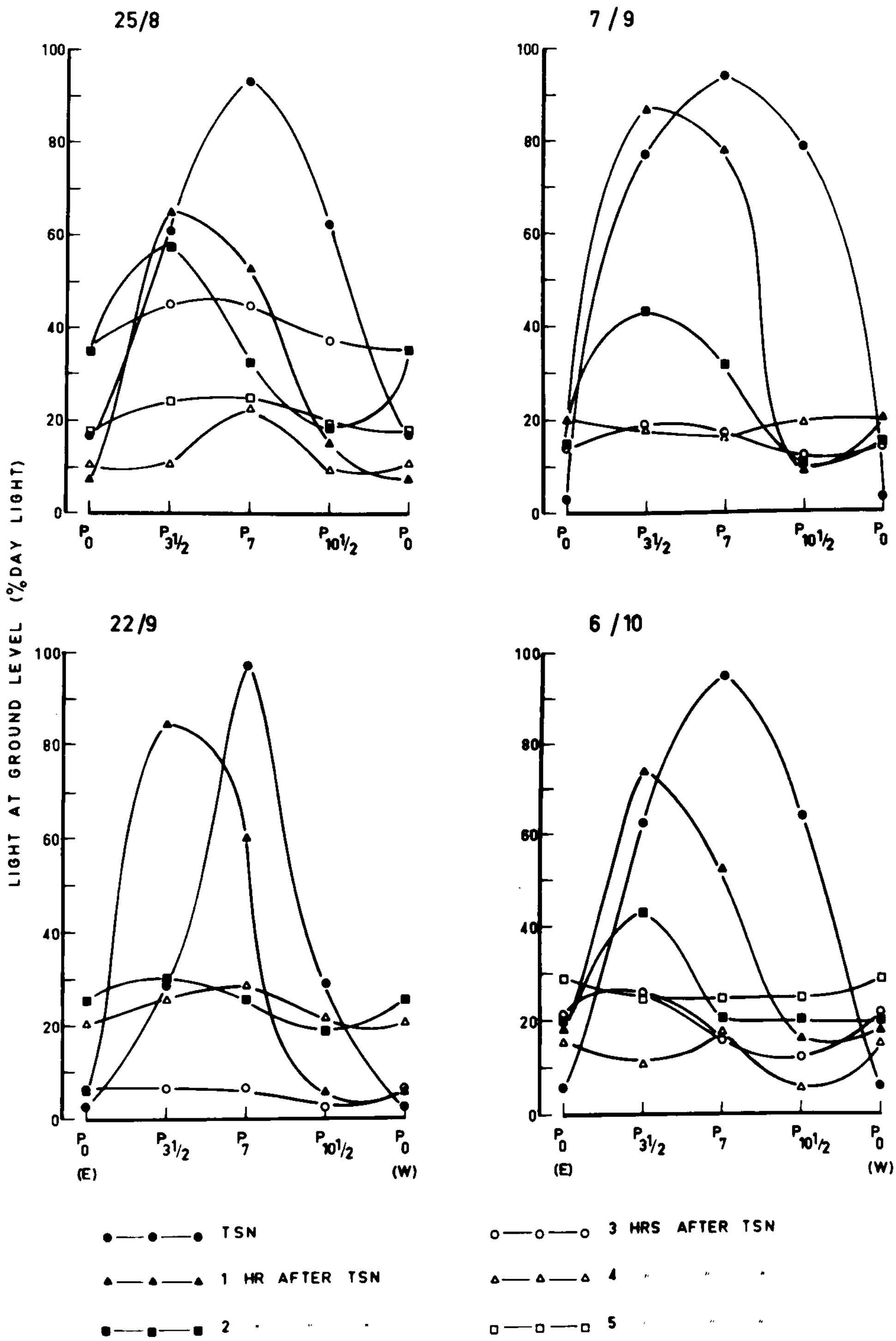

15 LBS/AC
30 " "
45 " "
60 " "
LIGHT AT GROUND LEVEL (% DAY LIGHT)
P0
P3½ & 10½
P7
WEEKS FROM SOWING
JUN
JUL
AUG
SEP
OCT
NOV

Fig. 47. Percentage daylight at ground level between rows at hourly intervals from solar noon on four dates in wheat sown at 45 lb/acre.

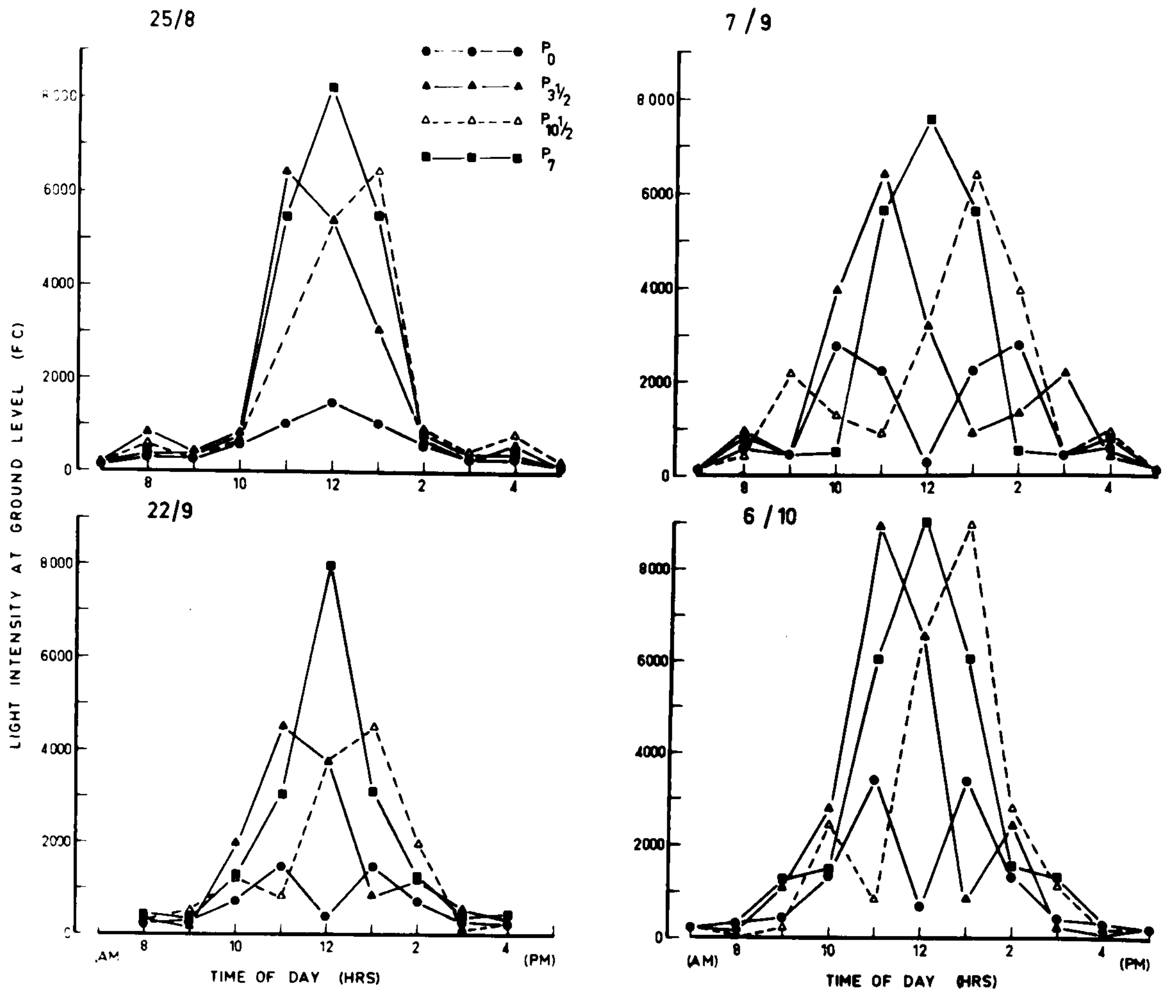

25/8
7 / 9
22/9
6 / 10
LIGHT AT GROUND LEVEL (% DAY LIGHT)
0
20
40
60
80
100
P0
P3½
P7
P10½
P0
(E)
(W)
TSN
1 HR AFTER TSN
2 " " "
3 HRS AFTER TSN
4 " " "
5 " " "

the day; P_7 at noon $P_{3\frac{1}{2}}$ at some time after noon, and P_0 still later. $P_{10\frac{1}{2}}$ would have reached its peak at a time before noon as did $P_{3\frac{1}{2}}$ after noon. The time at which $P_{3\frac{1}{2}}$ and $P_{10\frac{1}{2}}$ reach their peaks would depend on the height of the crop and the azimuth and altitude of the sun. It would be reasonable to assume that in the absence of differential cloudiness $P_{3\frac{1}{2}}$ and $P_{10\frac{1}{2}}$ in the morning would follow the mirror image of $P_{10\frac{1}{2}}$ and $P_{3\frac{1}{2}}$ respectively in the afternoon, while P_7 and P_0 would be the mirror image of themselves.

5.4.11. Interim discussion

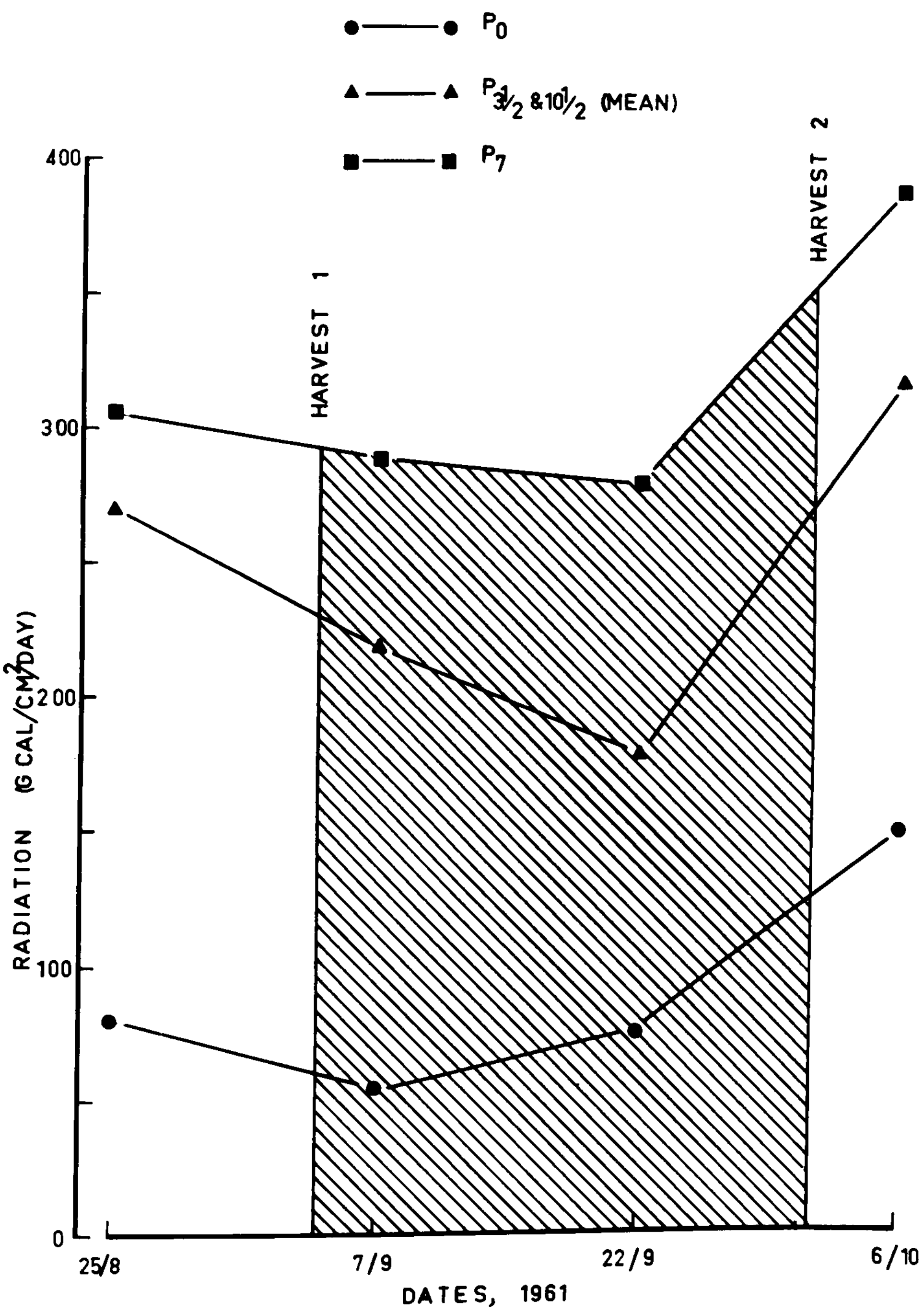
Accepting the reversal pattern for the various positions, the light recorded in foot candles at the different positions was plotted against time of day from 7 a.m. to 5 p.m. Though it would be true that the light intensity would be different in the early morning and late afternoon hours due to atmospheric conditions it was considered that the difference would not make the assumption totally untenable as the intensities recorded at the various positions including those above the crops were very low in the early morning and late afternoon when compared to the rest of the day (Fig. 48). From these curves the total illumination for the day as foot-candle-hours was obtained. This quantity was converted to kilo lux-hours and from that to G Cals. cm^{-2}. Day^{-1} using the formula x = 1.404, y - 15.2 of Black (1960). These radiation values were then plotted against time (Fig. 49) and from them the total radiation received at the various positions between the first and second harvests were calculated.

Fig. 48. Light intensity at ground level at the various positions from 7 a.m. to 5 p.m. on four dates in 30 lbs/acre wheat.



25/8
7 / 9
22/9
6 / 10
P0
P3½
P10½
P7
LIGHT INTENSITY AT GROUND LEVEL (FC)
8000
6000
4000
2000
0
8
10
12
2
4
(AM)
(PM)
TIME OF DAY (HRS)

Fig. 49. Estimated solar radiation at ground level at the various positions in 30 lbs/acre wheat from 25/8 - 6/10.



P0
P3½ & 10½ (MEAN)
P7
HARVEST 1
HARVEST 2
400
300
200
100
0
RADIATION (G CAL/CM²/DAY)
25/8
7/9
22/9
6/10
DATES, 1961

The total radiation received at ground level at the various positions for the four rates of wheat sown and the increase in dry matter of clover between the two harvests are shown in Fig. 50. In the computation of both radiation and clover yields the values for $P_{3\frac{1}{2}}$ and $P_{10\frac{1}{2}}$ were pooled as they were not significantly different.

The dry matter increase per day between the two harvests for all plots and positions is shown against radiation received in Fig. 51. The linear relationship would suggest that the growth of clover was dependent on the amount of radiation available. This would then suggest that there was no competition for other factors such as soil moisture and nutrients. The yield of clover in the control treatment was however 16.60 gms. m^{-2}. day^{-1} between the two harvests and the mean radiation recorded on a Kipp solarimeter at the Waite Institute was 456 g.cals cm^{-2} day^{-1}. While the radiation dropped from 456 to 336 g. cals. cm^{-2} day^{-1} from the control plot to P_7 in R_1 the yield of clover dropped from 16.60 to 2.63 gm. m^{-2} day^{-1}. Closer examination of Fig. 51 would show that the efficiency of utilization of radiation decreased with increase in the distance of the clover from the base of the wheat plants. This may be due to greater competition for soil factors at some distance away from the wheat plants than directly beneath them; probably due to the concentration of the absorbtive regions of the roots of wheat being higher at some distance away from the base of the plants.

The computed radiation values did not take into account

Fig. 50. Estimated total radiation received at ground level and dry matter increase of clover between harvest 1 and 2 in the various positions of the 4 rates of sowing of wheat.

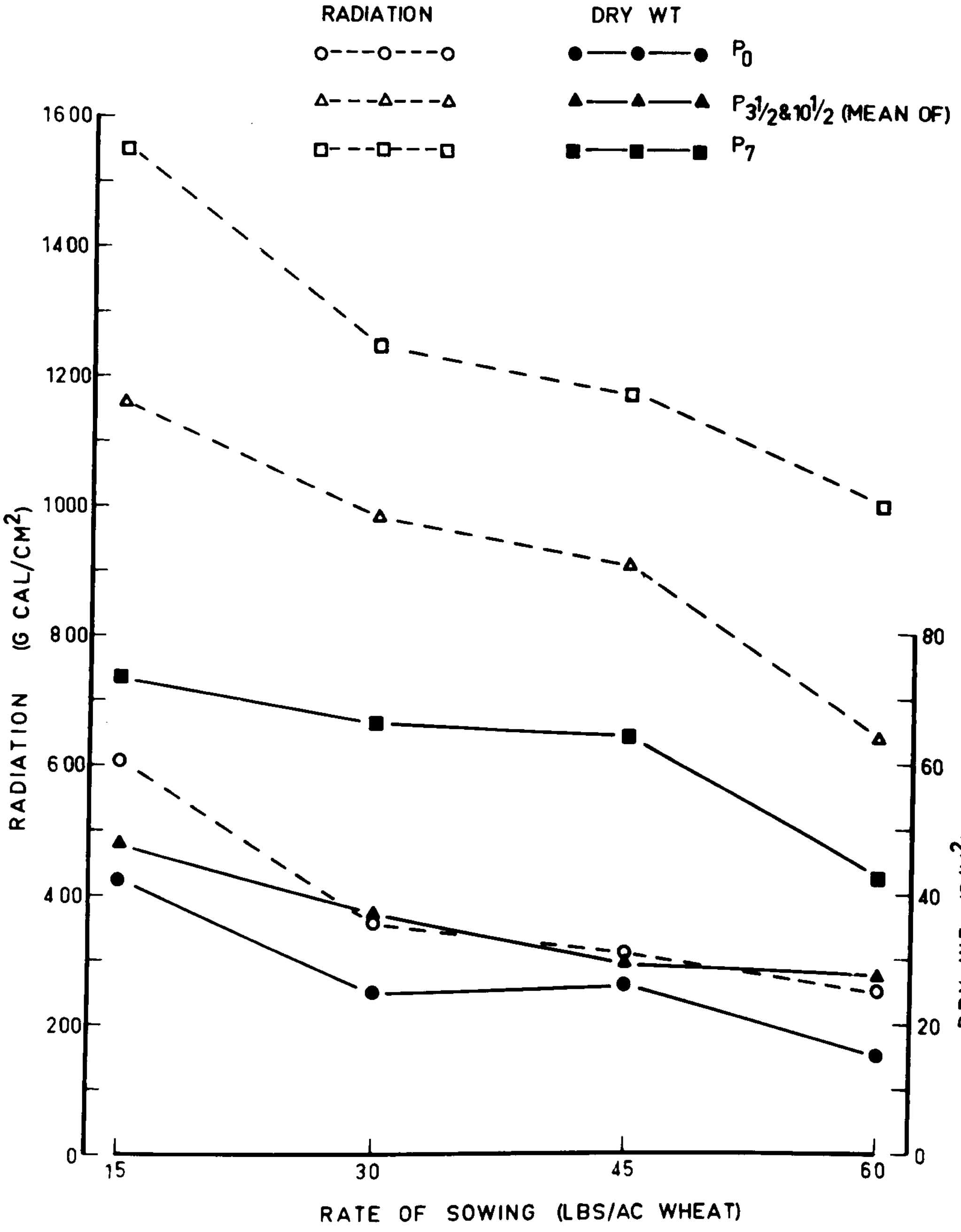
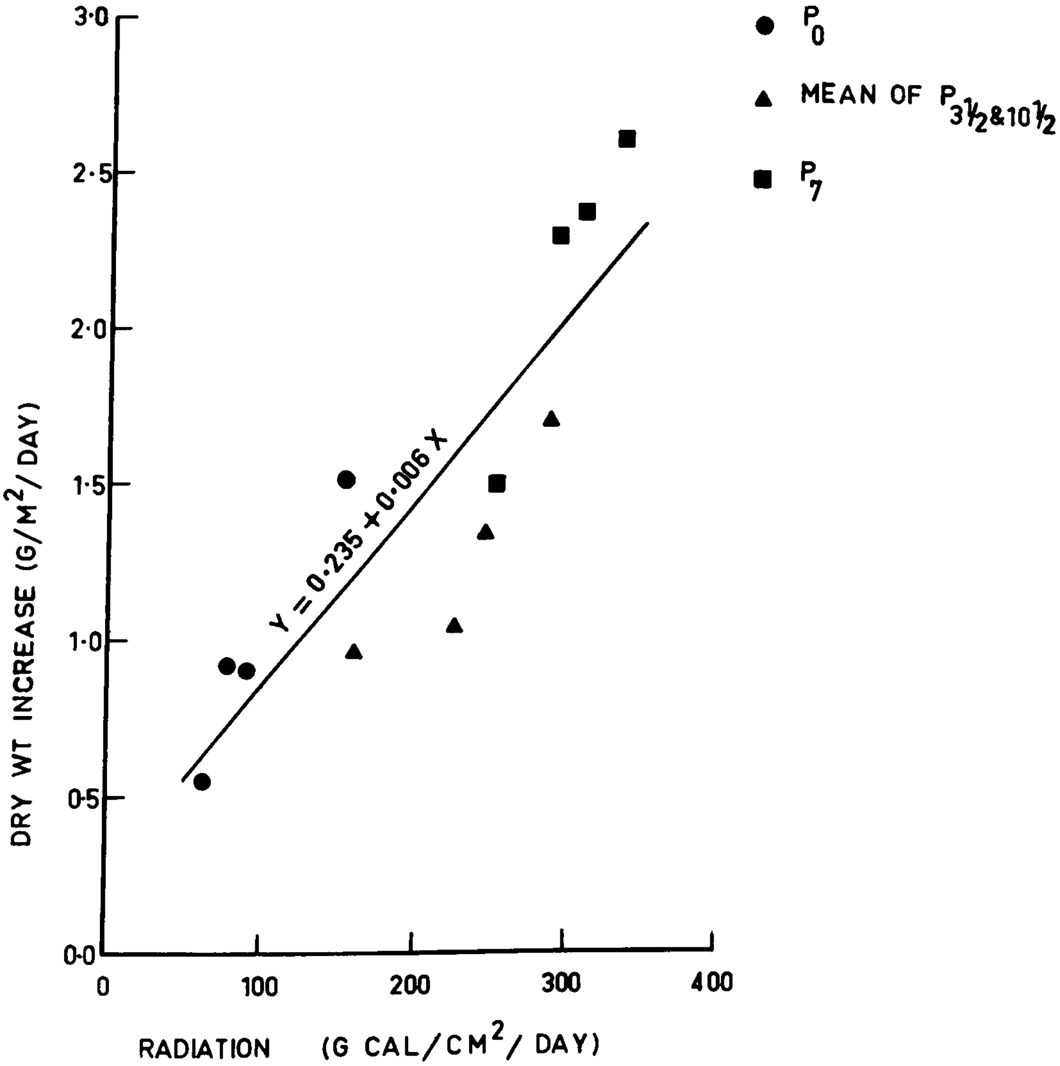

RADIATION
DRY WT
P0
P3½&10½ (MEAN OF)
P7
RADIATION (G CAL/CM2)
1600
1400
1200
1000
800
600
400
200
0
DRY WT (G/M2)
80
60
40
20
0
15
30
45
60
RATE OF SOWING (LBS/AC WHEAT)

Fig. 51. Dry wt. increase of clover and radiation received between harvest 1 and 2.



P0
MEAN OF P3½&10½
P7
Y = 0·235 + 0·006 X
DRY WT INCREASE (G/M2/ DAY)
3·0
2·5
2·0
1·5
1·0
0·5
0·0
0
100
200
300
400
RADIATION (G CAL/CM2/ DAY)

cloudiness. All the days on which hourly measurements were made happened to be cloud free and the computation would be somewhat exaggerated. Even allowing for this fact the growth of clover would be far below that recorded for the control plots.

6.0.0. General discussion and conclusions

In all experiments the growth and yield of undersown pasture was significantly reduced by the wheat. This was no doubt due to the competitive advantage of the wheat over the pasture plants. As pointed out by Rademacher (1940), wheat is at an advantage by its greater stature, enabling it to exploit deeper layers of the soil for moisture and nutrients and to shade the pasture above the ground. In the 1961 experiments Block differences were significant. The field received uniform treatment for at least six years prior to the planting of the experiments and no explanation can be offered for these block differences.

6.1.0. Competition for nutrients

The extent of competition for nutrients in these experiments was not assessed. It may be assumed that this would not be a serious factor in the experiments carried out in 1961, as the only pasture species studied was clover which presumably would be independant for its nitrogen requirements. Superphosphate was applied at 1 cwt./acre at time of planting and other nutrients were expected to be in sufficient supply in the soil. Certainly no symptoms of nutrient deficiency were observed. In the 1960 Experiment, where Wimmera rye grass was a component of the pasture, the soil contained 30 p.p.m. nitrate nitrogen at the time of sowing, which amount was considered sufficient for satisfactory growth in all treatments. No symptoms of nitrogen deficiency were observed during the growth of the crops. In the following year, however, all treatments showed symptoms of nitrogen deficiency in the early stages and each plot was therefore divided into halves, one of which received urea at 1 cwt./acre. At the subsequent harvests there was no interaction between treatments and nitrogen, indicating that in the previous year all treatments exhausted the soil nitrogen to the same extent. Under the circumstances it would be possible that there may have been a shortage of nitrogen in the first year; the wheat may have been able to obtain its requirements from the deeper layers of the soil by virtue of its deeper root system while the grass was limited in its growth due to insufficient nitrogen. This however could not be ascertained without analysis of the plant material and soil at periodic intervals during growth. On the other hand the low nitrogen level in the soil at the beginning of the 1961 season may have been due to leaching caused by the heavy rainfall recorded at that time.

6.2.0. Competition for soil moisture

Soil moisture measurements made in 1960 showed no significant differences between treatments, suggesting that there was no competition for this factor. Soil moisture was at or near field capacity throughout the major portion of the season and when the soil commenced to dry out, the pasture species at least were nearing maturity. The effect of the wheat on the yield of pasture had been noticed at the first harvest, and soil moisture could hardly be held limiting up to that time. In 1961, which was a relatively dry year, the clover sown with the wheat in the non irrigated experiments died following the third harvest and at the fourth, dry matter being reduced below that recorded in the previous harvest. In contrast, in the control clover treatments there was an increase in the dry weight. This death of clover in the presence of wheat was mainly due to soil moisture stress, as could easily be seen on casual observation. The soil under the control clover sward was wet while under wheat it was dry and cracks appeared on the surface.

The influence of soil moisture stress in reducing the growth of undersown clover was greater than that of the shade cast by the wheat as was shown in the "yield - radiation" relationship between control and undersown clover swards. The literature review particularly stressed the failure of undersown pasture in areas susceptible to drought, but few studies had been carried outin a Mediterranean type environment, where the soil moisture is usually sufficient during the major part of the growing season. It is therefore particularly interesting to obtain data on the behaviour of undersown clover pastures as the soil dry out with the onset of the summer. It is clear that in a dry year, when the soil dries out early, the shortage of soil moisture can have a catastrophic effect on clover growth and, presumably, seed set, on which growth in the following year depends. In a wet year, moisture would be sufficient for both crops.

6.3.0. Availability of light

Light, unlike the soil factors, is instaneous and has to be intercepted by the plants and utilised instantly (Donald 1961). The light available at any time has both a direct and a diffuse component. On a clear day the amount of diffuse light is small, but within that day the amount would be high around sun rise and sun set, decreasing to a minimum at noon. With increase in cloudiness the total intensity and direct light would decrease and the amount of diffuse light would increase.

In a crop of cereals with definite rows of plants with restricted tillering and erect habit the distribution of plant material would be uneven and hence light penetration would be different at different positions. The difference would depend on the spacing and height of the crop, the altitude and azimuth of the sun and the atmospheric conditions (cloudiness).

Considering first a wheat crop at 7" spacing with the sun at 90° altitude and 0° azimuth : on a clear day, the shadow cast would be directly beneath the rows and the intensity of light "beneath" and "between" rows would vary with the distribution of plant material in the two positions. Under these conditions there would be no difference between N-S and E-W rows. The difference between the amounts of light received beneath and between rows would increase with increase in the row space as long as the plants do not spread and cover the inter rwo space. A solar altitude of 90°

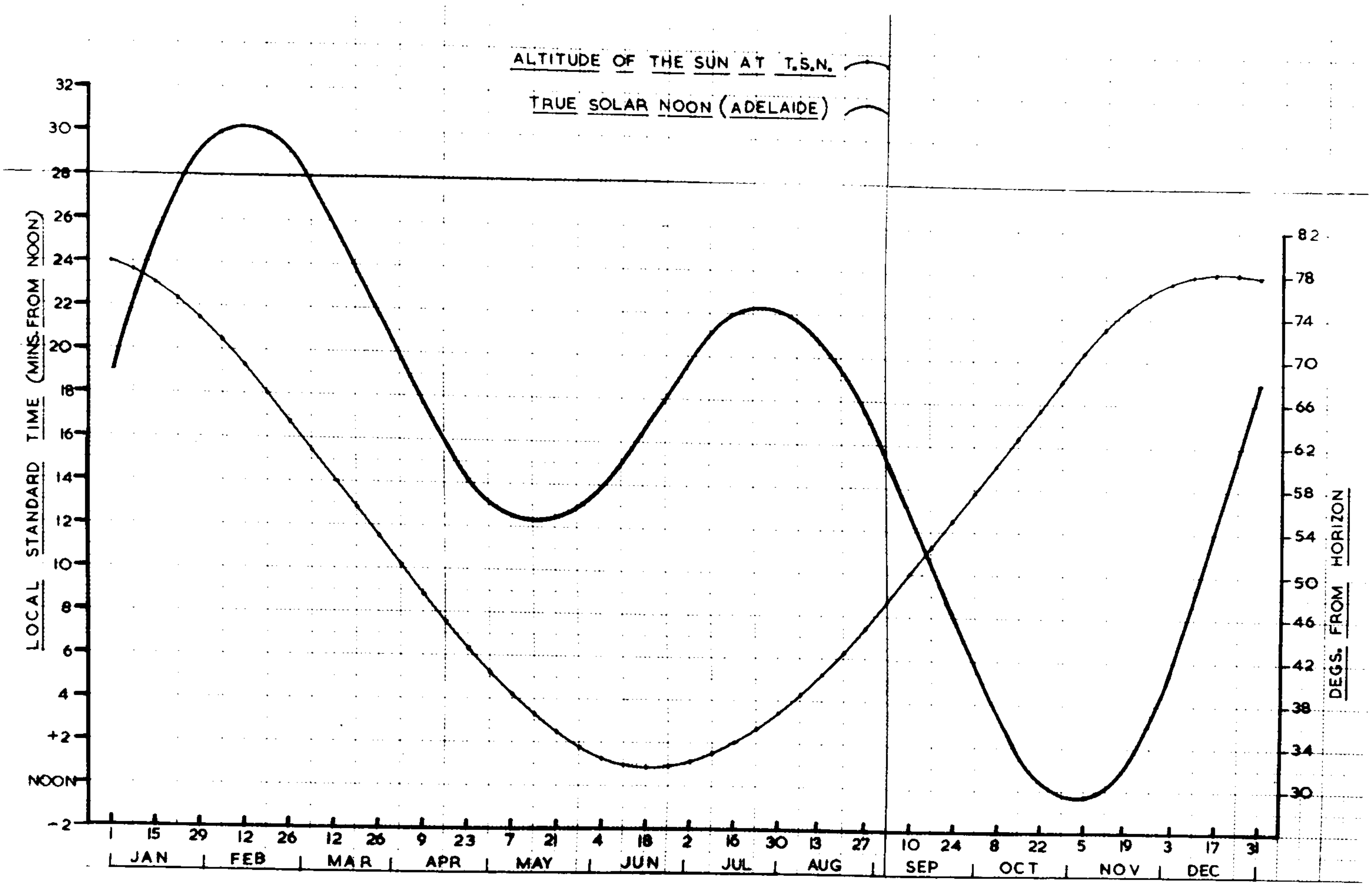
would be attained only within the tropics at noon at a particular time of the year. Outside the tropics, an altitude of 90° would not be achieved and towards the poles the maximum solar altitude decreases, resulting in the sun being on the South in the northern hemisphere and on the North in the southern hemisphere. In Adelaide (lat. 34.5°S) the maximum solar altitude is 78.5° at the summer solstice (December 21 approx.) at noon. Such a solar angle will always cast a shadow to the south of an object. In an individual row of a crop running E-W the shadow would be on the southern side of the row, and there could be direct illumination on the northern side; in the case of a row running N-S, the shadow would be directly beneath it - as would be the case when the solar altitude is 90°. The solar altitude in Adelaide increases from 32.5° at the winter solstice (June 21 approx.) to 78.5° at the summer solstice, and then follows the reverse pattern (Fig. 52). The shadow cast by a crop of unit height would vary with the altitude of the sun according to the equation;

$$\text{shadow length} = \frac{1}{\tan_{\theta}}$$

where θ = the altitude of the sun.

In Adelaide wheat is sown in May - June and harvested in December - January. For the present purpose the period between the two solstices may be considered as the growing period of the crops in Adelaide. With the increase in the altitude of the sun through this season, the length of the shadow cast would decrease; but at the same time the crop would increase in height. A diagram of the

Fig. 52. Altitude of the sun at True Solar Noon and derivation of True Solar noon from Local Noon (12 Noon Local Standard Time) in Adelaide.

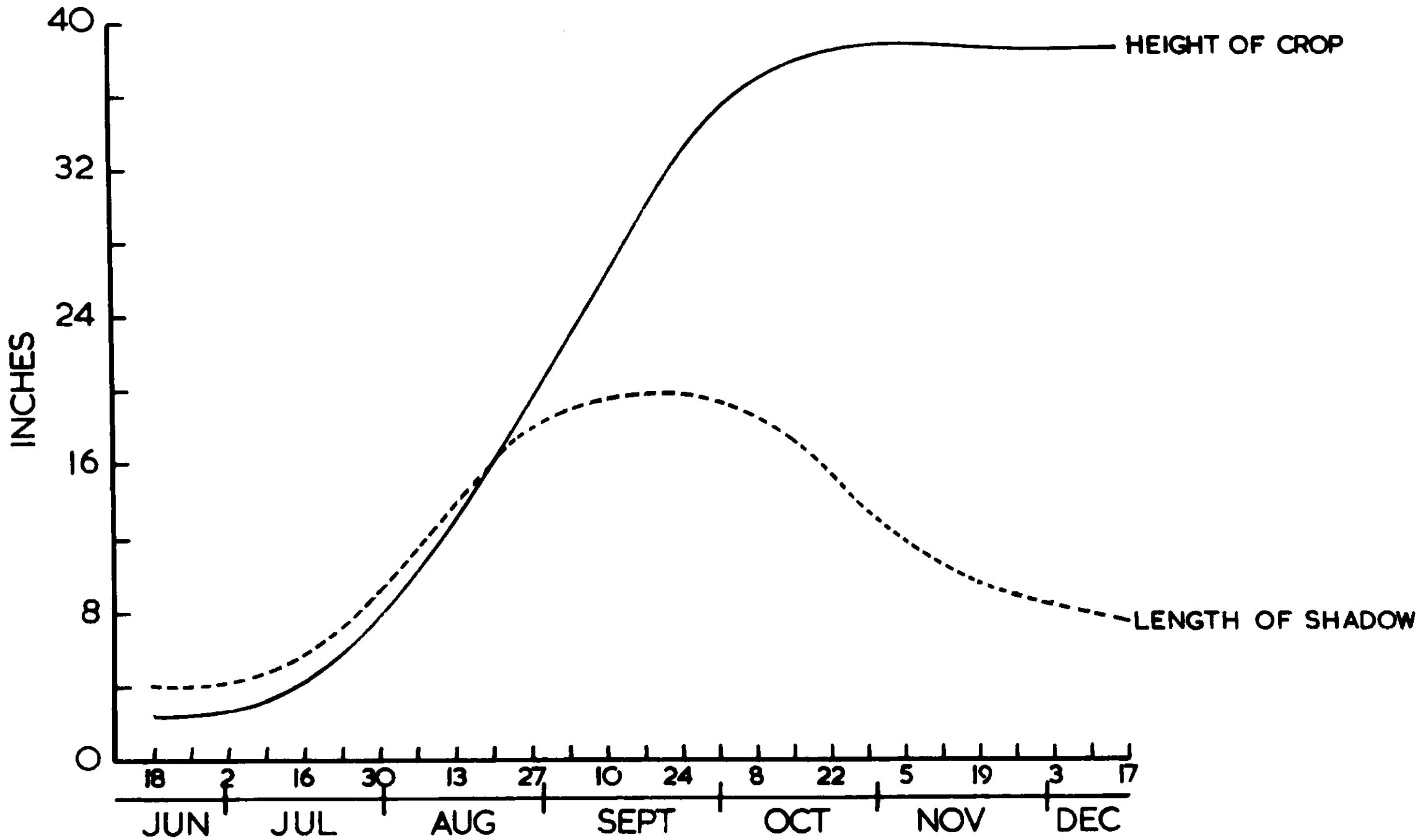

ALTITUDE OF THE SUN AT T.S.N.
TRUE SOLAR NOON (ADELAIDE)
LOCAL STANDARD TIME (MINS. FROM NOON)
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
+2
NOON
-2
DEGS. FROM HORIZON
82
78
74
70
66
62
58
54
50
46
42
38
34
30
1 15 29 12 26 12 26 9 23 7 21 4 18 2 16 30 13 27 10 24 8 22 5 19 3 17 31
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

length of shadow cast by a crop of wheat at solar noon reaching a height of 40 inches is shown in Fig. 53.

At times other than noon the solar altitude would vary between 0^{o} and the maximum for the day and this again would change the length of the shadow. The azimuth will also change. This change of azimuth would alter the direction in which the shadow is cast and would be of significance in N-S rows, where the shadow would move from beneath the rows into the inter-space. The extent to which the shadow of a N-S row would extend into the interspace depends on the azimuth and the altitude of the sun and the height of the crop. The "day light" azimuth of the sun increases from the winter to the summer solstice, resulting in the sun rising more and more in the East and therefore setting more and more in the West. The azimuth traversed by the sun during this period for Adelaide is shown at monthly intervals in Fig. 54. When the sun rises due East and therefore sets due West the shadow cast by an E-W row at those times would be similar to that cast by a N-S row at noon.

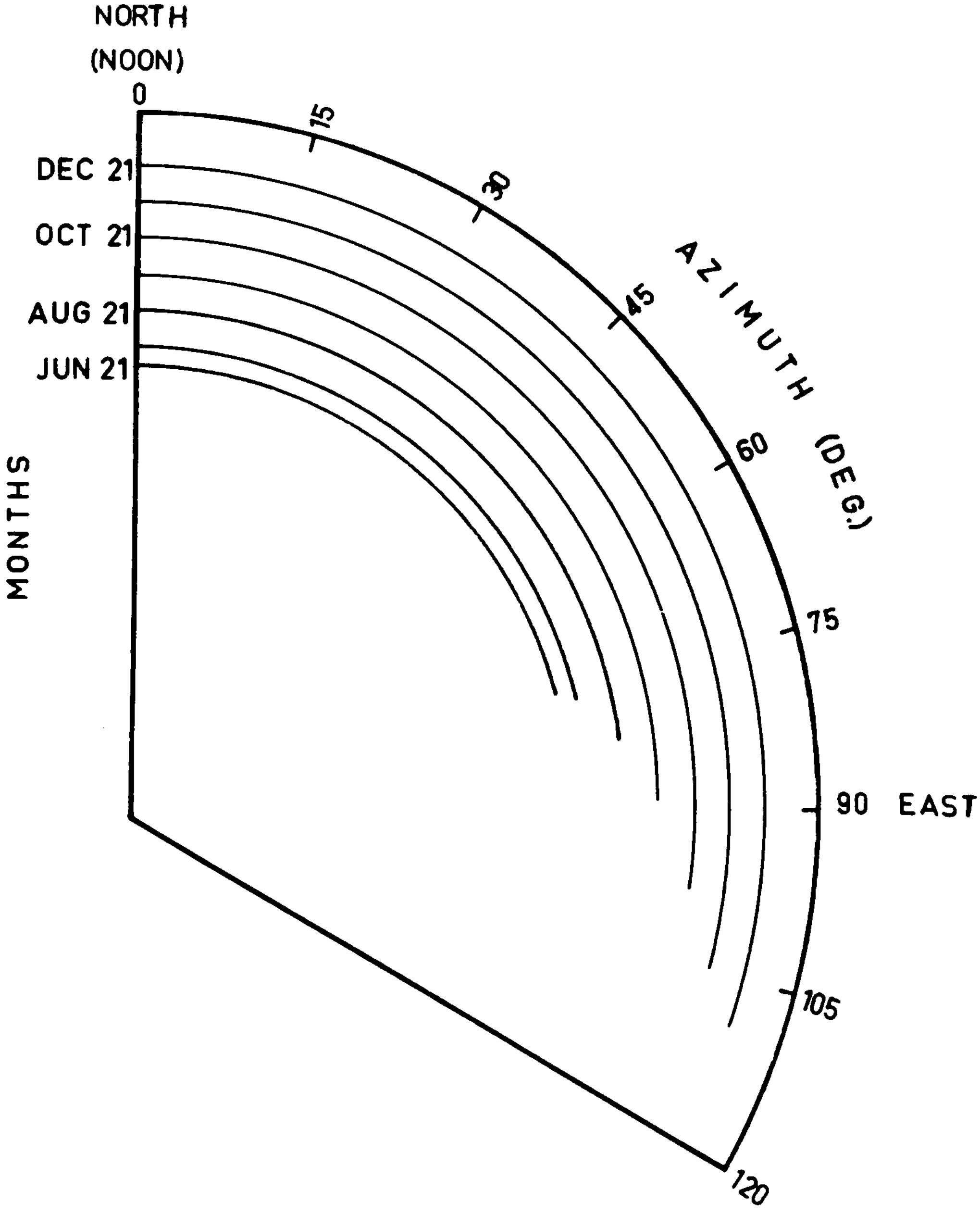
When rows are parallel to each other as in crops the illumination at noon in the interspace would depend on the height of the crop and direction and spacing of the rows. If the spacing is greater than the length of the shadow, then the northern side of an E-W row will receive full sun light; but with a decrease in the distance between rows the ground would be completely shaded when the row distance is equal to the length of the shadow. Further decrease in the row space would gradually decrease the depth to which the

Fig. 53. Height of crop and length of shadow at True Solar Noon throughout the growing season in Adelaide.



40
32
24
16
8
0
INCHES
HEIGHT OF CROP
LENGTH OF SHADOW
18
2
16
30
13
27
10
24
8
22
5
19
3
17
JUN
JUL
AUG
SEPT
OCT
NOV
DEC

Fig. 54. "Day light" azimuth from sun rise to True Solar Noon from the winter solstice to summer solstice in Adelaide.


NORTH
(NOON)
0
15
30
45
60
75
90 EAST
105
120
AZIMUTH (DEG.)
DEC 21
OCT 21
AUG 21
JUN 21
MONTHS

northern side of the rows would receive full illumination and finally a stage would be reached where only the top layers of the crop would receive full light.

Before and after noon the altitude of the sun would be less than at noon and this would increase the length of the shadow. Minimum shadow would thus be cast at noon, and on either side of noon the decrease in solar altitude would be tantamount to decreasing the space between rows. In rows running N-S the shadow at noon would be directly beneath the rows and if the rows were wider than the lateral spread of the plants then that portion of the interspace into which the crop has not spread would receive full illumination, but as the row space decreases and the spread from adjacent rows overlap the interspace would also be shaded. Where the row spacing is such that at noon the central region of the interspace receives full illumination, with change in azimuth the shadow would traverse into the interspace and approach the same pattern as in E-W rows. The extent to which a crop with N-S rows approaches a crop with E-W rows would depend on the spacing between rows and the height of the crop.

It is therefore clear that the maximum difference between N-S and E-W row directions would be at noon and for some period before and after noon, the extent of which would depend on the height and spacing of the crops. For a given spacing and height of crop the difference between N-S and E-W row direction, would increase with a decrease in the altitude of the sun around noon; that is, the difference would be greater at higher latitudes. Conversely at a given latitude the difference between N-S and E-W row would be greater, the narrower the space between rows. There is however a limit to which the space between rows could be reduced, beyond which overlapping of leaves would form a canopy resulting in the elimination of the row effect.

With a decrease in the inter row space the difference between N-S and E-W rows would increase but simultaneously the time during which the difference is maintained would decrease. As far as growth and yield of the undersown pasture and the cover crop are concerned, the time factor may be too small to cause any measurable difference. Therefore below a certain row spacing, even though the difference in the available light around noon between N-S and E-W rows would be relatively high, the difference in the total quantity of light energy received would be reduced. The optimum row distance would depend on the height and spread of the crops at a given latitude.

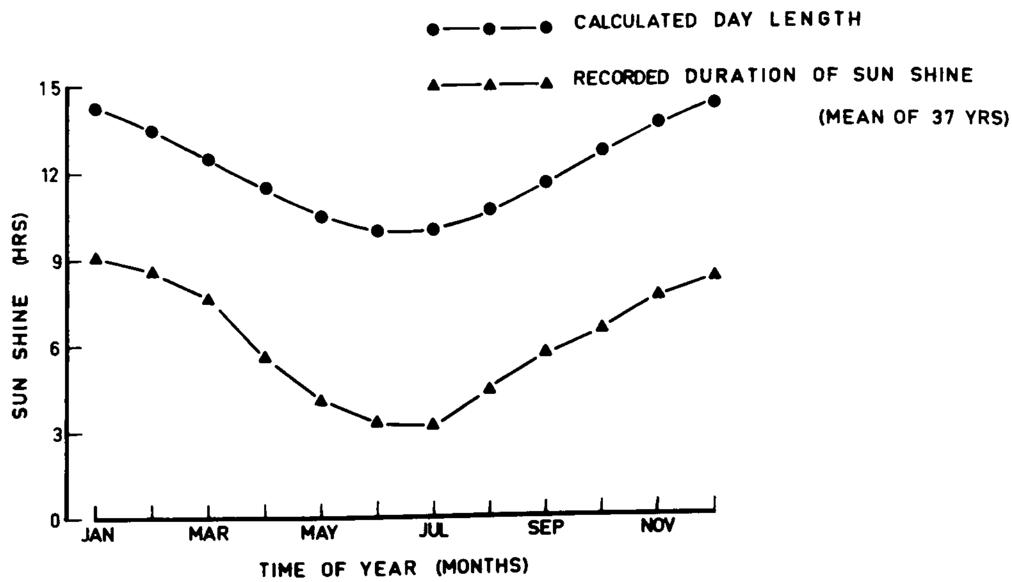
The above discussion was restricted to the study of illumination on clear days. Under cloudy conditions, where direct illumination is eliminated and the total illumination is diffuse light only, there would be no directional effect : the difference between N-S and E-W rows would then depend on the amount of direct light received around noon. In Adelaide the day length increases from a minimum at the winter solstice to a maximum at the summer solstice (Fig. 55) but due to cloudiness the actual duration of direct sunlight would be much less than the calculated values. Since the period around

(a)

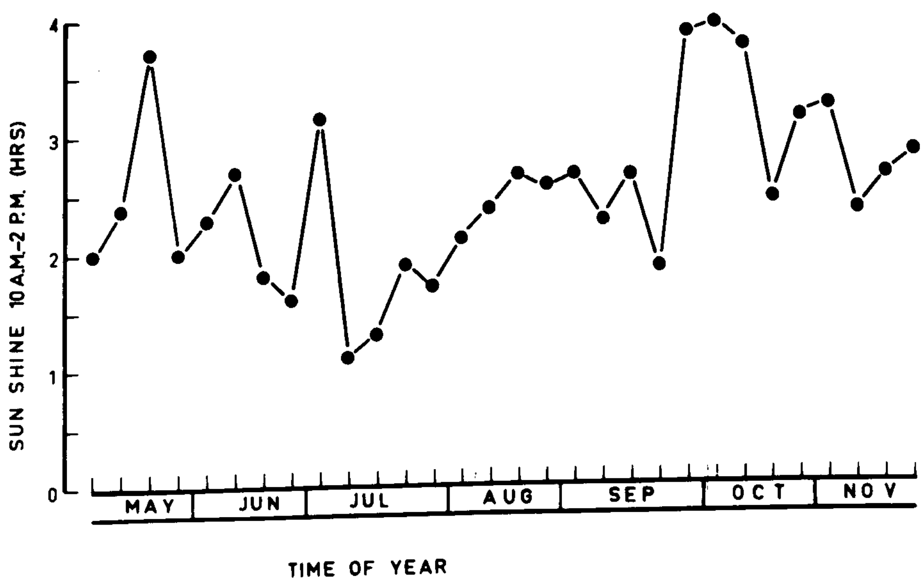
Fig. 55. Day length and recorded duration of sunshine in Adelaide (Waite Institute data).

(b)

Hours of direct sunshine between 10 a.m. and 2 p.m. from May to November 1961 in Adelaide (Waite Institute data)



CALCULATED DAY LENGTH
RECORDED DURATION OF SUN SHINE
(MEAN OF 37 YRS)
15
12
9
6
3
0
SUN SHINE (HRS)
JAN
MAR
MAY
JUL
SEP
NOV
TIME OF YEAR (MONTHS)



4
3
2
1
0
SUN SHINE 10 A.M.-2 P.M. (HRS)
MAY
JUN
JUL
AUG
SEP
OCT
NOV
TIME OF YEAR

noon is the most effective in row direction the hours of bright sunshine between 10 a.m. and 2 p.m. read off the cards of a Campbell-Stokes recorder are also presented at weekly intervals for May to November 1961 in Fig. 55. During July to September direct sunlight was received only for about 2.25 hours of the possible 4.00 hours per day between 10 a.m. and 2 p.m. This reduction in the available direct sunlight would result in a decreased effect of row direction.

The percentage daylight at ground level recorded at noon in the various treatments of wheat showed a steady decline with time, reaching a minimum value coinciding with heading. Thereafter it gradually increased with the death of the leaves. Black (1952) in England, Stahler (1954) and Klebesadle and Smith (1959) in U.S.A. observed a rather considerable period during which the low light value remained constant. In the present experiments such a period was evident only in the noon measurements of E-W rows of wheat planted early (Experiment 2A).

The amount of shade cast and the length of time over which it is maintained would depend on the amount of plant material available for light interception. The authors quoted above worked in climatic conditions which would permit longer period of vegetative growth, and it is also probable that the rate of sowing of the crops studied by them there would have had more plant material.

When soil moisture was limiting, the undersown pasture died;

when the moisture stress was less severe, yield was related to the amount of radiation received. Even here the yield of pasture was reduced to a very great extent due to competition for soil factors (presumably soil moisture) and at that reduced level of growth the yield was linearly related to the radiation received (Fig. 51).

The radiation received between 10 a.m. and 2 p.m. accounted for a very high proportion of the total, and the growth of the clover at the various positions between the rows of wheat in both N-S and E-W rows bore a very close relationship to the % light received directly above them at noon. In other words, yield of clover increased with increase in the light received. In this respect these results are directly opposite to those of Larson and Willis (1957) and Pendleton and Dungan (1958), who observed better establishment and yield of undersown legumes in positions receiving least amount of light.

Larson and Willis carried out experiments in three successive years (1954-1956). In 1954 when the rainfall during July - September was 2.1" less than the average there was very little difference between the positions between rows in the establishment and yield of clover, while lucerne establishment and yield was higher at positions receiving full sunlight in 80" spaced corn rows in E-W direction. There was very little difference between positions in 1955 when the rainfall was 3.8 - 5.7" less than the average. In 1956 however, the establishment was higher in positions receiving least amount of light. In their data no account of rainfall was given for

1956; but it appears from their conclusions that establishment and yield of undersown legumes were related to soil moisture in the first instance and when that factor was present in adequate supply, growth was related to the amount of radiation received. Pendleton and Dungan concluded that in their experiments the evaporative effect of solar radiation received, far exceeded the photosynthetic advantage.

In Adelaide, where the mean soil temperature during winter and early spring are considerably lower than during summer in U.S.A. and the maximum light intensity even on clear days is also relatively low, the heating effect of the radiation would be negligible. Thus radiation is unlikely to reduce establishment under Adelaide conditions. Black (1955) showed that the relative growth rate of subterranean clover var. Bacchus March in the early stages of growth depended on the radiation received and not on the temperature. If this is so, the yield of clover would be high at positions where radiation received was high provided soil moisture was not limiting.

6.4.0. Regrowth of undersown pasture

Experiment 1 was carried on into the following year, and it was shown that the establishment and early yield of the grass and clover seedlings in that season were closely related to the amount of seed produced in the previous season. A marked response to added nitrogen was also observed at the early stages. With time, however, these differences were reduced and at the final harvest there was no significant difference in the total yield per plot between the original treatments or the applied nitrogen. This attainment of ceiling yield with time from stands of differing initial densities is in accordance with the work of Donald (1951). There was, however, a significant difference between the yield of grass and the yield of clover due to applied nitrogen. Where nitrogen was applied there was more grass than clover and vice versa. Similar results have frequently been obtained with grass - clover mixtures and have recently been examined in detail by Stern (1960). The conclusion reached by Stern - that with applied nitrogen clover is shaded out following increased grass growth - undoubtedly holds here.

6.5.0. Effect of pasture on wheat

A considerable reduction in the yield of wheat caused by the presence of clover was observed where the rate of sowing were 15 and 30 lbs/acre in the 14" and 7" spacing respectively. It is interesting to note that in all experiments where the yield of wheat was reduced due to the presence of pasture the number of wheat plants per meter length of row was the same (12 plants approx.)

In the experiment where rye grass was included a greater reduction was observed in 14" treatments than in 7". Within the 14" treatments the reduction was greater when the rows of the two crops were alternate than when mixed. At this spacing the better the growth of the pasture the greater was the reduction in the yield of wheat. The reduction in the yield of wheat was considerably higher where the pasture consisted of rye grass and clover than when clover only was present. Charles (1961) concluded that grasses have a greater effect on the cereals reducing their vegetative as well as reproductive yields while legumes depress the reproductive yield slightly. These experiments lend support to his findings, despite the climatic differences between Adelaide and the U.K.

6.6.0. Concluding remarks

It is obvious from these experiments that the growth and yield of undersown pastures in the year of sowing depend on the rate, spacing and row direction of the cover crop and the relative position of the pasture species. The effect of the cover crop on the pasture was carried over into the early growth in the following year. Based on this it may be argued that as far as regrowth is concerned, early feed in any case being comparatively small, there would be no harm in undersowing with wheat at 7" spacing, for any loss of early feed in the following year would be compensated by correspondingly higher cereal yields in the year of sowing. It should however be pointed out that the rate of wheat sown at 7" in the 1960 Experiment was half the normal rate of sowing in South Australia. It would be difficult to assess from these data the effect of the normal rate in the year of sowing and hence in the following year.

When soil moisture was limiting early in the season undersown clover plants died and no seeds were set even when the cover crop was at 14" spacing, showing the severity of competition for soil moisture. When soil moisture stress was less severe due to irrigation there was no interaction between positions of clover and the radiation received. It is therefore reasonable to conclude that when soil moisture is limiting there would be no advantage due to either wider spacing and/or reduced rate of sowing of the cereal, and when soil moisture is in sufficient supply the effect of the cereal cover crop will not be carried over with serious consequences.

It should however be remembered that in these experiments only annual pasture species were studied. The results of undersowing perennial species may well show advantage to rate of sowing, row spacing and row direction of the cover crop and the relative position of the pasture plants to the rows of the cereal.

6.7.0. Yield of wheat in Experiments 2 and 2A.

In Experiment 2 there was no difference to the rate of sowing in yield/m^2, but row spacing was significant. This was true even when the number of plants per acre were equal (D_2 and D_3). There was no significant difference due to row direction. In Experiment 2A however, the reverse was the case. These contrasting results require some attempt at explanation.

The main difference between these two experiments were that Experiment 2A was planted 4 weeks before Experiment 2 and in a different field. It would be difficult to assess to what extent each of these factors contributed to the difference in the results observed.

Though the two fields were located at some considerable distance, the soil types and the past history were the same and it is unlikely that this could have been the reason for such differences. On the other hand, the plants in Experiment 2A by virtue of early planting were maintained at satisfactory soil moisture conditions during their vegetative growth and were able to grow better, reaching a ceiling yield, while those in Experiment 2, due to dry conditions following heading, were unable to grow to the same extent. This can be seen in the change in the dry matter produced with time. In Experiment 2 there was no increase in dry matter after the third harvest which was made on 11 September following anthesis. Normally a crop continues to increase in dry weight until maturity.

With adequate supply of soil moisture and nutrients the effect of rate of sowing will first be lost, followed by that of spacing, because of the greater population pressure along the rows than between rows. In Experiment 2 there was no significant effect due to rate of sowing but on the other hand spacing was significant. In Experiment 2A however, spacing was not significant and therefore it would be in order to expect the rate of sowing also to be without effect. Rate of sowing was however significant.

In both experiments the N-S rows yielded higher than the E-W rows (significant only in Experiment 2A). The increase due to N-S direction was higher in 7" than in 14" and within each spacing the lower rate of sowing gave higher difference than the high rate.

(Table 31). That the difference between N-S and E-W directions would

Table 31

% increase due to N-S direction over E-W

		Experiment 2	Experiment 2A
60 lbs/acre	7"	5.5	10.1
30 lbs/acre	7"	17.0	41.3
30 lbs/acre	14"	3.4	2.5
15 lbs/acre	14"	7.4	10.8

be higher at the narrower spacing that at the wider spacing has already been discussed; but a higher response at lower rate of sowing is difficult to explain at this juncture. Even though the "rate of sowing X direction" interaction in Experiment 2A was not significant, the difference between the low and high rates of sowing in E-W row direction (272.1 to 339.7 gms.) was higher than in N-S direction (344.1 to 361.0 gms.), and this was probably the cause of the significant effect of rate of sowing in that experiment, providing a possible explanation of the anomaleus finding mentioned earlier.

6.8.0. Light and leaf area distribution in wheat crops

There was no difference in the proportion of lateral distribution of leaf area in any of the treatments (rates, spacing and row direction) at the two harvests of Experiment 2. There was however, some differences in the vertical distribution due to rate of sowing and spacing (Fig. 28), where relatively more leaf area was near the top than at the base in 7" crops, while in 14" crops there was a more uniform distribution.

In Figs. 30 and 31 the isopleths of light intensity and leaf area distribution in Experiment 2 are shown. There were considerable differences in the distribution of light at noon. The light along the rows of plants was more evenly distributed in the E-W rows than in N-S rows, while between rows there was better distribution in N-S than in E-W rows. It has already been shown that nearly 70% of the total leaf area in both row directions was at P_0; this would mean that at noon there was better illumination of the majority of the leaves in E-W rows than in N-S rows, which then should result in better growth of E-W than N-S rows. However, the superiority of N-S over E-W rows has been established.

At noon in N-S rows the light has to penetrate the full depth of the crop along the row while in E-W rows the depth of crop to be penetrated would depend on the solar altitude and the row spacing. The light profiles along the various positions at the time of maximum interception are shown in Fig. 35. It should be noted that at noon in 14" E-W rows the depth of the crop to which full day light reaches increase from North to South (P_0 to $P_{10\frac{1}{2}}$). The depth to which full day light would penetrate the northern side of E-W rows would depend on the solar altitude and the effective space between rows according to the equation

$$\text{depth of penetration} = \tan\theta \times \text{effective row space.}$$

Penetration would therefore be at maximum at noon and would decrease with decrease in solar altitude.

With the change in the solar altitude after noon, where the direction also changes from East to West, the angle of penetration of light would change in N-S rows and the depth to which full daylight would reach the eastern side of the row prior to noon and the western side after noon would depend on the solar azimuth. On the date taken in Fig. 35 to be the time of maximum light interception (9/9), the solar altitude at noon was 50^{o} and at that altitude the light profile along the row in E-W rows was better distributed than in N-S rows. Before and after noon the profile in E-W rows would show greater interception at the top of the crop and less penetration to the lower layers. In N-S rows however with change in azimuth and altitude there would be even more penetration to the lower layers.

The extent of light penetration and the interception and utilisation would largely depend on the angular dispersion of the individual leaves, so that it is necessary to study the leaf angle as well as the direction of the leaf plane. If for example the majority of the leaves form very acute angles with the stem and due to intra row density are pushed laterally into the inter row space and are hence exposed with the leaf plane parallel to the rows, then in N-S rows at noon and around that period these leaves would be parallel to the incident light or form very small angles to it. Due to low angle of incidence of the light the intensity at interception would then be low and considerable amounts would pass to the leaves behind and below. In the E-W rows the leaves would be at right angles to the incoming light and intercept at high intensity, much more than necessary for maximum utilisation, and at the same time reduce the intensity of the transmitted light considerably. In other words the E-W row would behave like a clover sward while N-S row would behave like a grass sward. This difference between N-S and E-W rows would be greater for a given row spacing at lower solar altitude at noon.

If leaf arrangement was as suggested above, the continued light interception on the northern side of E-W rows and relatively low light on the Southern side would lead to less efficient utilisation of light as compared to the change in the illumination and hence interception in N-S rows.

An interesting feature observed in Fig. 35 was the occasional lower light at 3" height than at ground level. This could be caused by the disposition of leaves, where, at low solar altitudes a more or less erect leaf flagging at its distal end would intercept the light and cast a shadow behind it while below it the light may not be intercepted and hence record a higher value. This effect was particularly marked in E-W rows than in N-S, probably due to greater flagging of leaves parallel to the rows on either side and therefore being at right angles in E-W rows and parallel in N-S rows to the incident light at least around noon. This discussion, far from explaining the advantage of N-S rows over E-W has focussed attention on the need for further studies on leaf dispersion and more frequent light measurements.

6.9.0. Some problems of light measurements in cereal crops

As far as the author is aware there have been no detailed studies of light measurements within cereal crops. Considerable difficulties and restrictions were imposed on such measurements due to the nature of the crops. In this investigation a Weston light meter was used for all light measurements. The receptive surface was 1.5" in diameter and the breadth of the whole probe was 2.0". The insertion of such a probe into a crop undoubtedly caused considerable disturbance, resulting in large errors. A smaller probe would have caused less disturbance but at the same time increased errors due to sun flecks and contact with leaves would increase. In the measurements made along the rows (P_0), the probe had to be placed in the gaps between plants on the row rather than among the tillers due to risk of disturbing the crop. This again introduced considerable errors, resulting in the measurements being artifically increased. Due to the directional effect of the sun it was not possible to insert the probe from any direction. The observer always had to face the sun and insert the probe ahead to avoid casting shade at the point of measurement.

Due to the large number of readings that had to be made and since the light intensity varies rapidly with time the operation had to be carried out very quickly. This again restricted randomisation of the order of measurements in the various treatments and as a rule in Experiments 2 and 2A the E-W row plots were measured first commencing 30 minutes before solar noon. Two of these plots were completed within 15 minutes and then all four plots of N-S row direction were measured; by then it was 15 minutes past solar noon, and the remaining two plots in the E-W direction were finally measured. In the morning and afternoon either the E-W or the N-S set were completed first.

Because of the need to make measurements quickly the probe could not be aligned perfectly horizontally and all levels were made by eye estimation only. This variation in the angle in which the probe was held would have caused considerable error. The time factor restricted the number of replications to only one block in each experiment and in each plot to only two internal replications per position in 14" and three in 7" crops.

A very serious problem encountered was the change in the percentage light recorded at the various positions between clear and cloudy conditions. To measure this effect, a coin was placed at P_7 on the ground in the 30 lbs 14" crop in E-W row direction at noon on a day with patches of clouds. Measurements were made immediately above the coin and the crop when the sun was obscured by a patch of clouds and when it was clear, and are shown in Table 32. Under

Table 32

Intensity of light beneath and above a crop of wheat under clear and cloudy conditions

	Clear		Cloudy	
	Above	Beneath	Above	Beneath
F.c.	9800	1640	3100	1000
%	100	16.7	100	32.2

cloudy conditions the % light reaching ground level was 32.2 compared to 16.7 under clear conditions. The time lapse between the measurements was only a few minutes. In a programme of investigation such as was undertaken here it would not be possible to select particular conditions to make light measurements. Furthermore it is questionable whether measurements should be made on clear days or on overcast days only. Neither of these would be typical and for a fuller understanding of the nature and mode of light interception by crops it would be necessary to study interception under both conditions. Better still, an integrating device could be used. The errors in measurements would be considerably reduced under overcast conditions and it would be possible to show smooth trends in light profiles, isopleths and time trends. It has already been shown that under overcast conditions there would be no directional effects, and had all measurements been made under those conditions it would not have been possible to explain many of the phenomenon observed in the course of these investigations. These large variations in the light interception the very wide scatter of points in the figures showing time trends in the light at ground level.

No doubt many of the improvements in the methods of light measurements suggested by Stern (1960) would be beneficial. A grid system of integrators either of photoelectrical or chemical nature would be most useful, yet the present and widely available instruments would help to add considerably to our knowledge of light interception and utilisation by crops. A very useful improvement to the present apparatus would be a narrow receptive surface of sufficient length that would minimise the errors caused by the irregularity of plant distribution along the rows.

The most important factors to be encountered in cereal crops are row direction, spacing, position and time of light measurements. As pointed out earlier in this thesis the early records of light measurements within cereal crops have made no reference to these factors. From the conclusions derived in the last section the importance of the time of measurement cannot be over emphasised. Unless the rows are planted due N-S and E-W with reference to true and not magnetic north, light measurements at noon would not be correct records, because of the deviation of the magnetic north from the true north, which, in Adelaide, is 7.25° west of north. Furthermore the term "noon" can be very misleading, meaning either local noon (Local Standard Time), mean solar noon or true solar noon. The true solar noon fluctuates from the local noon through the year and correction has to be made from time to time. The deviation of the

T.S.N. with local noon in Adelaide is shown in Fig. 52.

The position at which measurements are made also needs characterisation. This would be important as the row width increases; similarly the time of measurement becomes important due to shadow movement. All previous light records in cereal crops have been either at or near ground level only. No data is available on the light profile through the height of the crops except some measurements by Rademacher (1940) in connection with weed control in cereal crops, and some unpublished data of Black (private communication). While measurements at ground level would describe to some extent the light microclimate available for undersown pasture growth, the growing pasture would be extending its photosynthetic tissues to various heights within the cover crops and the light available at these heights would not only be higher than at ground level but could be quite different between the various positions from beneath one row across to the next in the various row directions. To characterise adequately the light microclimate within cereal crops it is necessary to make frequent measurements and on each occasion at different times of the day because of the marked directional effects.

6.10.0. General conclusions

These experiments clearly demonstrate that the growth of undersown pasture was greater at wider spacings of wheat rows (14") than at normal spacings (7"), and when the pasture row was midway between rows of wheat at that spacing than at any other position.

There was an indication that the growth in N-S rows may be superior to that in E-W rows. At 14" spacing of wheat the growth of undersown clover decreased linearly with increase in the rate of wheat sown.

When soil moisture was limiting the undersown pastures died even though the wheat remained green. When moisture stress was less severe there was a marked reduction in the growth of the pasture plants, and at this reduced level, growth was linearly related to the amount of radiation received. There was also some indication that the efficiency of utilisation of radiation increased with a decrease in the distance between the rows of wheat and clover. The radiation received between 10 a.m. and 2 p.m. each day formed a very high proportion of the total per day and the effect of row direction was largely due to the direct radiation received during those four hours.

With the increase in the growth and yield of undersown pasture there was a corresponding decrease in the growth and yield of the wheat; this was due to reduction in the number of wheat plants per unit area and actual depression by the pasture. The depression of wheat yield was greater when grass was a component of the pasture.

The regrowth and early yield of the pastures in the following year was related to the amount of seeds produced, but with time all treatments yielded the same amount. Applied nitrogen increased the overall yields at the early stages, and later the proportion of the grass in the pasture.

Wheat crops planted early in the season yielded higher in

N-S than in E-W rows, and the difference was higher in 7" than in 14" spaced crops, probably due to greater difference in the amount and better distribution of radiation received around noon, but with late planting no similar relationships were demonstrated.

Regardless of rate of sowing and row spacing and direction between 70 and 75% of the total leaf area of a row of wheat was distributed within a strip 3½" along the row, the remainder was equally distributed within strips of 3½" on either side. For a fuller understanding of the advantage of N-S over E-W rows it would be necessary to study the leaf angle and plane with frequent measurements of light intensity within the crops.

Although the experiments were not designed to form the basis for practical recommendations, a great deal of data on the competitive relationships of undersown pastures and cereal crops have been analysed and have led to an increased understanding of the mechanisms of competition involved.

7.0.0. Summary

Four field experiments were carried out at the Waite Agricultural Research Institute, Adelaide, during 1960 and 1961 to study the nature of competition between wheat and undersown pasture, with particular emphasis on the light factor.

In Experiment 1, wheat and pasture both alone and together at 7" and 14" row spacings and in alternate rows at 7" spacing were planted in N-S rows to study the effect of competition between the two crops. The presence of wheat reduced the growth and yield of pasture in all combinations. Pasture yields were greater at 14" spacing than at 7", and at the wider spacing pasture rows midway between rows of wheat (alternate rows of the two crops) yielded more than those mixed with the rows of wheat. The reverse was true of the yield of wheat.

Soil moisture measurements made at fortnightly intervals at depths of 0-9" and 9-18" showed no difference between treatments, indicating no differential exhaustion of soil moisture in the various treatments.

Light measurements were made in all treatments at weekly intervals around noon. A series of measurements were made at 3" intervals from ground level upwards through the crops so as to obtain a complete picture of the light microclimate within the various treatments. These measurements showed, as expected, that the 7" wheat crop intercepted more light than the 14". The % daylight above

the pasture in the 7" mixed treatment was lower than that in the corresponding 14" treatment, which was lower than that in the alternate row treatment.

The experiment was continued so that the regrowth of the pastures in the following season would be studied. The yield at the early stages bore a close relationship to the seeds produced in the previous year, but with time the yield of all treatments became the same.

In the second season, a particular study was made of row direction and the position of pasture rows vis-a-vis wheat. In Experiments 2 and 2A wheat was sown in 2 row directions (N-S and E-W) at 2 rates of sowing (30 and 60 lbs/acre) and 2 row spacings (7" and 14") to study the light microclimate within wheat crops and their leaf area distribution and also the yield of wheat.

More light was received between rows at 14" spacing than at 7" and there was very little difference between the rates of sowing at each spacing.

Difference between row directions was evident only at noon and in direct sunlight.

Under these conditions in N-S rows the least amount of light was received beneath the rows (P_0) and the highest midway between rows (P_7). The intermediate positions ($P_{3\frac{1}{2}}$ and $_{10\frac{1}{2}}$) received equal amounts and were intermediate to that received at P_0 and P_7. In E-W rows the amount of light received increased from beneath the rows to midway between rows from north to south. There was no difference between the midway position and that $3\frac{1}{2}$" further south ($P_{10\frac{1}{2}}$). Beneath the rows the E-W direction received more light than the N-S direction and at midway between rows the reverse was true, particularly at noon.

The vertical and lateral distribution of leaf area was measured at the first two harvests in Experiment 2 by a technique developed for the purpose. Regardless of the rate of sowing, row spacing and row direction, 70 to 75% of the total leaf area was found within $3\frac{1}{2}$" on each side of the centre of the row, the remainder being distributed equally in strips $3\frac{1}{2}$" wide on either side thereof.

At the wider spacing the vertical distribution was uniform over the height of the crop. In the narrower spacing more leaf area was found near the top than at the base of the crops.

The high rate of sowing yielded more than the low rate at the early stages, but with time the effect due to rate of sowing was eliminated and the wider spacing yielded more than the narrow spacing.

Wheat crops planted early in the season (May) yielded higher in N-S than in E-W rows, and the difference was higher in 7" than in 14" spaced crops, but with late planting (June) no such relationships were demonstrated.

In Experiments 3 and 3A, clover was planted in rows at four distances (0, $3\frac{1}{2}$, 7 and $10\frac{1}{2}$") from wheat rows at 14" spacing in N-S and E-W row directions, to study the effect of competition. The yield of clover was directly related to the % daylight received at those positions at noon and it was also noticed that the yield of clover in the control treatment in N-S row direction was higher than in E-W rows. When soil moisture became limiting the clover sown with wheat died, while that sown alone continued to grow.

In Experiment 4 wheat was planted in N-S rows and 14" spacing at 4 rates of sowing and clover was broadcast in split plots. An additional pure clover sward was also planted to measure the growth of clover in absence of wheat. Metal quadrats were placed in the Wheat-Clover subplots to mark out strips 3½" wide which would represent the positions studied in the previous experiments. Clover reduced the yield of wheat only at the lowest rate of sowing, but the presence of wheat markedly reduced the growth of clover.

At the reduced level of growth the yield of clover decreased almost linearly with increase in the rate of sowing of wheat, both in the total per treatment and also for the various positions. The position effect was similar to that recorded for N-S rows in Experiments 3 and 3A.

The growth of clover at the various positions under the wheat was linearly related to the amount of radiation received at those positions. There was an indication that the efficiency of utilisation of radiation increased with a decrease in the distance between the wheat and clover plants.

These results are discussed from the point of view of competition between the two crops. It was concluded that soil moisture was a very important factor in the success of undersowing. When soil moisture was in sufficient supply the cover crop would depress the growth of pasture by reducing the amount of radiation available to the pasture.

The availability of light under Adelaide conditions and its effect on row direction are discussed. For a fuller understanding of the effect of row direction both for the growth of the cover crop and the undersown pasture it is necessary to study the leaf angle and plane as well as to obtain frequent measurements of light.

Many problems were encountered in the course of light measurements within wheat crops. These were discussed, and the need for frequent or integrated measurements stressed.

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10.0.0. Appendix

10.1.0. Experiment 1

10.1.1. Plant numbers/m row length (Means)

(a) Wheat

	T_1	T_3	T_4	T_5	T_7	Mean	L.S.D.
At emergence	10.3	10.8	11.2	11.7	11.6	11.1	
At 1st Harvest	10.1	9.3	11.8	11.7	10.7	10.7	
Mean	10.2	10.1	11.5	11.7	11.1		N.S.

	DF	SS	MS	VR
Blocks	4	22.67	5.66	13.47*
Times	1	2.33	2.33	5.54
Error (i)	4	1.70	0.42	
Treats.	4	22.59	5.64	3.15
Time x Tr.	4	6.72	1.68	N.S.
Error (ii)	32	57.44	1.79	
Total	49	113.45		

(b) <u>Grass</u>

	T_2	T_3	T_4	T_6	T_7	Mean
At emergence	18.9	14.8	23.3	30.7	19.9	21.6
At 1st Harvest	18.2	12.3	19.4	24.6	15.4	16.0
Mean	18.6	13.6	21.4	27.7	17.7	

	DF	SS	MS	VR
Blocks	4	93.67	23.41	2.53
Times	1	157.08	157.08	16.97**
Error (i)	4	37.03	9.25	
Treats.	4	1098.42	274.60	10.40***
Times x Tr.	4	41.27	10.31	N.S.
Error (ii)	32	844.97	26.40	
Total	49	2272.36		

L.S.D. 5% = 3.4

1% = 4.7

0.1% = 6.5

(c) Clover

	T_2	T_3	T_4	T_6	T_7	Mean
At emergence	8.5	7.6	9.7	12.6	10.2	9.0
At 1st Harvest	9.5	5.3	8.1	13.3	7.3	8.8
Mean	9.1	6.5	8.9	13.0	9.0	

Blocks	4	69.98	17.49	13.45*
Times	1	12.30	12.30	9.46
Error (i)	4	5.22	1.30	
Treats.	4	219.00	54.75	5.73*
Time x Treat.	4	26.16	6.54	N.S.
Error (ii)	32	305.60	9.55	
Total	49	638.26		

L.S.D. 5% = 2.1

1% = 3.0

0.1% = 4.0

10.1.2. Dry weight g/1.75 m^2 (Means)

(a) Total

		H_1	H_2	H_3	H_4	H_5
T_1		260.0	771.2	1368.6	1567.8	1932.2
T_2		194.8	593.8	1007.8	1495.8	1071.8
T_3		338.2	853.8	1718.2	1802.8	1844.6
T_4		221.0	655.0	1217.8	1724.0	1496.4
T_5		199.4	618.2	1196.0	1521.8	1342.6
T_6		129.8	380.6	860.4	1142.2	795.0
T_7		216.0	630.0	1144.8	1653.4	1407.6
L.S.D.	5%	51.2	43.5	73.9	53.0	105.6
	1%	69.4	59.0	100.1	71.9	143.2
	0.1%	92.9	79.0	134.0	96.2	191.7

Harvest 1

	D.F.	SS	MS	V.R.
Blocks	4	17165	4291	1.98
Treats.	6	123842	10640	9.53***
Error	24	51983	2165	
Total	34	192990		

Harvest 2

	D.F.	SS	MS	V.R.
Blocks	4	9333	2333	1.49
Treats.	6	66537	11089	7.12***
Error	24	37344	1556	
Total	34	113214		

Harvest 3

	D.F.	SS	MS	V.R.
Blocks	4	15573	3893	N.S.
Treats	6	225382	37563	8.35***
Error	24	107957	4498	
Total	34	348912		

Harvest 4

	D.F.	SS	MS	VR
Blocks	4	32657	8164	3.52
Treats.	6	137374	22895	9.89***
Error	24	55538	2314	
Total	34	225569		

Harvest 5

Blocks	4	47294	11823	1.28
Treats	6	483064	80510	8.76***
Error	24	220433	9184	
Total	34	750791		

(b) Wheat

		H_1	H_2	H_3	H_4	H_5
T_1		260.04	771.26	1368.66	1568.31	1932.23
T_3		274.56	709.48	1423.68	1426.18	1612.21
T_4		140.80	392.22	732.07	1102.70	1041.54
T_5		199.43	618.05	1196.06	1521.98	1342.54
T_7		170.92	531.73	876.80	1329.34	1152.55
L.S.D.	5%	60.89	148.18	92.00	62.34	43.46
	1%	83.89	204.17	126.77	85.88	59.88
	0. 1%	115.32	280.64	174.25	188.04	82.31

Harvest 1

	D.F.	SS	MS	VR
Blocks	4	23641	5910	2.86
Treats.	4	65485	16371	7.93***
Error	16	33020	1064	
Total	24	122146		

Harvest 2

Blocks	4	39810	9952	N.S.
Treats.	4	446849	111712	9.15***
Error	16	195234	12202	
Total	24	681893		

Harvest 3

Blocks	4	26058	6514	1.38
Treats.	4	186950	46737	9.92***
Error	16	75366	4710	
Total	24	288374		

Harvest 4

Blocks	4	23724	5931	2.74
Treats.	4	68371	17092	7.91**
Error	16	34560	2160	
Total	24	126655		

Harvest 5

Blocks	4	5869	1467	1.39
Treats.	4	26001	6500	6.20**
Error	16	16779	1048	
Total	24	48649		

(c) Pasture

		H_1	H_2	H_3	H_4	H_5
T_2		194.88	593.77	1007.89	1495.79	1071.87
T_3		63.69	164.40	294.63	376.33	232.36
T_4		80.15	262.68	485.75	621.11	454.68
T_6		129.45	380.78	860.36	1142.34	794.98
T_7		44.97	98.85	277.24	324.17	255.20
L.S.D.	5%	10.96	94.55	150.43	138.44	184.23
	1%	15.10	130.10	209.47	172.74	253.83
	0.1%	20.76	185.09	275.43	262.18	348.90

Harvest 1

	D.F.	SS	MS	VR
Blocks	4	135.4	33.85	N.S.
Treats.	4	7287.6	1821.90	27.25***
Error	16	1069.7	66.85	
Total	24	8492.7		

Harvest 2

	D.F.	SS	MS	VR
Blocks	4	47150	11787	2.36
Treats.	4	765337	191334	38.42***
Error	16	79683	4980	
Total	24	892170		

Harvest 3

	D.F.	SS	MS	VR
Blocks	4	33227	8306	N.S.
Treats.	4	2217681	554420	47.06***
Error	16	188477	11779	
Total	24	2439385		

Harvest 4

	D.F.	SS	MS	VR
Blocks	4	126473	31618	2.96
Treats.	4	5194523	1298630	121.71***
Error	16	170705	10669	
Total	24	5491701		

Harvest 5

	D.F.	SS	MS	VR
Blocks	4	55030	13757	N.S.
Treats.	4	2642748	660687	35.94***
Error	16	294071	18379	
Total	24	2991849		

(d) Grass

	H_1	H_2	H_3	H_4	H_5
T_2	160.60	593.77	823.17	1277.56	970.68
T_3	51.37	164.40	194.98	249.40	201.04
T_4	69.30	262.68	389.55	507.22	425.08
T_6	109.91	380.78	695.13	975.95	745.18
T_7	36.41	98.85	199.69	225.92	222.10
L.S.D. 5%	31.76	94.55	166.21	169.39	134.83
1%	43.76	130.28	229.00	233.39	185.77
.1%	60.16	179.07	314.77	320.80	255.35

Harvest 1

	D.F.	SS	MS	VR
Blocks	4	1447.10	361.77	N.S.
Treats.	4	50360.90	12590.22	22.43***
Error	16	8990.05	561.87	
Total	24	60798.05		

Harvest 2

	D.F.	SS	MS	VR
Blocks	4	47150	11787	2.36
Treats.	4	765337	191334	38.42***
Error	16	79683	4980	
Total	24	892170		

Harvest 3

	D.F.	SS	MS	VR
Blocks	4	34575	8643	N.S.
Treats.	4	1650678	412669	26.81***
Error	16	246238	15389	
Total	24	1931491		

Harvest 4

	D.F.	SS	MS	VR
Blocks	4	7766	1941	1.21
Treats.	4	430369	107592	67.41***
Error	16	25540	1596	
Total	24	463675		

Harvest 5

Blocks	4	154575	38643	3.81*
Treats.	4	2265261	566315	55.84***
Error	16	162262	10141	
Total	24	2582098		

(e) Clover

T_2	34.28	110.55	184.71	218.23	101.18
T_3	12.32	52.72	99.65	126.92	31.32
T_4	10.85	60.82	96.19	113.88	29.60
T_6	19.53	75.43	165.23	166.39	49.80
T_7	8.55	26.31	77.55	98.25	33.70
L.S.D. 5%	7.83	35.61	60.42	80.35	56.60
1%	10.79	49.07	83.25	110.70	77.99
.1%	14.83	67.45	114.43	152.17	107.20

Harvest 1

	D.F.	SS	MS	VR
Blocks	4	207.42	54.85	1.51
Treats.	4	2179.53	544.88	15.95***
Error	16	546.56	34.16	
Total	24	2933.51		

Harvest 2

	D.F.	SS	MS	VR
Blocks	4	6122	1530	2.14
Treats.	4	19242	4810	6.75**
Error	16	11399	712	
Total	24	36763		

Harvest 3

	D.F.	SS	MS	VR
Blocks	4	13729	3432	1.69
Treats.	4	44539	11134	5.49**
Error	16	32425	2026	
Total	24	90693		

Harvest 4

	D.F.	SS	MS	VR
Blocks	4	12821	3205	N.S.
Treats.	4	56500	14125	3.92*
Error	16	57524	3595	
Total	24	126845		

Harvest 5

	D.F.	SS	MS	VR
Blocks	4	12448	3112	1.73
Treats.	4	18234	4558	2.54
Error	16	28675	1792	
Total	24	59357		

10.1.3. Components of Yield

(a) Wheat

(i) Tillers/plant (Mean)

	T_1	T_3	T_4	T_5	T_7	L.S.D. 5%	L.S.D. 1%	L.S.D. .1%
Harvest 1	3.5	5.4	3.6	5.1	4.7	1.1	1.5	2.0
Harvest 5	5.1	4.4	6.1	8.5	6.5	1.0	1.4	2.0

Harvest 1

	D.F.	SS	MS	VR
Blocks	4	4.36	1.09	1.69
Treats.	4	14.44	3.61	5.59**
Error	16	10.32	0.64	
Total	24	29.12		

Harvest 5

Blocks	4	3.49	0.87	1.42
Treats.	4	47.48	11.87	19.45***
Error	16	9,81	0.61	
Total	24	60.78		

(ii) Weight/Tiller

	H_1	H_2	H_3	H_4	H_5
T_1	0.76	2.14	3.42	3.98	4.20
T_3	0.74	1.97	3.67	4.16	4.49
T_4	0.65	2.02	3.67	4.38	4.37
T_5	0.69	1.87	4.19	4.51	4.05
T_7	0.69	1.86	3.42	4.44	4.28
L.S.D.	N.S.	N.S.	N.S.	N.S.	N.S.

Harvest 1

	D.F.	SS	MS	VR
Blocks	4	0.089	0.022	1.29
Treats.	4	0.035	0.009	N.S.
Error	16	0.027	0.017	
Total	24	0.403		

Harvest 2

	D.F.	SS	MS	VR
Blocks	4	0.952	0.238	N.S.
Treats.	4	0.234	0.058	N.S.
Error	16	6.738	0.421	
Total	24	7.924		

Harvest 3

	D.F.	SS	MS	VR
Blocks	4	0.027	0.007	N.S.
Treats.	4	1.182	0.296	N.S.
Error	16	1.061	0.316	
Total	24	6.270		

Harvest 4

	D.F.	SS	MS	VR
Blocks	4	1.29	0.32	1.60
Treats.	4	0.96	0.24	1.20
Error	16	3.33	0.20	
Total	24	5.58		

Harvest 5

Blocks	4	1.36	0.34	2.12
Treats.	4	0.60	0.15	N.S.
Error	16	2.67	0.16	
Total	24	4.63		

(iii) Leaf area index

		H_1	H_2	H_3
T_1		1.09	1.76	0.78
T_3		1.08	1.44	0.91
T_4		0.58	0.82	0.44
T_5		0.92	1.20	0.58
T_7		0.74	1.08	0.47
L.S.D.	5%	0.28	0.52	0.32
	1%	0.37	N.S.	N.S.
	.1%	0.53	N.S.	N.S.

Harvest 1

	D.F.	SS	MS	VR
Blocks	4	0.1916	0.0479	1.09
Treats.	4	0.9587	0.2396	5.45**
Error	16	0.7033	0.0439	
Total	24	1.8536		

Harvest 2

	D.F.	SS	MS	VR
Blocks	4	0.3121	0.0780	N.S.
Treats.	4	2.5425	0.6356	4.19*
Error	16	2.4269	0.1516	
Total	24	5.2815		

Harvest 3

	D.F.	SS	MS	VR
Blocks	4	0.3657	0.0914	1.61
Treats.	4	0.8320	0.2080	3.68*
Error	16	0.9048	0.0565	
Total	24	2.1025		

(iv) Grain yield, g/1.75 m^2

	B_1	B_2	B_3	B_4	B_5	Total	Mean
T_1	893.39	1253.22	767.58	615.10	696.90	4226.19	845.23
T_3	638,74	625.61	642.16	586.38	690.45	3183.34	626.66
T_4	682.59	469.69	268.34	519.82	271.77	2212.21	442.44
T_5	538.13	651.82	704.68	522.11	507.74	2924.48	584.89
T_7	419.25	514.55	687.37	455.70	389.44	2466.31	493.26
Total	3172.10	3514.89	3070.13	2699.11	2556.30	15012.53	

	D.F.	SS	MS	VR
Blocks	4	117404	29351	1.34
Treats.	4	489653	122413	5.62**
Error	16	348490	21780	
Total	24	955547		

L.S.D. 5% = 198.00

1% = 272.23

(v) Grain yield g/m row length

	B_1	B_2	B_3	B_4	B_5	Total	Mean
T_1	89.33	125.32	76.75	61.51	69.69	422.60	84.52
T_3	63.87	62.56	64.21	58.63	69.04	318.31	63.66
T_4	136.51	93.93	53.66	103.96	54.35	442.41	88.48
T_5	107.42	130.36	140.93	104.40	101.55	584.66	116.93
T_7	83.85	102.91	137.47	91.14	75.88	491.25	98.25
Total	480.98	515.08	473.02	419.64	370.51	3259.23	

	D.F.	SS	MS	VR
Blocks	4	258.96	64.74	1.22
Treats.	4	759.37	189.84	3.58*
Error	16	847.79	52.98	
Total	24	1866.12		

L.S.D. 5% = 17.61
1% = 24.28

(vi) ~~1000~~ grain weight

	B_1	B_2	B_3	B_4	B_5	Total	Mean
T_1	43.10	42.60	43.60	43.60	43.60	216.50	43.30
T_3	40.80	40.30	40.80	42.60	42.10	206.60	41.32
T_4	42.10	39.50	40.30	39.40	39,50	200.80	40.16
T_5	41.20	44.10	44.10	39.10	43.10	211.60	42.32
T_7	42.60	40.80	42.10	42.60	42.10	210.20	42.04
Total	209.80	207.30	210.90	207.30	210.40	1045.70	

	D.F.	SS	MS	VR
Blocks	4	2.38	0.59	N.S.
Treats.	4	27.48	6.87	3.90*
Error	16	28.22	1.76	
Total	24	58.08		

L.S.D. 5% = 1.78

(b) <u>Grass</u>

(i) Tillers/plant at Harvest 1

	B_1	B_2	B_3	B_4	B_5	Total	Mean
T_2	13.18	10.53	22.65	14.45	16.16	76.97	15.39
T_3	11.32	8.27	10.06	8.26	10.24	48.15	9.63
T_4	8.24	11.81	10.06	6.06	7.84	44.01	8.80
T_6	18.99	10.49	18.99	12.64	14.46	75.57	15.11
T_7	5.94	4.75	7.62	9.80	4.56	32.67	6.53
Total	57.67	45.85	69.38	51.21	53.26	277.37	

	D.F.	SS	MS	VR
Blocks	4	62.78	15.69	2.02
Treats.	4	314.20	78.55	10.61***
Error	10	123.70	7.73	
Total	24	500.68		

L.S.D. 5% 3.72

1% 5.13

.1% 7.05

(ii) Weight/tiller

	H_1	H_2	H_3	H_4
T_2	0.079	0.212	0.524	0.774
T_3	0.058	0.176	0.555	0.616
T_4	0.083	0.225	0.509	0.718
T_6	0.062	0.185	0.554	0.634
T_7	0.075	0.168	0.464	0.576
L.S.D. 5%	N.S.	N.S.	N.S.	N.S.

Harvest 1

	D.F.	SS	MS	VR
Blocks	4	0.032	0.008	N.S.
Treats.	4	0.236	0.006	2.00
Error	16	0.473	0.006	
Total	24	0.741		

Harvest 2

	D.F.	SS	MS	VR
Blocks	4	0.005	0.001	N.S.
Treats.	4	0.012	0.003	1.50
Error	16	0.027	0.002	
Total	24	0.044		

Harvest 3

	D.F.	SS	MS	VR
Blocks	4	0.118	0.030	N.S.
Treats.	4	0.028	0.007	N.S.
Error	16	0.516	0.032	
Total	24	0.662		

Harvest 4

	D.F.	SS	MS	VR
Blocks	4	0.04	0.010	N.S.
Treats.	4	0.13	0.032	3.55**
Error	16	0.15	0.009	
Total	24	0.32		

(iii) Leaf area index

		H_1	H_2	H_3
T_2		0.94	3.14	2.04
T_3		0.36	0.78	0.64
T_4		0.44	1.14	0.94
T_6		0.70	1.62	1.49
T_7		0.25	0.60	0.63
L.S.D.	5%	0.23	0.63	0.53
	1%	0.32	0.87	0.73
	.1%	0.44	1.20	1.01

Harvest 1

	D.F.	SS	MS	VR
Blocks	4	0.118	0.0295	N.S.
Treats.	4	1.555	0.3888	13.03***
Error	16	0.479	0.0299	
Total	24	2.152		

Harvest 2

	D.F.	SS	MS	VR
Blocks	4	1.450	0.363	1.63
Treats.	4	20.742	5.185	23.33***
Error	16	3.555	0.222	
Total	24	25.747		

Harvest 3

	D.F.	SS	MS	VR
Blocks	4	0.575	0.1436	N.S.
Treats.	4	7.664	1.9159	12.17***
Error	16	2.519	0.1573	
Total	24	10.758		

(iv) Seed yield, g/4 ft.^{2}

	B_1	B_2	B_3	B_4	B_5	Total	Mean
T_2	28.80	28.85	23.90	39.20	27.90	145.65	29.13
T_3	11.30	11.45	12.40	19.85	16.55	71.55	14.31
T_4	21.60	19.00	21.15	12.50	25.35	99.60	19.92
T_6	27.35	18.25	22.75	22.40	27.55	118.30	23.66
T_7	13.60	13.00	13.05	18.40	20.90	78.95	15.79
Total	102.65	87.55	93.25	112.35	118.25	514.05	

	D.F.	SS	MS	VR
Blocks	4	130.74	32.68	1.29
Treats.	4	595.66	148.91	5.90**
Error	16	403.30	25.20	
Total	24	1129.70		

L.S.D. 5% 3.80
1% 5.23
.1% 7.20

(c) Clover

(i) Leaf area index

		H_1	H_2
T_2		0.21	0.30
T_3		0.08	0.48
T_4		0.06	0.56
T_6		0.10	0.63
T_7		0.05	0.22
L.S.D.	5%	0.04	N.S.
	1%	0.06	
	.1%	0.08	

Harvest 1

	D.F.	SS	MS	VR
Blocks	4	0.0087	0.0021	1.90
Treats.	4	0.0752	0.0188	17.90***
Error	16	0.0187	0.0011	
Total	24	0.1026		

Harvest 2

	D.F.	SS	MS	VR
Blocks	4	0.4008	0.1002	1.43
Treats.	4	0.9069	0.2267	3.25
Error	16	1.1159	0.0697	
Total	24	2.4236		

(ii) Seed Yield, g/4 ft.^{2}

	B_1	B_2	B_3	B_4	B_5	Total	Mean
T_2	1.46	1.08	1.20	1.18	1.10	6.02	1.20
T_3	0.57	1.34	0.80	0.70	0.65	4.06	0.81
T_4	1.05	1.20	0.81	2.10	1.29	6.45	1.29
T_6	2.23	1.50	0.71	0.99	0.81	6.24	1.25
T_7	0.64	0.85	1.30	1.04	0.56	4.39	0.88
Total	5.95	5.97	4.82	6.01	4.41	27.16	

	D.F.	SS	MS	VR
Blocks	4	0.4622	0.1155	N.S.
Treats.	4	1.0006	0.2501	1.38
Error	16	2.8972	0.1810	
Total	24	4.3600		

10.1.4. Soil moisture. Mean Percentage

(a) 0-9"

	25/5	29/6	9/9	12/10	26/10	9/11	24/11
T_1	17.25	17.29	20.47	12.10	6.51	6.00	10.26
T_2	17.77	17.95	21.41	10.87	5.57	4.83	9.05
T_3	17.93	17.29	20.48	11.71	5.38	4.33	11.28
T_4	17.08	17.19	20.90	11.94	5.78	4.70	10.14
T_5	17.14	17.60	20.83	12.83	6.39	5.63	11.70
T_6	17.00	16.85	20.46	11.57	5.80	5.16	9.12
T_7	18.07	17.83	20.38	12.95	6.61	5.95	9.38
L.S.D.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

(b) 9-18"

	25/5	29/6	9/9	12/10	26/10
T_1	16.17	16.07	17.54	13.08	11.06
T_2	17.09	15.82	17.54	12.26	8.76
T_3	15.99	16.19	16.79	12.23	8.28
T_4	16.58	16.11	16.72	13.06	8.71
T_5	15.96	15.88	16.48	13.13	9.82
T_6	16.28	16.17	17.00	13.86	9.25
T_7	16.54	16.32	17.25	13.14	10.37
L.S.D.	N.S.	N.S.	N.S.	N.S.	N.S.

10.2.0. <u>Experiment 1, Regrowth 1961</u>

10.2.1. Plant Counts Number/eight 3" cores

(a) Grass

	B_1	B_2	B_3	B_4	B_5	Total	Mean
T_2	1072	1333	1524	1217	1523	6669	1334
T_3	227	451	339	622	378	2017	403
T_4	751	556	778	709	660	3454	691
T_6	1338	529	1108	1105	1152	5232	1040
T_7	678	716	496	781	550	3221	644
Total	4066	3585	4245	4434	4263	20593	

	D.F.	SS	MS	VR
Blocks	4	84761	21190	N.S.
Treats.	4	2681661	670415	17.49***
Error	16	612996	38312	
Total	24	3379418		

L.S.D. 5% 146 1% 202 .1% 277

(b) Clover

	B_1	B_2	B_3	B_4	B_5	Total	Mean
T_2	28	31	34	16	19	128	27
T_3	15	26	36	16	18	111	22
T_4	49	42	12	33	29	165	33
T_6	52	42	2	21	17	134	27
T_7	39	46	25	19	26	155	31
Total	183	187	109	105	109	693	

	DF	SS	MS	VR
Blocks	4	1440	360	2.88
Treats.	4	373	93	N.S.
Error	16	2013	125	
Total	24	3826		

10.2.2. Dry matter yield $g/0.25\ m^2$

(a) Pasture

		T_2	T_3	T_4	T_6	T_7	L.S.D. 5%	L.S.D. 1%	L.S.D. .1%
H_1	N_0	36.5	24.5	23.9	35.3	20.1			
	N_1	46.0	31.7	25.7	42.1	32.0			
Mean		41.2	28.1	24.8	38.7	26.0	3.2	4.4	6.0
H_2	N_0	55.6	45.7	43.9	55.0	40.7			
	N_1	76.0	64.5	56.1	78.2	61.4			
Mean		65.3	55.0	49.9	66.7	51.1	10.3	14.2	19.5
H_3	N_0	130.1	133.2	129.5	131.4	126.3			
	N_1	135.1	152.9	142.5	132.5	151.3			
Mean		132.6	143.3	136.0	132.0	138.9	22.6	30.6	-
H_4	N_0	172.4	175.2	167.2	163.0	169.2			
	N_1	177.2	164.2	154.2	163.6	193.8			
Mean		175.7	169.6	160.8	163.3	181.6			

Harvest 1

	DF	SS	MS	VR
Blocks	4	455.7	113.9	2.19
Treats.	4	2326.6	381.6	11.22***
Error (i)	16	829.5	51.8	
Nitrogen	1	691.9	691.9	28.59***
T_2 x N.	4	141.1	35.2	1.45
Error(ii)	20	485.3	24.2	
Total	49	4930.1		

Harvest 2	DF	SS	MS	VR
Blocks	4	824.9	206.2	1.74
Treats.	4	2498.6	624.6	5.27**
Error (i)	16	1896.2	118.5	
Nitrogen	1	4621.4	4621.4	105.27***
T_2 x N	4	206.2	51.5	1.17
Error (ii)	20	879.5	43.9	
Total	49	10926.8		

Harvest 3

	DF	SS	MS	VR
Blocks	4	2116	529.0	N.S.
Treats.	4	762	190.5	N.S.
Error (i)	16	8915	557.1	
Nitrogen	1	2033	2033.0	4.85*
T_2 x N	4	1065	266.2	N.S.
Error (ii)	20	8380	419.0	
Total	49	23271		

Harvest 4

	DF	SS	MS	VR
Blocks	4	4809	1201	1.13
Treats.	4	2965	741	N.S.
Error (i)	16	16987	1061	
Nitrogen	1	5	5	N.S.
T_2 x N	4	2279	569	1.45
Error (ii)	20	7843	392	
Total	49	34888		

(b) Grass

		T_2	T_3	T_4	T_6	T_7	L.S.D. 5%	1%	.1%
H_1	N_0	31.3	19.1	18.2	30.9	13.7			
	N_1	41.9	23.3	21.4	35.5	26.1			
Mean		36.6	21.2	19.8	33.2	19.9	5.7	7.9	10.9
H_2	N_0	50.4	29.3	30.4	43.6	29.6			
	N_1	70.1	54.1	45.7	69.9	51.7			
Mean		60.2	41.7	38.0	56.7	40.6	1.9	2.7	3.7
H_3	N_0	75.1	59.7	81.5	85.5	60.5			
	N_1	119.4	122.3	121.7	97.3	113.8	21.9	31.7	43.6
Mean		97.3	91.0	101.6	91.5	87.2			
H_4	N_0	100.4	76.2	58.0	79.2	74.6			
	N_1	141.8	123.2	99.2	135.4	131.8			
Mean		121.1	99.7	77.6	107.3	104.2	38.5	53.0	72.9

Harvest 1

	df	SS	MS	VR
Blocks	4	242.0	60.5	1.62
Treats.	4	2628.0	657.0	17.66***
Error (i)	16	596.4	37.2	
Nitrogen	1	612.5	612.5	31.01***
$T_2 \times N$	4	175.4	43.8	2.22
Error (ii)	20	395.0	19.7	
Total	49	4649.3		

Harvest 2

	DF	SS	MS	VR
Blocks	4	32.75	8.18	1.95
Treats.	4	417.33	104.33	24.95***
Error (i)	16	66.96	4.18	
Nitrogen	1	585.03	585.03	60.49***
T_2 x N	4	18.90	4.72	N.S.
Error (ii)	20	193.43	9.67	
Total	49	1314.40		

Harvest 3

	DF	SS	MS	VR
Blocks	4	10509.4	2627.3	4.44*
Treats.	4	1300.0	325.0	N.S.
Error (i)	16	9448.7	590.5	
Nitrogen	1	22527.2	22527.2	39.03***
T_2 x N	4	3680.6	920.1	1.59
Error (ii)	20	11540.4	577.0	
Total	49	59006.3		

Harvest 4

	DF	SS	MS	VR
Blocks	4	16866	4216	2.55
Treats.	4	9983	2495	1.51
Error (i)	16	26443	1652	
Nitrogen	1	28560	28560	27.20***
T_2 x N	4	613	153	N.S.
Error (ii)	20	21018	1050	
Total	49	103483		

(c) Clover

		T_2	T_3	T_4	T_6	T_7	L.S.D. 5%	1%	.1%
H_1	N_0	6.30	4.30	5.70	4.40	6.40			
	N_1	4.10	8.40	4.30	6.70	5.90			
Mean		5.20	6.30	5.00	5.50	6.10		N.S.	
H_2	N_0	5.09	15.70	13.59	11.48	11.17			
	N_1	5.96	10.90	10.07	8.39	11.59			
Mean		5.30	13.30	11.83	9.93	11.38		N.S.	
H_3	N_0	55.50	73.60	48.10	46.50	65.90			
	N_1	15.70	50.60	20.70	35.20	37.60			
Mean		35.60	61.20	34.40	40.80	51.70		N.S.	
H_4	N_0	73.00	98.00	109.00	85.00	93.00			
	N_1	35.00	41.00	57.00	28.00	50.00			
Mean		54.00	69.50	83.00	56.50	71.50		N.S.	

Harvest 1

	DF	SS	MS	VR
Blocks	4	45.45	11.36	N.S.
Treats.	4	13.75	3.43	N.S.
Error (i)	16	207.30	12.95	
Nitrogen	1	0.00	0.00	N.S.
T_2 x N	4	68.58	17.14	2.50
Error (ii)	20	137.05	6.85	
Total	49			

Harvest 2

	DF	SS	MS	VR
Blocks	4	248.61	62.15	2.31
Treats.	4	354.09	88.52	3.30
Error (i)	16	426.92	26.82	
Nitrogen	1	51.21	51.21	1.93
T_2 x N	4	63.60	15.90	N.S.
Error (ii)	20	529.72	26.48	
Total	49	1674.15		

Harvest 3

	DF	SS	MS	VR
Blocks	4	4822.3	1205.5	2.88
Treats.	4	5547.9	1386.9	3.31
Error (i)	16	6693.3	418.3	
Nitrogen	1	8416.2	8416.2	26.06***
T_2 x N	4	1055.0	263.7	N.S.
Error (ii)	20	6459.5	322.9	
Total	49	32999.2		

Harvest 4

	DF	SS	MS	VR
Blocks	4	4626	1156	1.76
Treats.	4	5663	1415	2.15
Error (i)	16	10497	656	
Nitrogen	1	30406	30406	46.99***
T_2 x N	4	782	195	N.S.
Error (ii)	20	12959	647	
Total	49	64933		

10.3.0. Experiment 2

10.3.1. Dry matter yield of wheat g/3m length of rows (Means)

						L.S.D.		
		D_1	D_2	D_3	D_4	5%	1%	.1%
	N - S	33.62	29.11	35.05	26.81			
	E - W	35.77	24.96	43.07	28.20			
H_1	Mean	34.70	27.04	39.01	27.51	6.19	8.39	11.23
	N - S	154.90	132.70	222.90	189.60			
	E - W	155.10	121.10	194.40	186.00			
H_2	Mean	155.00	123.90	208.65	187.80	3.38	4.58	6.14
	N - S	392.15	332.17	588.20	520.61			
	E - W	351.56	337.88	594.17	488.14			
H_3	Mean	371.85	335.02	591.19	504.38	47.63	64.55	86.43
	N - S	400.40	365.30	572.00	504.30			
	E - W	368.30	313.60	578.50	505.90			
H_4	Mean	384.35	339.45	575.20	505.10	44.93	60.89	81.53
	N - S	373.20	333.80	585.40	502.60			
	E - W	339.20	319.80	523.00	509.40			
H_5	Mean	356.20	326.40	554.20	506.00	49.66	67.30	90.10

(a) Analysis of variance as 2 (main plots) x 4 (spacing-rate combination) randomised block design.

Harvest 1

	DF	SS	MS	VR
Blocks	4	1157.35	289.33	16.91**
Direction	1	34.61	34.61	2.02
Error (i)	4	68.41	17.10	
Densities	3	1022.42	340.80	7.52**
Dir. x Den.	3	187.15	62.38	1.37
Error (ii)	24	1086.49	45.27	
Total	39	3556.43		

Harvest 2

	DF	SS	MS	VR
Blocks	4	614.11	153.52	13.68*
Direction	1	8.78	8.78	N.S.
Error (i)	4	44.88	11.22	
Densities	3	415.54	138.51	10.26***
Dir. x Den.	3	12.64	4.21	N.S.
Error (ii)	24	324.11	13.50	
Total	39	1420.06		

Harvest 3

	DF	SS	MS	VR
Blocks	4	185626	46406	10.91*
Direction	1	2355	2355	N.S.
Error (i)	4	17002	4250	
Densities	3	422143	140714	52.78***
Dir. x Den.	3	4570	1523	N.S.
Error (ii)	24	63987	2666	
Total	39	695683		

Harvest 4

	DF	SS	MS	VR
Blocks	4	213189	53297	9.15*
Direction	1	3572	3572	N.S.
Error (i)	4	23289	5822	
Densities	3	352380	117460	49.51***
Dir. x Den.	3	5802	1934	N.S.
Error (ii)	24	56933	2372	
Total	39	655165		

Harvest 5

	DF	SS	MS	VR
Blocks	4	201389	50347	13.33*
Direction	1	6812	6812	1.80
Error (i)	4	15100	3775	
Densities	3	372511	124170	42.90***
Dir. x Den.	3	6476	2158	N.S.
Error (ii)	24	69467	2894	
Total	39	671755		

(b) Analysis of variance as a 2 (main plot) x 2 (spacing) x 2 (rate) factorial design.

Harvest 1

	DF	SS	MS	VR
Blocks	4	1557.35	289.33	16.91**
Direction	1	34.61	34.61	2.02
Error (i)	4	68.41	17.10	
Spacing	1	58.83	58.83	1.29
Rate	1	925.35	925.35	20.44***
Dir. x Sp.	1	82.06	82.06	1.81
Dir. x R.	1	105.01	105.01	2.31
Sp. x R	1	38.24	38.24	N.S.
D X Sp. x R.	1	0.08	0.08	N.S.
Error (ii)	24	1086.49	45.27	
Total	39	3556.43		

Harvest 2

	DF	SS	MS	VR
Blocks	4	614.11	153.52	13.68*
Direction	1	8.78	8.78	N.S.
Error (i)	4	44.88	11.22	
Spacing	1	345.45	345.75	25.58***
Rate	1	67.47	67.47	4.99*
Dir. x Sp.	1	4.46	4.46	N.S.
Dir. x R.	1	2.28	2.28	N.S.
Sp. x R.	1	2.62	2.62	N.S.
D x Sp. x R.	1	5.70	5.70	N.S.
Error (ii)	24	324.11	13.50	
Total	39	1420.06		

Harvest 3

	DF	SS	MS	VR
Blocks	4	185626.0	46406.0	10.91*
Direction	1	2355.0	2335.0	N.S.
Error (i)	4	17002.0	4250.0	
Spacing	1	377681.0	37681.0	141.66***
Rate	1	38218.0	38128.0	14.33***
Dir. x Sp.	1	43.0	43.0	N.S.
Dir. x R	1	38.0	38.0	N.S.
Sp. x R	1	6244.0	6244.0	2.34
D x Sp. x R.	1	4489.0	4489.0	1.68
Error (ii)	24	63987.0	2666.0	
Total	39	695683.0		

Harvest 4

	DF	SS	MS	VR
Blocks	4	213189.0	53297.0	9.15*
Direction	1	3572.0	3572.0	N.S.
Error (i)	4	23289.0	5822.0	
Spacing	1	317730.0	317730.0	133.95***
Rate	1	33062.0	33062.0	13.93**
Dir. x Sp.	1	5290.0	5290.0	2.23
Dr. x R.	1	378.0	378.0	N.S.
Sp. x R.	1	1588.0	1588.0	N.S.
D x Sp. x R.	1	134.0	134.0	N.S.
Error (ii)	24	56933.0	2372.0	
Total	39	655165.0		

Harvest 5

	DF	SS	MS	VR
Blocks	4	201389.0	50347.0	13.33*
Direction	1	6812.0	6812.0	1.80
Error (i)	4	15100.0	3774.0	
Spacing	1	356455.0	356455.0	123.17***
Rate	1	15210.0	15210.0	5.25*
Dir. x Sp.	1	29.0	29.0	N.S.
Dir. x R.	1	4884.0	4884.0	1.68
Sp. x R.	1	846.0	846.0	N.S.
D. x Sp. x R.	1	1563.0	1563.0	N.S.
Error (ii)	24	69467.0	2894.0	
Total	39	671755.0		

10.3.2. Number of tillers/m length of row (Mean)

		D_1	D_2	D_3	D_4	L.S.D. 5%	L.S.D. 1%	L.S.D. .1%
H_1	N - S	69.2	50.0	84.8	57.4			
	E - W	77.5	51.0	87.4	57.8			
	Mean	73.3	50.5	86.1	57.6	7.4	10.0	13.4
H_2	N - S	69.8	58.6	83.6	75.0			
	E - W	66.4	51.8	85.2	79.6			
	Mean	68.1	55.2	84.4	72.3	12.8	17.4	23.3
H_3	N - S	61.6	46.6	83.2	69.6			
	E - W	63.4	52.2	84.2	65.8			
	Mean	62.5	49.4	83.7	67.7	7.9	10.7	14.3
H_4	N - S	63.6	49.6	80.8	71.6			
	E - W	59.6	43.0	76.2	66.2			
	Mean	62.6	46.3	78.5	68.9	5.5	7.5	10.0

Harvest 1

	DF	SS	MS	VR
Blocks	4	1870.0	467.5	6.40*
Direction	1	93.0	93.0	1.27
Error (i)	4	292.0	73.0	
Spacing	1	990.0	990.0	15.34***
Rate	1	6579.0	6579.0	102.00***
Dir. x Sp.	1	24.0	24.0	N.S.
Dir. x R.	1	56.0	56.0	N.S.
Sp. x R.	1	82.0	82.0	1.27
D x Sp. x R.	1	15.0	15.0	N.S.
Error (ii)	24	1548.0	64.5	
Total	39	11549.0		

Harvest 2

	DF	SS	MS	VR
Blocks	4	5050.0	1262.0	114.72*
Direction	1	122.0	122.0	11.09*
Error (i)	4	45.0	11.0	
Spacing	1	2788.0	2788.0	14.29 ***
Rate	1	1562.0	1562.0	8.01 **
Dir. x Sp.	1	27.0	27.0	N.S.
Dir. x R.	1	68.0	68.0	N.S.
Sp. x R.	1	3.0	3.0	N.S.
D. x Sp. x R.	1	6.0	6.0	N.S.
Error (ii)	24	4693.0	195.0	
Total	39	14364.0		

Harvest 3

	DF	SS	MS	VR
Blocks	4	4433.0	1108.0	92.33***
Direction	1	13.0	13.0	1.08
Error (i)	4	49.0	12.0	
Spacing	1	3900.0	3900.0	53.42***
Rate	1	2117.0	2117.0	29.00***
Dir. x Sp.	1	66.0	66.0	N.S.
Dr. x R	1	1.0	1.0	N.S.
Sp. x R.	1	21.0	21.0	N.S.
D x Sp. x R	1	46.0	46.0	N.S.
Error (ii)	24	1764.0	73.0	
Total	39	12410.0		

Harvest 4

	DF	SS	MS	VR
Blocks	4	4161.0	1040.0	17.93*
Direction	1	319.0	319.0	5.50
Error (i)	4	233.0	58.0	
Spacing	1	3705.0	3705.0	102.91***
Rate	1	1677.0	1677.0	46.58***
Dir. x Sp.	1	5.0	5.0	N.S.
Dir. x R.	1	1.0	1.0	N.S.
Sp. x R.	1	113.0	113.0	3.13
D x Sp. x R.	1	0.0	0.0	N.S.
Error (ii)	24	873.0	36.0	
Total	39	11087.0		

10.3.3. Weight/Tiller (Mean)

		D_1	D_2	D_3	D_4	L.S.D. 5%	L.S.D. 1%	L.S.D. .1%
H_1	N-S	0.157	0.158	0.157	0.155			
	E-W	0.152	0.161	0.165	0.162			
	Mean	0.155	0.160	0.152	0.159		N.S.	
H_2	N-S	0.716	0.841	0.890	0.825			
	E-W	0.775	0.745	0.796	0.885			
	Mean	0.746	0.793	0.844	0.855		N.S.	
H_3	N-S	1.927	2.377	2.358	2.507			
	E-W	1.869	2.314	2.352	2.487			
	Mean	1.898	2.346	2.355	2.497	0.097	0.131	0.176
H_4	N-S	2.000	2.480	2.374	2.562			
	E-W	2.127	2.384	2.445	2.641			
	Mean	2.063	2.432	2.409	2.601	0.167	0.227	0.301
H_5	N-S	1.868	2.424	2.304	2.425			
	E-W	2.020	2.235	2.266	2.504			
	Mean	1.944	2.329	2.285	2.464	0.198	0.268	0.359

Harvest 1

	DF	SS	MS	VR
Blocks	4	0.004		
Direction	1	0.000		
Error (i)	4	0.001		
Spacing	1	0.000		
Rate	1	0.000		
Dir. x Sp.	1	0.000		
Dir. x R.	1	0.000		
Sp. x R.	1	0.000		
D x Sp. x R.	1	0.001		
Error (ii)	24	0.001		
Total	39	0.007		

Harvest 2

	DF	SS	MS	VR
Blocks	4	0.027	0.007	14.00*
Direction	1	0.001	0.001	2.00
Error (i)	4	0.002	0.005	
Spacing	1	0.007		
Rate	1	0.001		
Dir. x Sp.	1	0.000		
Dir. x R.	1	0.000		
Sp. x R.	1	0.001		
D x Sp. x R.	1	0.004		
Error (ii)	24	0.010		
Total	39	0.053		

Harvest 3

	DF	SS	MS	VR
Blocks	4	0.179	0.044	8.80*
Direction	1	0.014	0.014	2.80
Error (i)	4	0.022	0.005	
Spacing	1	0.925	0.925	84.09***
Rate	1	0.871	0.871	79.18***
Dir. x Sp.	1	0.005	0.005	N.S.
Dir. x R.	1	0.014	0.014	1.27
Sp. x R.	1	0.233	0.233	21.18***
D x Sp. x R.	1	0.000	0.000	
Error (ii)	24	0.264	0.011	
Total	39	2.527		

Harvest 4

	DF	SS	MS	VR
Blocks	4	0.108	0.027	N.S.
Direction	1	0.020	0.020	N.S.
Error (i)	4	0.207	0.051	
Spacing	1	0.664	0.664	20.12***
Rate	1	0.784	0.784	23.81***
Dir. x Sp.	1	0.009	0.009	N.S.
Dir. x R	1	0.029	0.029	N.S.
Sp. x R.	1	0.078	0.078	2.36
D x Sp. x R.	1	0.033	0.033	1.00
Error (ii)	24	0.798	0.033	
Total	39	2.732		

Harvest 5

	DF	SS	MS	VR
Blocks	4	0.331	0.082	N.S.
Direction	1	0.000	0.000	N.S.
Error (i)	4	0.333	0.083	
Spacing	1	0.567	0.567	12.32***
Rate	1	0.798	0.793	17.34***
Dir. x Sp.	1	0.003	0.003	N.S.
Dir. x R.	1	0.031	0.031	N.S.
Sp. x R.	1	0.105	0.105	2.28
D x Sp. x R.	1	0.133	0.133	2.89
Error (ii)	24	1.102	0.046	
Total	39	3.403		

10.3.4. Grain Yield, g/3 m length of row

		B_1	B_2	B_3	B_4	B_5	Total	Mean
N-S	D_1	148.8	175.2	176.2	94.6	119.8	714.6	142.9
	D_2	232.7	163.0	114.8	113.1	126.5	750.1	150.0
	D_3	156.6	219.7	290.1	212.4	192.1	1070.9	214.2
	D_4	210.8	241.0	229.4	153.5	112.3	947.0	189.4
Total		748.9	798.9	810.5	573.6	550.7	3482.6	
E-W	D_1	149.4	139.6	144.3	118.6	125.2	677.1	135.4
	D_2	142.7	122.2	154.4	95.7	125.8	640.8	128.2
	D_3	242.6	239.9	228.7	185.5	138.8	1035.5	207.1
	D_4	244.4	233.6	210.3	183.0	151.2	1022.5	204.5
Total		779.1	735.3	737.7	582.8	541.0	3375.9	
G/total		1528.0	1534.2	1548.2	1156.4	1091.7	6858.5	

	DF	SS	MS	VR
Blocks	4	25843.0	6460.0	25.43**
Direction	1	285.0	285.0	1.12
Error (i)	4	1019.0	254.0	
Spacing	1	41816.0	41816.0	38.18***
Rate	1	474.0	474.0	N.S.
Dir. x Sp.	1	873.0	873.0	N.S.
Dir. x R.	1	38.0	38.0	N.S.
Sp. x R.	1	463.0	463.0	N.S.
D x Sp. x R.	1	834.0	834.0	N.S.
Error (ii)	24	26291.0	1095.0	
Total	39	97936.0		

L.S.D. 5% = 30.5
1% = 41.4
.1% = 55.4

10.3.4. Total L (Mean)

		D_1	D_2	D_3	D_4	L.S.D. 5%	L.S.D. 1%	L.S.D. 0.1%
	N - S	1.523	1.093	0.563	0.451			
	E - W	1.452	0.984	0.731	0.414			
H_1	Mean	1.487	1.038	0.647	0.432	0.193	0.271	0.384
	N - S	2.770	1.988	1.589	1.625			
	E - W	2.609	2.103	1.798	1.404			
H_2	Mean	2.689	2.045	1.093	1.514	0.363	0.510	-

Harvest 1

	DF	SS	MS	VR
Blocks	2	0.126	0.063	2.25
Direction	1	0.001	0.001	N.S.
Error (i)	2	0.057	0.028	
Densities	3	3.880	1.293	26.38***
Dir. x Den.	3	0.069	0.023	N.S.
Error (ii)	12	0.599	0.049	
Total	23	4.732		

Harvest 2

	DF	SS	MS	VR
Blocks	2	0.678	0.339	4.18
Direction	1	0.002	0.002	N.S.
Error (i)	2	0.163	0.081	
Densities	3	4.842	1.614	9.55**
Dir. x Den.	3	0.196	0.065	N.S.
Error (ii)	12	2.035	0.169	
Total	23	7.916		

10.3.5. L. distribution

A - E are lateral sections with the centre of the plants in "C" reading E to W in N-S rows and N to S in E-W rows.

(a) Harvest 1 E - W rows
60 lbs/acre 7" spacing (D_1)

	A	B	C	D	E	Total
12-15"	-	-	-	-	-	-
9-12"	-	-	0.06	0.01	-	0.07
6-9"	-	0.03	0.44	0.20	-	0.67
3-6"	-	0.07	1.11	0.23	-	1.41
0-3"	0.01	0.06	0.56	0.07	0.01	0.71
Total	0.01	0.16	2.17	0.51	0.01	2.86

30 lbs/acre 7" spacing (D_2)

	A	B	C	D	E	Total
12-15"	-	-	-	-	-	-
9-12"	-	-	0.04	-	-	0.04
6-9"	-	0.09	0.26	0.05	-	0.40
3-6"	-	0.16	0.67	0.08	-	0.91
0-3"	-	0.08	0.46	0.04	-	0.58
Total	-	0.33	1.43	0.17	-	1.93

30 lbs/acre 14" spacing (D_3)

	A	B	C	D	E	Total
12-15"	-	-	0.01	-	-	0.01
9-12	-	-	0.10	0.01	-	0.11
6-9	0.01	0.09	0.39	0.17	-	0.66
3-6	-	0.17	1.02	0.16	-	1.35
0-3	-	0.09	0.59	0.06	-	0.74
Total	0.01	0.35	2.11	0.40	-	2.87

15 lbs/acre 14" spacing (D_4)

	A	B	C	D	E	Total
12-15"	-	-	-	-	-	-
9-12"	-	-	0.02	-	-	0.02
6-9"	-	0.02	0.21	0.05	-	0.28
3-6"	-	0.07	0.65	0.09	-	0.81
0-3"	-	0.05	0.42	0.06	-	0.53
Total	-	0.14	1.34	0.20	-	1.64

(b) Harvest 1 N - S rows

60 lbs/acre 7" spacing (D_1)

	A	B	C	D	E	Total
12-15"	-	-	-	-	-	-
9-12"	-	0.04	0.07	0.02	-	0.13
6-9"	0.01	0.11	0.49	0.18	0.01	0.80
3-6"	-	0.09	1.21	0.14	-	1.44
0-3"	-	0.05	0.52	0.05	-	0.62
Total	0.01	0.29	2.29	0.39	0.01	2.99

30 lbs/acre 7" spacing (D_2)

	A	B	C	D	E	Total
12-15"	-	-	-	-	-	-
9-12"	-	-	0.09	0.02	-	0.11
6-9"	-	0.06	0.33	0.12	0.01	0.52
3-6"	-	0.06	0.78	0.16	-	1.00
0-3"	-	0.06	0.39	0.07	0.01	0.53
Total	-	0.18	1.59	0.37	0.02	2.16

30 lbs/acre 14" spacing (D_3)

	A	B	C	D	E	Total
12-15"	-	-	-	-	-	-
9-12"	-	0.01	0.07	0.02	-	0.10
6-9"	-	0.09	0.41	0.09	-	0.59
3-6"	-	0.08	0.84	0.14	-	1.06
0-3"	-	0.04	0.39	0.04	-	0.47
Total	-	0.22	1.71	0.29	-	2.22

15 lbs/acre 14" spacing (D_4)

	A	B	C	D	E	Total
12-15"	-	-	-	-	-	-
9-12"	-	0.02	0.03	0.01	-	0.06
6-9"	-	0.07	0.24	0.06	-	0.37
3-6"	-	0.08	0.66	0.11	-	0.85
0-3"	-	0.09	0.39	0.02	-	0.50
Total	-	0.26	1.32	0.20	-	1.78

(c) Harvest 2. E - W rows

60 lbs/acre 7" spacing

	A	B	C	D	E	Total
24-27"	-	-	0.07	0.04	-	0.11
21-24"	-	0.02	0.47	0.11	-	0.60
18-21"	-	0.11	0.75	0.12	-	0.98
15-18"	-	0.06	0.69	0.14	-	0.89
12-15"	0.01	0.03	0.65	0.11	0.01	0.81
9-12"	-	0.07	0.53	0.15	0.03	0.78
6-9"	0.01	0.02	0.57	0.02	-	0.62
3-6"	-	0.02	0.24	0.01	0.01	0.28
0-3"	-	-	0.03	-	-	0.03
Total	0.02	0.33	4.00	0.70	0.05	5.10

30 lbs/acre 7" spacing (D_2)

	A	B	C	D	E	Total
24-27"	-	-	0.03	-	-	0.03
21-24"	-	0.02	0.26	0.10	-	0.38
18-21"	-	0.03	0.50	0.16	-	0.69
15-18"	-	0.08	0.55	0.09	-	0.72
12-15"	-	0.09	0.57	0.13	0.01	0.80
9-12"	-	0.07	0.46	0.04	-	0.57
6-9"	-	0.06	0.42	0.06	-	0.54
3-6"	0.01	-	0.28	-	-	0.29
0-3"	-	0.02	0.06	0.01	-	0.09
Total	0.01	0.37	3.13	0.59	0.01	4.11

30 lbs/acre 14" spacing (D_3)

	A	B	C	D	E	Total
24-27"	-	-	0.11	0.06	-	0.17
21-24"	-	0.02	0.27	0.12	-	0.41
18-21"	-	0.03	0.61	0.29	0.04	0.97
15-18"	-	0.09	0.94	0.26	0.02	1.31
12-15"	-	0.06	0.85	0.22	0.05	1.18
9-12"	-	0.07	0.97	0.20	0.01	1.25
6-9"	-	0.08	0.69	0.15	0.01	0.93
3-6"	0.01	0.04	0.51	0.09	-	0.65
0-3"	0.01	0.02	0.13	0.03	-	0.19
Total	0.02	0.41	5.08	1.42	0.13	7.06

15 lbs/acre 14" spacing (D_4)

	A	B	C	D	E	Total
24-27"	-	-	0.01	-	-	0.01
21-24"	-	-	0.12	0.06	-	0.18
18-21"	-	0.04	0.35	0.19	0.02	0.60
15-18"	-	0.04	0.65	0.23	-	0.92
12-15"	-	0.05	0.68	0.16	-	0.89
9-12"	-	0.02	0.74	0.17	0.01	0.94
6-9"	-	0.14	0.73	0.14	-	1.01
3-6"	-	0.11	0.53	0.06	-	0.70
0-3"	-	0.02	0.23	0.06	-	0.31
Total	-	0.42	4.04	1.07	0.03	5.56

(d) Harvest 2. N-S rows

60 lbs/acre 7" spacing (D_1)

	A	B	C	D	E	Total
27-30"	-	-	0.05	-	-	0.05
24-27"	-	-	0.23	0.10	-	0.33
21-24"	-	0.01	0.64	0.11	-	0.76
18-21"	-	0.13	0.82	0.14	-	1.09
15-18"	-	0.05	0.76	0.13	0.01	0.95
12-15"	-	0.06	0.62	0.04	-	0.72
9-12"	-	0.05	0.66	0.02	-	0.73
6-9"	-	0.04	0.50	0.04	-	0.58
3-6"	-	0.02	0.17	0.01	-	0.20
0-3"	-	-	0.04	-	-	0.04
Total	-	0.36	4.49	0.59	0.01	5.45

30 lbs/acre 7" spacing (D_2)

	A	B	C	D	E	Total
27-30"	-	-	-	0.01	-	0.01
24-27"	-	-	0.06	0.04	-	0.10
21-24"	-	0.01	0.28	0.09	-	0.38
18-21"	-	0.07	0.50	0.11	0.01	0.69
15-18"	-	0.08	0.52	0.09	-	0.69
12-15"	-	0.05	0.43	0.03	-	0.51
9-12"	-	0.03	0.38	0.05	-	0.46
6-9"	-	0.05	0.34	0.02	-	0.41
3-6"	-	0.04	0.22	0.02	-	0.28
0-3"	-	0.01	0.10	0.01	-	0.12
Total	-	0.34	2.83	0.47	0.01	3.65

30 lbs/acre 14" spacing (D_3)

	A	B	C	D	E	Total
24-27"	-	-	0.05	0.04	-	0.09
21-24"	-	0.03	0.47	0.14	-	0.64
18-21"	-	0.09	0.85	0.11	-	1.05
15-18"	-	0.03	0.96	0.17	-	1.16
12-15"	-	0.08	0.82	0.09	-	0.99
9-12"	-	0.08	0.71	0.09	-	0.88
6-9"	-	0.06	0.70	0.08	-	0.84
3-6"	-	0.08	0.54	0.05	-	0.67
0-3"	-	0.04	0.17	-	-	0.21
Total	-	0.49	5.27	0.77	-	6.53

15 lbs/acre 14" spacing (D_4)

	A	B	C	D	E	Total
27-30"	-	-	0.01	0.01	-	0.02
24-27"	-	-	0.12	0.10	-	0.22
21-24"	-	-	0.38	0.22	0.01	0.61
18-21"	0.01	0.03	0.68	0.19	0.14	1.05
15-18"	-	0.10	0.62	0.19	0.02	0.93
12-15"	-	0.23	0.64	0.15	0.01	1.03
9-12"	-	0.15	0.67	0.17	0.01	1.00
6-9"	-	0.11	0.58	0.09	-	0.78
3-6"	-	0.09	0.40	0.06	-	0.55
0-3"	-	0.04	0.15	0.01	-	0.20
Total	0.01	0.75	4.25	1.19	0.19	6.39

10.3.6. Harvest 2. Wt. of dead leaves (% of total dry matter).

	B_1	B_2	B_3	Total	Mean
D_1	9.4	11.5	7.7	28.6	9.53
D_2	7.4	6.5	8.1	22.0	7.33
D_3	5.2	4.7	4.9	14.8	4.93
D_4	3.5	1.9	2.1	7.5	2.50
N - S Total	25.5	24.6	22.8	72.9	
D_1	12.9	14.0	7.1	34.0	11.33
D_2	8.0	10.7	5.7	24.4	8.13
D_3	8.3	7.1	3.3	18.7	6.23
D_4	4.8	1.7	4.5	11.0	3.66
E - W Total	34.0	33.5	20.6	88.1	

	DF	SS	MS	VR
Blocks	2	19.9	9.95	N.S.
Direction	1	9.6	9.60	N.S.
Error (i)	2	9.9	4.95	
Densities	3	176.0	58.66	15.85***
Dir. x Den.	3	0.8	0.26	N.S.
Error (ii)	12	44.4	3.70	
Total	23	256.1		

L.S.D. 5% = 1.77
1% = 2.40
.1% = 3.22

10.3.7. Light intensity at ground level (% daylight)

(a) 60 lbs/acre 7" spacing N - S rows (D_1)

	a.m.			Noon			p.m.		
Date	P_0	$P_{3\frac{1}{2}}$	Mean	P_0	$P_{3\frac{1}{2}}$	Mean	P_0	$P_{3\frac{1}{2}}$	Mean
30/7	54.7	57.9	56.3	52.3	92.5	72.4	57.3	62.9	60.1
5/8	52.8	56.8	54.8	34.0	74.8	54.4	53.9	54.7	54.3
12/8	11.4	13.7	12.5	51.0	57.2	54.1	16.8	12.0	14.4
19/8	9.0	16.8	12.9	4.6	59.0	31.8	5.0	4.1	4.5
26/8	20.2	15.9	18.0	16.2	62.3	39.2	2.9	3.8	3.4
2/9	5.0	4.8	4.9	14.7	50.8	32.7	2.5	1.9	2.2
9/9	13.7	16.4	15.1	7.2	34.9	21.1	15.8	12.6	14.2
16/9	3.7	2.9	3.3	15.2	15.8	15.5	2.0	2.0	2.0
23/9	1.5	1.5	1.5	1.1	51.1	26.1	1.3	1.3	1.3
30/9	-	-	-	-	-	-	-	-	-
7/10	5.0	6.8	5.9	2.3	49.9	26.1	8.1	10.8	9.5
15/10	6.2	7.5	6.8	8.5	8.3	8.4	4.7	4.1	4.4
22/10	12.6	4.6	8.6	8.9	75.0	41.9	17.0	18.3	18.0
29/10	18.3	23.3	20.8	8.9	73.1	41.0	12.1	12.0	12.1
5/11	5.7	9.3	7.5	19.2	50.2	34.7	-	-	-
12/11	8.5	4.6	5.1	17.2	66.6	41.9	22.1	20.3	21.2
19/11	-	-	-	11.9	63.8	37.9	-	-	-

(b) 60 lbs/acre 7" spacing E - W rows (D_1)

	a.m.			Noon			p.m.		
Date	P_0	$P_{3\frac{1}{2}}$	Mean	P_0	$P_{3\frac{1}{2}}$	Mean	P_0	$P_{3\frac{1}{2}}$	Mean
30/7	49.9	58.3	54.1	89.4	83.6	86.5	48.1	55.8	51.9
5/8	62.3	71.2	66.7	49.4	51.8	50.6	56.6	70.0	63.3
12/8	22.6	20.1	21.3	68.1	72.9	70.5	18.1	17.5	17.8
19/8	10.1	13.0	11.5	30.1	27.4	28.7	10.0	5.0	7.5
26/8	22.2	17.8	20.0	33.3	19.7	26.5	4.3	4.1	4.2
2/9	8.2	9.0	8.6	14.3	17.0	15.7	6.3	10.5	8.4
9/9	10.7	12.9	11.8	20.6	20.6	20.6	27.6	29.9	28.8
16/9	3.3	3.6	3.4	15.8	20.3	17.7	1.7	1.2	1.4
23/9	2.4	2.2	2.3	16.6	4.4	10.5	2.1	4.3	3.2
30/9	-	-	-	-	-	-	-	-	-
7/10	1.7	1.8	1.7	8.1	24.7	16.4	23.4	23.0	23.2
15/10	8.3	16.8	12.5	24.7	27.1	25.7	11.9	14.3	13.1
22/10	6.0	31.5	18.7	30.5	36.0	33.2	29.7	32.9	31.3
29/10	26.6	28.8	27.7	49.0	55.7	42.3	9.1	31.5	20.3
5/11	6.4	62.4	34.3	47.3	52.7	49.9	-	-	-
12/11	37.4	34.0	35.7	46.9	49.3	48.1	15.6	73.3	44.4
19/11	-	-	-	64.4	40.7	52.5	-	-	-

(c) 30 lbs/acre 7" spacing. N - S rows (D_2)

	a.m.			Noon			p.m.		
Date	P_0	$P_{3\frac{1}{2}}$	Mean	P_0	$P_{3\frac{1}{2}}$	Mean	P_0	$P_{3\frac{1}{2}}$	Mean
30/7	65.8	64.2	65.0	68.2	90.1	79.2	57.0	66.6	61.8
5/8	63.7	69.4	66.5	34.8	88.4	61.6	59.4	66.1	62.8
12/8	22.2	22.2	22.2	66.2	79.3	72.8	5.4	6.9	6.1
19/8	14.4	17.5	16.0	12.6	55.0	33.8	11.8	5.1	8.4
26/8	15.2	21.3	18.2	20.9	81.8	51.4	3.0	2.9	3.0
2/9	12.0	21.9	16.9	21.7	49.4	35.5	6.6	5.8	6.2
9/9	14.3	18.4	16.3	8.5	35.0	21.8	17.0	24.9	21.0
16/9	4.1	4.1	4.1	17.1	24.1	20.6	2.1	2.0	2.0
23/9	1.3	1.3	1.3	1.8	36.6	19.2	1.3	2.7	2.0
30/9	-	-	-	-	-	-	-	-	-
7/10	9.9	1[illegible].0	10.4	4.4	86.0	45.2	15.6	14.9	15.3
15/10	11.6	[illegible].9	12.2	14.6	14.9	14.7	10.3	9.0	9.6
22/10	21.3	7.7	14.6	9.1	63.4	36.2	20.9	25.3	23.1
29/10	25.0	31.6	28.3	14.9	72.6	43.8	18.5	20.5	19.5
5/11	7.9	8.6	8.2	13.2	70.7	41.9	-	-	-
12/11	11.2	10.7	10.9	11.5	55.6	33.5	16.6	17.9	17.2
19/11	-	-	-	17.7	75.5	46.6	-	-	-

(d) 30 lbs/acre 7" spacing. E - W rows (D_2)

	a.m.			Noon			p.m.		
Date	P_0	$P_{3\frac{1}{2}}$	Mean	P_0	$P_{3\frac{1}{2}}$	Mean	P_0	$P_{3\frac{1}{2}}$	Mean
30/7	39.2	56.5	47.9	83.0	84.7	83.9	57.1	61.1	59.1
5/8	59.6	69.8	64.7	77.7	67.8	72.8	55.3	59.2	57.2
12/8	22.1	23.5	22.8	67.4	73.0	70.2	21.6	17.2	19.4
19/8	12.8	12.1	12.4	37.2	30.6	33.9	4.4	15.1	9.7
28/8	8.6	16.0	12.3	31.2	53.7	42.4	3.1	4.5	3.8
2/9	3.1	11.9	10.0	36.0	19.0	27.5	7.6	9.6	8.6
9/9	15.2	24.0	19.6	31.8	29.6	30.7	23.0	26.3	24.7
16/9	3.3	4.9	4.1	25.0	26.1	25.5	1.2	3.3	2.2
23/9	2.3	2.2	2.2	18.2	27.4	22.8	2.2	2.1	2.1
30/9	-	-	-	-	-	-	-	-	-
7/10	1.5	2.2	1.9	41.1	22.1	31.6	14.6	15.7	15.1
15/10	7.3	8.7	81.0	34.1	34.8	34.5	8.0	11.2	9.6
22/10	7.0	32.1	19.5	54.2	33.6	43.9	27.6	31.4	29.5
29/10	25.0	31.2	28.1	61.5	54.6	58.0	9.2	30.8	20.0
5/11	5.0	54.3	29.6	60.1	50.9	55.5	-	-	-
12/11	11.7	13.2	14.9	54.8	55.0	51.6	24.0	37.0	30.5
19/11	-	-	-	65.5	72.2	68.8	-	-	-

(e) 30 lbs/acre 14" spacing N - S rows (D_3)

(i) a.m.

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	Mean
30/7	58.3	58.3	66.6	73.3	65.3
5/8	60.1	66.7	80.3	73.0	70.0
12/8	8.0	14.8	41.6	23.1	21.9
19/8	7.0	5.0	4.7	6.9	5.9
26/8	23.4	15.7	15.7	43.3	19.5
2/9	34.7	16.6	19.7	26.5	24.4
9/9	26.1	30.4	35.5	33.6	31.4
16/9	9.5	8.4	7.8	10.9	9.1
23/9	1.6	1.6	1.6	2.5	1.8
30/9	-	-	-	-	-
7/10	21.3	11.8	18.4	20.2	17.9
15/10	19.6	19.4	21.7	26.3	21.7
22/10	14.7	18.7	26.6	31.3	22.8
29/10	41.6	41.6	44.4	47.2	43.7
5/11	22.7	16.2	22.8	27.2	22.2
12/11	20.0	14.1	17.4	11.6	15.8
19/11	-	-	-	-	-

(ii) Noon

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	Mean
30/7	75.0	95.0	100.0	93.0	90.7
5/8	30.6	84.3	100.0	87.6	75.6
12/8	56.6	73.3	84.9	71.2	71.5
19/8	19.0	87.5	100.0	87.3	72.4
26/8	36.7	77.6	100.0	76.7	72.7
2/9	19.5	64.1	83.5	61.6	57.2
9/9	22.0	48.7	65.8	47.9	42.3
16/9	25.7	36.5	41.2	31.2	33.6
23/9	1.6	58.8	97.1	57.7	53.8
30/9	-	-	-	-	-
7/10	5.1	50.7	88.7	50.1	48.6
15/10	18.3	21.0	30.2	74.4	23.5
22/10	8.7	80.8	96.3	77.2	59.4
29/10	10.2	83.3	95.6	87.8	67.2
5/11	13.2	87.5	91.8	87.7	60.4
12/11	8.9	82.1	100.0	91.0	70.5
19/11	16.6	65.0	100.0	62.5	61.6

(iii) p.m.

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	Mean
30/7	68.9	71.7	75.9	56.4	68.2
5/8	59.1	71.7	77.0	65.9	68.4
12/8	32.9	37.7	26.2	14.0	27.7
19/8	25.2	14.3	18.0	5.2	15.6
26/8	10.1	39.3	13.9	6.9	17.5
2/9	6.9	14.5	20.8	7.1	12.3
9/9	21.5	24.8	23.2	10.6	20.0
16/9	20.1	30.0	7.0	3.1	15.0
23/9	13.8	5.2	23.6	7.8	12.6
30/9	-	-	-	-	-
7/10	22.9	28.5	29.8	20.9	25.5
15/10	31.1	45.0	37.5	31.5	36.3
22/10	39.7	37.9	32.7	31.0	35.3
29/10	33.6	28.8	24.9	26.8	28.5
5/11	-	-	-	-	-
12/11	49.9	66.6	55.2	55.3	56.7
19/11	-	-	-	-	-

(f) 30 lbs/acre 14" spacing. E - W Rows (D_3)

(i) a.m.

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	Mean
30/7	42.2	61.8	57.5	62.5	56.0
5/8	55.3	82.7	83.9	82.1	76.0
12/8	13.8	16.6	19.4	40.9	22.7
19/8	24.1	6.6	15.4	32.6	19.7
26/8	28.8	19.8	48.1	48.9	36.4
2/9	13.5	18.9	23.2	22.1	19.4
9/9	25.3	31.3	34.9	37.6	32.3
16/9	9.7	7.5	4.3	10.4	8.0
23/9	3.6	7.2	57.6	81.5	42.5
30/9	-	-	-	-	-
7/10	4.5	14.7	54.5	73.8	36.8
15/10	14.3	16.6	53.1	81.6	41.4
22/10	6.5	53.2	75.3	73.2	52.0
29/10	29.9	43.3	43.3	43.3	39.9
5/11	4.3	66.2	81.6	81.4	58.4
12/11	12.4	28.1	62.5	86.4	47.3
19/11	-	-	-	-	-

(ii) Noon

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	Mean
30/7	76.8	86.4	97.6	87.5	87.0
5/8	69.5	72.1	81.6	91.5	78.7
12/8	59.5	79.2	86.9	79.2	76.2
19/8	83.1	16.6	70.9	91.6	65.5
26/8	53.1	18.3	37.0	95.0	50.9
2/9	73.9	28.3	37.9	40.1	45.0
9/9	30.4	25.0	26.9	48.5	32.7
16/9	41.8	39.7	45.8	36.4	40.9
23/9	14.4	22.6	9.8	28.4	18.8
30/9	-	-	-	-	-
7/10	50.4	34.1	19.8	42.3	36.6
15/10	36.8	36.7	44.9	45.6	41.0
22/10	72.2	29.5	32.2	30.7	41.0
29/10	82.3	22.6	37.4	53.9	49.0
5/11	83.3	62.2	59.7	87.6	73.2
12/11	61.1	29.4	37.4	67.8	48.9
19/11	58.3	45.8	63.3	95.0	65.6

(iii) p.m.

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	Mean
30/7	63.3	57.1	87.5	86.6	73.6
5/8	55.0	76.3	85.9	71.8	72.2
12/8	35.5	22.5	32.5	39.1	32.4
19/8	27.0	11.5	9.6	54.5	25.6
26/8	10.5	6.4	7.2	20.0	11.0
2/9	18.7	22.0	21.6	15.6	19.4
9/9	38.1	40.7	42.0	38.4	39.8
16/9	2.0	4.3	3.0	2.0	3.3
23/9	15.2	21.6	13.6	45.4	23.9
30/9	-	-	-	-	-
7/10	28.8	33.1	36.8	35.7	33.6
15/10	20.9	17.0	20.8	59.3	29.5
22/10	34.5	42.8	53.5	44.2	45.6
29/10	9.4	27.5	50.8	83.5	42.8
5/11	-	-	-	-	-
12/11	13.7	71.2	76.8	87.5	68.7
19/11	-	-	-	-	-

(g) 15 lbs/acre 14" spacing N - S rows (D_4)

(i) a.m.

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	Mean
30/7	66.6	74.9	74.9	83.3	74.9
5/8	63.6	79.0	89.2	75.6	76.8
12/8	17.1	24.5	30.5	29.4	25.3
19/8	12.4	5.0	15.2	7.8	10.1
26/8	11.0	20.8	24.1	21.9	19.4
2/9	12.7	14.6	17.6	18.5	15.8
9/9	32.6	35.6	39.0	39.4	36.6
16/9	14.7	7.9	10.5	10.7	10.9
23/9	5.8	4.9	3.3	21.3	8.9
30/9	-	-	-	-	-
7/10	10.0	14.4	16.6	19.0	15.0
15/10	21.3	17.7	27.8	26.5	23.3
22/10	9.8	20.3	22.6	22.8	18.8
29/10	41.6	41.6	47.2	47.2	44.4
5/11	10.8	10.8	11.9	10.8	11.0
12/11	7.2	9.6	8.8	13.6	9.8
19/11	-	-	-	-	-

(ii) Noon

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	Mean
30/7	67.7	96.5	100.0	95.6	83.1
5/8	35.4	96.7	100.0	90.3	86.0
12/8	59.7	81.4	92.3	76.8	77.5
19/8	11.7	83.8	100.0	100.0	73.8
26/8	14.9	75.7	95.7	68.5	63.6
2/9	18.3	62.5	89.2	62.0	58.0
9/9	14.4	48.8	56.8	51.6	42.9
16/9	43.1	44.0	55.3	43.6	46.5
23/9	2.2	63.6	97.7	63.2	49.9
30/9	-	-	-	-	-
7/10	4.0	42.5	93.5	61.2	47.7
15/10	19.5	24.5	26.7	25.0	23.8
22/10	7.8	83.6	78.4	96.1	66.6
29/10	10.1	80.1	93.6	80.8	66.9
5/11	16.5	70.0	89.0	71.0	61.6
12/11	13.3	84.2	100.0	83.6	70.2
19/11	16.6	77.0	100.0	73.0	66.5

(iii) p.m.

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	Mean
30/7	72.5	85.9	90.4	68.5	79.0
5/8	67.3	79.6	85.6	66.7	74.8
12/8	48.8	66.6	69.9	32.7	54.5
19/8	3.9	74.4	76.2	14.3	17.3
26/8	3.1	5.9	3.0	2.7	4.9
2/9	27.3	16.6	15.1	13.1	18.0
9/9	15.4	31.5	27.6	11.2	29.4
16/9	5.6	4.4	2.7	1.9	3.6
23/9	2.7	8.1	9.3	2.7	5.7
30/9	-	-	-	-	-
7/10	25.1	30.4	29.3	21.8	26.6
15/10	25.3	23.7	19.4	18.1	21.6
22/10	37.1	33.4	36.8	40.2	32.4
29/10	29.7	24.9	19.1	13.4	21.8
5/11	-	-	-	-	-
12/11	24.9	38.7	30.6	26.9	30.2
19/11	-	-	-	-	-

(h) 15 lbs/acre 14" spacing E - W rows (D_4)

(i) a.m.

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	Mean
30/7	59.8	77.3	71.4	78.5	71.7
5/8	78.5	87.2	88.9	89.0	85.9
12/8	35.0	30.2	15.3	40.0	30.1
19/8	25.4	11.2	27.5	50.1	28.5
26/8	20.1	16.1	18.0	16.1	17.6
2/9	11.5	13.3	27.4	33.2	21.3
9/9	30.0	36.0	36.7	39.7	35.6
16/9	11.6	8.4	9.6	13.1	10.7
23/9	12.0	5.2	4.3	40.5	11.7
30/9	-	-	-	-	-
7/10	16.9	10.1	21.7	65.0	28.4
15/10	14.8	15.6	37.3	80.0	36.9
22/10	11.8	21.8	66.4	45.2	36.3
29/10	43.7	53.1	59.3	53.1	52.3
5/11	6.2	90.6	83.3	79.1	64.8
12/11	7.1	72.3	74.0	43.7	38.1
19/11	-	-	-	-	-

(ii) Noon

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	Mean
30/7	78.1	84.3	100.0	90.6	88.3
5/8	90.6	67.7	98.2	95.9	88.1
12/8	70.7	83.8	92.8	83.9	82.8
19/8	63.9	23.4	50.6	94.6	58.1
26/8	98.3	31.1	42.0	90.0	66.6
2/9	38.8	43.4	48.8	52.5	45.8
9/9	35.6	28.0	37.5	58.1	39.8
16/9	33.6	33.3	34.6	38.7	35.0
23/9	89.9	29.9	19.4	50.5	47.4
30/9	-	-	-	-	-
7/10	29.8	34.6	47.4	66.2	44.5
15/10	26.1	38.9	38.8	30.5	33.5
22/10	60.8	13.7	64.1	69.5	52.0
29/10	72.0	19.9	48.0	75.8	53.9
5/11	80.0	53.5	40.5	54.0	57.0
12/11	62.5	72.2	70.5	84.8	72.5
19/11	71.8	76.3	99.0	85.4	83.1

(iii) p.m.

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	Mean
30/7	72.5	73.8	83.3	85.4	78.7
5/8	70.8	83.2	88.8	94.4	84.3
12/8	62.2	22.7	16.1	59.3	40.1
19/8	31.7	27.5	14.0	59.0	33.1
26/8	12.2	29.2	14.7	29.3	21.3
2/9	23.8	21.6	22.0	36.0	25.8
9/9	26.0	19.8	25.9	24.5	24.0
16/9	9.6	3.8	8.8	20.8	10.7
23/9	16.2	15.2	6.9	31.1	17.3
30/9	-	-	-	-	-
7/10	30.7	33.8	36.6	44.2	36.3
15/10	14.4	12.3	23.1	74.4	31.0
22/10	22.5	28.5	61.2	36.1	43.4
29/10	9.8	19.6	64.2	76.7	42.6
5/11	-	-	-	-	-
12/11	43.7	53.1	81.2	81.2	64.8
19/11	-	-	-	-	-

10.3.8. Light intensity beneath rows. (% daylight transformed to degrees).

		D_1	D_2	D_3	D_4
13/8	N-S	29.10	28.83	23.12	26.93
	E-W	44.29	44.90	63.30	66.08
27/8	N-S	33.46	37.20	37.01	38.47
	E-W	35.88	39.11	38.11	44.43
10/9	N-S	10.34	11.46	11.31	12.22
	E-W	18.04	19.17	25.92	25.96
23/9	N-S	9.35	8.75	9.66	11.04
	E-W	21.90	21.32	29.32	35.12
7/10	N-S	13.54	14.62	11.03	14.59
	E-W	26.79	31.46	36.07	39.30
22/10	N-S	22.34	26.91	19.66	20.85
	E-W	37.18	44.50	45.19	46.42

13, August (Clear day)

	DF	SS	MS	VR
Blocks	4	775.0	193.5	1.78
Direction	1	7645.0	7645.0	70.45***
Error (i)	4	433.0	108.5	
Spacing	1	653.0	653.0	6.01*
Rate	1	31.0	31.0	N.S.
Dir. x Sp.	1	1444.0	1444.0	13.29**
Dir. x R.	1	0.0	0.0	N.S.
Sp. x R.	1	24.0	24.0	N.S.
D x Sp. x R.	1	1.0	1.0	N.S.
Error (ii)	24	2607.0	108.6	
Total	39	13613.0		

27, August (cloudy day)

	DF	SS	MS	VR
Blocks	4	872.0	218.0	8.48 *
Direction	1	81.0	81.0	3.15
Error (i)	4	103.0	25.7	
Spacing	1	95.0	95.0	3.66 *
Rate	1	136.0	136.0	5.25
Dirt x Sp	1	5.0	5.0	N.S
Dirt x R	1	12.0	12.0	N.S
Sp x R	1	1.0	1.0	N.S
D x Sp x R	1	18.0	18.0	N.S
Error (ii)	24	622.0	25.9	
Total	39	1945.0		

10, September (clear day)

	DF	SS	MS	VR
Blocks	4	304.0	76.0	2.57
Direction	1	1196.0	1196.0	40.54 **
Error (i)	4	118.0	29.5	
Spacing	1	168.0	168.0	10.37 **
Rate	1	6.0	6.0	N.S
Dirt x Sp	1	105.0	105.0	6.48 *
Dirt x R	1	1.0	1.0	N.S
Sp x R	1	1.0	1.0	N.S
D x Sp x R	1	0.0	0.0	N.S
Error (ii)	24	390.0	16.2	
Total	39	2289.0		

23, September (clear day)

	DF	SS	MS	VR
Blocks	4	1852.0	463.0	1.72
Direction	1	2963.0	2963.0	11.01 *
Error (i)	4	1076.0	269.0	
Spacing	1	355.0	355.0	17.40 ***
Rate	1	23.0	23.0	1.12
Dirt x Sp	1	217.0	217.0	10.63 **
Dirt x R	1	12.0	12.0	N.S
Sp x R	1	43.0	43.0	2.10
D x Sp x R	1	13.0	13.0	N.S
Error (ii)	24	491.0	20.4	
Total	39	7309.0		

7, October (clear day)

	DF	SS	MS	VR
Blocks	4	749.0	187.2	3.31
Direction	1	3984.0	3984.0	70.51 ***
Error (i)	4	226.0	56.5	
Spacing	1	132.0	132.0	3.18
Rate	1	98.0	98.0	2.36
Dirt x Sp	1	242.0	242.0	5.83 *
Dirt x R	1	6.0	6.0	N.S
Sp x R	1	1.0	1.0	N.S
D x Sp x R	1	10.0	10.0	N.S
Error (ii)	24	996.0	41.5	
Total	39	6444.0		

22, October (clear day)

	DF	SS	MS	VR
Blocks	4	422.0	105.5	3.17
Direction	1	4359.0	4359.0	131.29 ***
Error (i)	4	133.0	33.2	
Spacing	1	0.0	0.0	N.S
Rate	1	125.0	125.0	1.71
Dirt x Sp	1	216.0	216.0	2.95
Dirt x R	1	6.0	6.0	N.S
Sp x R	1	57.0	57.0	N.S
D x Sp x R	1	6.0	6.0	N.S
Error (ii)	24	1752.0	73.0	
Total	39	7078.0		

10. 3. 9 Light intensity midway between rows (% daylight transformed to degs.)

		D1	D2	D3	D4
13/8	N-S	62.07	81.82	85.17	87.16
	E-W	37.30	44.93	37.84	47.34
27/8	N-S	33.13	41.27	50.64	60.29
	E-W	39.47	41.03	50.26	59.88
10/9	N-S	51.43	66.82	83.78	86.01
	E-W	17.95	17.38	25.63	26.74
23/9	N-S	51.05	60.55	67.86	68.95
	E-W	21.92	32.89	28.40	28.95
7/10	N-S	52.63	63.44	70.70	70.15
	E-W	34.56	35.30	31.51	37.11
22/10	N-S	53.86	60.84	74.90	73.77
	E-W	43.10	43.93	40.98	49.81

13, August

	DF	SS	MS	UR
Blocks	4	1204.0	301.0	4.31
Direction	1	13841.0	13841.0	198.57 ***
Error (i)	4	279.0	69.7	
Spacing	1	616.0	616.0	7.78 *
Rate	1	945.0	945.0	11.94 **
Dirt x Sp	1	406.0	406.0	5.13 *
Dirt x R	1	12.0	12.0	N.S.
Sp x R	1	157.0	157.0	1.98
D X Sp X R	1	242.0	242.0	3.05
Error (ii)	24	1900.0	79.1	
Total	39	19602.0		

27. August (cloudy day)

	DF	SS	MS	VR	
Blocks	4	873.0	218.2	4.02	
Direction	1	18.0	18.0	NS	
Error (i)	4	217.0	54.2		
Spacing	1	2737.0	2737.0	73.77	***
Rate	1	525.0	525.0	14.15	***
Dirt x Sp	1	29.0	29.0	N.S.	
Dirt x R	1	11.0	11.0	N.S.	
Sp x R	1	57.0	57.0	1.53	
D X Sp X R	1	43.0	43.0	1.15	
Error (ii)	24	892.0	37.1		
Total	39	5402.0			

10, September (clear day)

	DF	SS	MS	VR	
Blocks	4	565.0	141.2	3.48	
Direction	1	25084.0	25084.0	619.35	***
Error (i)	4	162.0	40.5		
Spacing	1	2939 .0	2939.0	64.45	***
Rate	1	207.0	207.0	4.53	*
Dirt X Sp	1	744.0	744.0	16.31	***
Dirt X R	1	182.0	182.0	3.99	
Sp X R	1	82.0	82.0	1.79	
D X Sp x R	1	137.0	137.0	3.00	
Error (ii)	24	1095.0	45.6		
Total	39	31197.0			

23, September (clear day)

	DF	SS	MS	VR	
Blocks	4	2074.0	518.5	6.98	*
Direction	1	8769.0	8769.0	52.82	**
Error (i)	4	664.0	166.0		
Spacing	1	346.0	346.0	4.51	*
Rate	1	172.0	172.0	2.24	
Dirt X Sp	1	424.0	424.0	5.52	*
Dirt X R	1	10.0	10.0	N.S.	
Sp X R	1	27.0	27.0	N.S.	
D X Sp X R	1	164.0	164.0	2.13	
Error (ii)	24	1842.0	76.7		
Total	39	13645.0			

7, October (clear day)

	DF	SS	MS	VR	
Blocks	4	1227.0	306.7	1.84	
Direction	1	8769.0	8769.0	52.82	**
Error (i)	4	664.0	166.0		
Spacing	1	346.0	346.0	4.51	*
Rate	1	172.0	172.0	2.24	
Dirt X Sp	1	424.0	424.0	5.52	*
Dirt X R	1	10.0	10.0	N.S.	
Sp X R	1	27.0	27.0	N.S.	
D X Sp X R	1	164.0	164.0	2.13	
Error (ii)	24	1842.0	76.7		
Total	39	13645.0			

22, October (clear day)

	DF	SS	MS	VR	
Blocks	4	1446.0	361.5	4.42	
Direction	1	4573.0	4573.0	55.97	***
Error (i)	4	327.0	81.7		
Spacing	1	890.0	890.0	7.43	*
Rate	1	151.0	151.0	1.26	
Dirt X Sp	1	570.0	570.0	4.76	*
Dirt X R	1	9.0	9.0	N.S	
Sp X R	1	0.0	0.0	N.S	
D X Sp X R	1	162.0	162.0	1.35	
Error (ii)	24	2874.0	119.7		
Total	39	11002.0			

10.4.0 Experiment 2.A.

10.4.1 Dry matter yield (g/1 m length of row)

		D_1	D_2	D_3	D_4	L.S.D.		
						5%	1%	1%
		14.25	11.62	17.12	11.81			
		15.11	8.17	15.36	9.24			
H_1	Mean	14.68	9.90	16.24	10.52	1.80	2.44	3.26
	N-S	124.40	117.06	207.77	170.22			
	E-W	115.77	114.04	166.93	154.44			
H_2	Mean	120.08	115.55	187.35	162.33	25.24	24.20	45.80
	N-S	198.20	184.53	344.40	272.86			
	E-W	182.60	153.33	333.73	242.86			
H_3	Mean	190.43	168.93	339.06	258.36	27.39	37.12	49.70

Harvest 1

	DF	SS	MS	VR	
Blocks	4	326.07	21.51	7.02	*
Direction	1	6.06	6.06	N.S.	
Error (i)	4	46.41	11.60		
Spacing	1	2.42	2.42	N.S.	
Rate	1	55.77	55.77	14.71	***
Dirt X Sp	1	0.38	0.38	N.S.	
Dirt X R	1	3.33	3.33	N.S.	
Sp X R	1	0.43	0.43	N.S.	
D X Sp X R	1	1.55	1.55	N.S.	
Error (ii)	24	91.06	3.79		
Total	39	533.48			

Harvest 2

	DF	SS	MS	VR	
Blocks	4	95206.0	23801.0	28.71	**
Direction	1	5898.0	5898.0	7.11	*
Error (i)	4	3319.0	829.0		
Spacing	1	65843.0	65843.0	89.21	***
Rate	1	4422.0	4422.0	5.99	*
Dirt X Sp	1	2561.0	2561.0	3.47	
Dirt X R	1	1190.0	1190.0	1.61	
Sp X R	1	2126.0	2126.0	2.88	
D X Sp X R	1	479.0	479.0	N.S.	
Error (ii)	24	17720.0	738.0		
Total	39	19876.0			

Harvest 3

	DF	SS	MS	VR
Blocks	4	93029.0	23257.0	44.46 **
Direction	1	4206.0	4206.0	8.04 *
Error (i)	4	2995.0	523.0	
Spacing	1	127556.0	127556.0	144.95 ***
Rate	1	23486.0	23486.0	26.68 ***
Dirt x Sp	1	28.0	28.0	N.S
Dirt x R	1	647.0	647.0	N.S
Sp x R	1	7849.0	7849.0	8.91 **
D x Sp x R	1	50.0	50.0	N.S
Error (ii)	24	21132.0	880.0	
Total	39	280078.0		

10. 4. 2. Grain yield

		D_1	D_2	D_3	D_4
g/M_2	N-S	368.0	394.2	353.9	294.0
	E-W	334.2	279.0	345.2	265.2
	Mean	351.1	336.6	349.5	279.6
g/m.b.r.	N-S	61.3	65.7	118.0	98.0
	E-W	55.7	46.5	115.1	88.4
	Mean	58.5	56.1	116.5	93.2

g/m^2

	DF	SS	MS	VR
Blocks	4	199.7	49.9	3.09
Direction	1	217.2	217.2	13.49 *
Error (i)	4	64.6	16.1	
Spacing	1	85.8	85.8	3.20
Rate	1	178.2	178.2	6.64 *
Dirt x Sp	1	77.6	77.6	2.89
Dirt x R	1	64.4	64.4	2.40
Sp x R	1	77.1	77.1	2.87
D x Sp x R	1	23.4	23.4	N.S
Error (ii)	24	644.7	26.8	
Total	39	1632.7		

g/m row length

	DF	SS	MS	VR
Blocks	4	14667.0	3666.0	2.97
Direction	1	7835.0	7835.0	6.35
Error (i)	4	4934.0	1233.0	
Spacing	1	203490.0	203490.0	133.61 ***
Rate	1	14900.0	14900.0	9.78 **
Dirt x Sp	1	854.0	854.0	N.S
Dirt x R	1	2307.0	2307.0	1.51
Sp x R	1	9841.0	9841.0	6.46 *
D x Sp x r	1	266.0	266.0	N.S
Error (ii)	24	36553.0	1523.0	
Total	39	295705.0		

10. 4. 3 Light intensity at ground level (% daylight)

(a) N-S Rows

Date	D_1	D_2	D_3	D_4
7/7	37.6	41.0	78.9	82.7
21/7	21.6	27.8	54.5	56.9
4/8	16.7	19.2	33.2	36.5
18/8	8.6	6.5	12.0	29.0
1/9	8.9	13.3	16.8	27.2
15/9	3.7	10.1	14.6	23.4
29/9	36.3	3.9	42.5	48.6
13/10	26.5	38.0	68.8	64.7
27/10	34.5	32.4	67.1	68.9
10/11	43.1	52.9	39.0	41.1

(b) E-W Rows

Date	D_1	D_2	D_3	D_4
7/7	32.3	30.9	60.7	62.3
21/7	9.4	17.3	37.0	48.0
4/8	9.5	13.9	25.6	38.7
18/8	8.8	10.8	25.4	23.6
1/9	7.4	24.1	21.6	24.3
15/9	3.7	18.2	12.8	19.1
29/9	4.8	13.2	23.3	33.2
13/10	25.3	60.0	27.8	42.6
27/10	18.0	53.0	42.6	50.9
10/11	31.5	41.9	36.1	42.6

10. 5. 0 Experiment 3

10. 5. 1 Dry matter yield of wheat (g/m^2)

	Control	P_o	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	L.S.D
N-S E-W	89.6 86.5	83.9 98.6	94.5 86.9	86.0 79.4	77.0 89.1	
H_1 Mean	88.0	91.2	90.7	82.7	83.1	N.S
N-S E-W	367.5 383.0	386.2 328.9	342.1 307.4	362.7 354.0	379.5 377.8	
H_2 Mean	375.3	357.5	324.7	358.4	378.6	N.S
N-S E-W	637.5 595.9	576.5 703.1	575.9 620.9	623.9 644.2	500.8 634.2	
H_3 Mean	616.7	639.8	598.4	634.0	567.5	N.S
N-S E-W	737.5 767.4	689.8 832.4	666.1 668.2	703.9 763.9	671.3 742.1	
H_4 Mean	752.4	761.1	667.1	733.9	706.7	N.S
N-S E-W	686.9 685.6	650.7 733.5	631.5 543.2	645.2 612.5	586.8 604.0	
H_5 Mean	686.3	692.1	587.3	628.9	595.4	N.S

Harvest 1

	DF	SS	MS	VR
Blocks Disection	4 1	17018.2 45.3	4254.5 45.3	5.48 N.S
Error (i)	4	3100.9	775.2	
Treats Dist x T_2	4 4	663.1 1141.0	165.7 285.2	N.S N.S
Error (ii)	32	13354.8	417.3	
Total	49	35323.3		

Harvest 2

	DF	SS	MS	VR
Blocks	4	112164	28041	2.66
Direction	1	3785	3785	N.S
Error (i)	4	42066	10516	
Treats	4	18260	4565	N.S
Dirt x T_2	4	8234	2058	N.S
Error (ii)	32	149812	4681	
Total	49	334321		

Harvest 3

	DF	SS	MS	VR
Blocks	4	59613	14903	
Direction	1	40254	40254	1.18
Error (i)	4	136448	34112	
Treats	4	34473	8618	1.81
Dirt x T_2	4	54728	13682	2.88
Error (ii)	32	151745	4742	
Total	49	477261		

Harvest 4

	DF	SS	MS	VR
Blocks	4	11993	2998	1.38
Direction	1	4656	4656	2.15
Error (i)	4	8657	2184	
Treats	4	5812	1453	2.04
Dirt x T_2	4	2801	700	N.S
Error (ii)	32	22799	712	
Total	49	56718		

Harvest 5

	DF	SS	MS	VR
Blocks	4	30826	7706	2.38
Directions	1	25	25	N.S
Error (i)	4	12943	3235	
Treats	4	9723	2430	1.95
Dirt x T_2	4	3980	995	N.S
Error (ii)	32	39880	1246	
Total	49	97377		

10. 5. 2. Grain yield of wheat (g/M^2)

	Control	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$
N-S	225.2	216.3	204.9	206.5	199.7
E-W	213.5	249.2	165.0	221.1	208.1
Mean	219.4	232.8	185.0	213.8	203.9

	DF	SS	MS	VR
Blocks	4	93135	23283	26.42 **
Direction	1	9	9	N.S
Error (i)	4	3524	881	
Treats	4	12711	3177	1.14
Dirt x T_2	4	7804	1951	N.S
Error (ii)	32	88660	2770	
Total	49	205843		

10. 5. 3. Dry matter yield of clover g/m^2

	Control	P_0	P3½	P_7	$P_{10\frac{1}{2}}$	L. S. D 5%	1%	1%
N-S	12.18	6.05	8.47	9.85	8.27			
E-W	10.73	8.57	8.49	9.89	8.89			
H_1 Mean	11.46	7.31	8.48	9.87	8.59	0.85	1.15	1.54
N-S	87.18	29.54	39.29	49.51	38.48			
E-W	72.09	32.45	36.95	40.90	40.08			
H_2 Mean	79.64	31.10	38.13	45.21	39.29	8.18	8.37	
N-S	248.90	45.10	72.70	77.90	72.60			
E-W	214.50	40.50	57.50	65.90	68.00			
H_3 Mean	231.70	42.80	65.10	71.90	70.30	4.25	5.76	7.71
N-S	309.70	40.30	59.40	67.50	58.90			
E-W	220.30	36.40	51.30	55.70	53.20			
H_4 Mean	265.00	38.35	55.30	61.60	56.05	13.52	18.32	

The analysis of variance and L.S.D. recorded are for the mixed treatments (P0 - P10½)

Harvest 1

	DF	SS	MS	VR
Blocks	4	14.89	3.72	N.S
Direction	1	6.34	6.34	1.07
Error (i)	4	23.67	5.91	
Treats	3	32.85	10.95	13.03 ***
Dirt x T_2	3	10.40	3.46	4.11 *
Error (ii)	24	20.24	0.84	
Total	39	108.39		

Harvest 2

	DF	SS	MS	VR
Blocks	4	38.72	9.68	N.S
Direction	1	27.51	27.51	N.S
Error (i)	4	136.73	34.03	
Treats	3	1004.68	334.89	7.46 **
Dirt x T_2	3	195.97	65.32	1.45
Error (ii)	24	1077.18	44.88	
Total	39	2480.19		

Harvest 3

	DF	SS	MS	VR
Blocks	4	36.16	9.04	1.01
Direction	1	82.81	82.81	9.27 *
Error (i)	4	35.74	8.93	
Treats	3	544.05	181.35	8.52 ***
Dirt x T_2	3	21.53	7.17	N.S
Error (ii)	24	510.71	21.27	
Total	39	1231.00		

Harvest 4

	DF	SS	MS	VR
Blocks	4	159.20	39.80	N.S
Direction	1	551.30	551.30	1.96
Error (i)	4	1122.50	280.60	
Treats	3	2977.70	992.50	4.62 *
Dirt x T_2	3	84.20	28.00	N.S
Error (ii)	24	5152.10	214.60	
Total	39	10047.00		

10. 6. 0 Experiment 3.A.

10. 6. 1 Dry matter yield of wheat (g/m^2)

	Control	P_o	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$
N-S	139.5	156.8	131.5	156.4	102.4
E-W	138.9	156.8	124.7	135.7	152.9
H_1 Mean	139.2	156.8	128.1	146.1	137.6
N-S	728.0	631.8	672.7	585.5	698.8
E-W	685.4	657.3	623.4	657.4	675.8
H_3 Mean	706.7	644.8	648.1	621.5	689.4

Harvest 1

	DF	SS	MS	VR
Blocks	4	34161.5	8540.3	13.30 *
Direction	1	1.4	1.4	N.S
Error (i)	4	2568.1	642.0	
Treats	4	4544.5	1136.1	N.S
Dirt x T_2	4	3512.0	878.0	N.S
Error (ii)	32	38519.9	1203.7	
Total	49	83307.4		

Harvest 3

	DF	SS	MS	VR
Blocks	4	9929	2482	1.33
Direction	1	8	8	N.S
Error (i)	4	7466	1866	
Treats	4	4881	1220	1.36
Dirt x T_2	4	2600	650	N.S
Error (ii)	32	28671	895	
Total	49	53555		

10. 6. 2 Grain yield of wheat g/m^2

	Control	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	5%	1%	1%
N-S	235.6	200.9	231.4	193.3	201.8			
E-W	236.2	215.6	184.2	200.5	205.7			
Mean	237.9	208.3	207.8	196.9	203.8	21.3	28.8	38.6

	DF	SS	MS	VR
Blocks	4	6634	1658	N.S
Direction	1	1106	1106	N.S
Error (i)	4	8727	2181	
Treats	4	9914	2478	4.68 **
Dirt x T_2	4	5204	1301	2.45
Error (ii)	32	16954	529	
Total	49	200639		

10. 6. 3 Dry matter yield of clover g/m^2

	Control	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$	L. S. D 5%	1%	1%
N-S	29.49	9.84	14.76	20.66	15.75			
E-W	28.98	11.90	17.96	19.28	14.77			
H_1 Mean	29.24	10.87	16.36	19.97	15.26	4.35	5.90	7.90
N-S	234.10	46.80	95.80	143.00	104.30			
E-W	211.60	64.40	100.40	131.60	110.20			
H_2 Mean	222.85	55.60	98.10	137.30	107.25	22.06	29.90	40.03

Analysis of variance and L.S.D. are for mixed treatments only.

Harvest 1

	DF	SS	MS	VR
Blocks	4	881.46	220.36	3.50
Direction	1	5.26	5.26	N.S
Error (i)	4	251.23	62.80	
Treats	3	421.63	140.54	6.29 **
Dirt x T_2	3	38.11	12.70	N.S
Error (ii)	24	535.82	22.32	
Total	39	2133.51		

Harvest 2

	DF	SS	MS	VR
Blocks	4	954.5	238.6	1.26
Direction	1	174.3	174.3	N.S
Error (i)	4	754.2		
Treats	3	34180.6	11393.5	19.92 ***
Dirt x T_2	3	1064.9	354.9	N.S
Error (ii)	24	13721.6	571.7	
Total	39	50850.1		

10. 7. 0 Experiment 4

10. 7. 1. Dry matter yield of wheat g/m^2

	R_1	R_2	R_3	R_4	L. S. D 5%	1%	1%
- Cl	93.16	160.01	191.22	257.16			
+ Cl	105.16	155.41	192.43	230.39			
H_1 Mean	99.16	157.71	191.83	243.78	28.10	39.40	55.70
- Cl	376.80	449.60	521.80	599.40			
+ Cl	338.00	466.60	505.20	580.20			
H_2 Mean	357.40	458.10	513.50	589.80	46.30	64.90	91.70
- Cl	536.00	617.00	712.40	758.00			
+ Cl	399.00	641.60	726.00	757.00			
H_3 Mean	467.60	629.40	719.50	757.70	55.90	78.40	110.80

Harvest 1

	DF	SS	MS	VR
Blocks	4	20695	5173	6.22 **
Rates	3	110496	36832	44.32 ***
Error (i)	12	9978	831	
Clover	1	206	206	N.S
R x Cl	3	2002	667	N.S
Error (ii)	16	11530	720	
Total	39	154907		

Harvest 2

	DF	SS	MS	VR
Blocks	4	72491	18122	8.03 **
Rates	3	386883	95627	42.38 ***
Error (i)	12	26828	2256	
Clover	1	2074	2074	N.S
R x Cl	3	4023	1341	N.S
Error (ii)	16	71438	4464	
Total	39	463737		

Harvest 3

	DF	SS	MS	VR
Blocks	4	12975	3243	9.85 ***
Rates	3	49957	16652	50.61 ***
Error (i)	12	3952	329	
Clover	1	615	615	1.36
R x Cl	3	7233	1421	3.14
Error (ii)	16	78997	452	
Total	39			

10. 7. 2 Number of tillers of wheat/M^2

	R1	R2	R3	R4	L.S.D. 5%	1%	1%
- Cl	146	226	263	360			
+ Cl	132	200	266	309			
H1 Mean	139	213	265	335	17	24	34
- Cl	166	224	253	315			
+ Cl	142	196	249	303			
H2 Mean	154	210	251	309	14	20	29
- Cl	143	199	247	301			
+ Cl	127	196	246	256			
H3 Mean	136	198	247	279	20	28	39

Harvest 1

	DF	SS	MS	VR
Blocks	4	7461	1865	5.42 **
Rates	3	205316	68438	198.94 ***
Error (i)	12	4133	344	
Clover	1	4906	4906	10.68 **
R x Cl	3	3820	1273	2.77
Error (ii)	16	7345	459	
Total	39	232981		

Harvest 2

	DF	SS	MS	VR
Blocks	4	8113	2028	9.17 **
Rates	3	128342	42780	193.57 ***
Error (i)	12	2654	221	
Clover	1	2958	2958	4.76 *
R x Cl	3	903	301	N.S
Error (ii)	16	9940	621	
Total	39	152910		

Harvest 3

	DF	SS	MS	VR
Blocks	4	21486	5371	12.97 ***
Rates	3	116851	38950	94.08 ***
Error (i)	12	4975	414	
Clover	1	2529	2529	3.86
R x Cl	3	3041	1013	1.54
Error (ii)	16	10478	654	
Total	39	159360		

10. 7. 3. Weight per tiller

	R1	R2	R3	R4	L. S. D. 5%	1%	1%
- Cl	0.67	0.73	0.74	0.74			
+ Cl	0.76	0.78	0.80	0.79			
H1 Mean	0.71	0.75	0.77	0.77		N.S	
- Cl	2.26	1.99	2.05	1.89			
+ Cl	2.37	2.21	1.98	1.90			
H2 Mean	2.32	2.11	2.02	1.90	0.04	0.06	0.08
- Cl	3.73	3.09	2.87	2.51			
+ Cl	3.11	3.29	2.89	2.81			
H3 Mean	3.43	3.20	2.89	2.67	0.02	0.03	0.04

Harvest 1

	DF	SS	MS	VR
Blocks	4	0.088	0.022	4.40 *
Rates	3	0.019	0.006	1.20
Error (i)	12	0.068	0.005	
Clover	1	0.036	0.036	7.20 *
R x Cl	3	0.003	0.001	N.S
Error (ii)	16	0.087	0.005	
Total	39	0.301		

Harvest 2

	DF	SS	MS	VR
Blocks	4	0.22	0.055	N.S
Rates	3	0.93	0.310	15.50
Error (i)	12	0.25	0.020	
Clover	1	0.05	0.450	N.S
R x Cl	3	0.12	0.040	N.S
Error (ii)	16	0.63	0.039	
Total	39	2.20		

Harvest 3

	DF	SS	MS	VR
Blocks	4	0.57	0.142	2.73
Rates	3	3.40	1.133	21.78 ***
Error (i)	12	0.63	0.052	
Clover	1	0.01	0.010	N.S
R x Cl	3	1.27	0.423	4.97 *
Error (ii)	16	1.36	0.085	
Total	39	7.24		

10. 7. 4. Grain yield of wheat g/M^2

	R1	R2	R3	R4	L. S. D 5%	1%	1%
- Cl	249.2	260.7	292.6	298.7	40.3	54.3	
+ Cl	171.3	274.1	292.2	286.6			
Mean	210.3	267.4	292.4	292.7	21.8	30.6	43.2

	DF	SS	MS	VR
Blocks	4	13788	3447	6.88 **
Rates	3	45162	10054	30.04 ***
Error (i)	12	6013	501	
Clover	1	3704	3705	3.14
R x Cl	3	12274	4091	3.47
Error (ii)	16	18850	1178	
Total	39	99791		

10. 7. 5. Total L

	R1	R2	R3	R4	L. S. D 5%	1%	1%
Harvest 1	0.646	1.188	1.400	2.034	0.203	0.290	0.427
Harvest 2	1.932	2.882	3.584	3.356	0.156	0.224	0.329

Harvest 1

	DF	SS	MS	VR
Blocks	3	0.357	0.119	3.30
Rates	3	3.954	1.318	36.61 ***
Error	9	0.326	0.036	
Total	15	4.637		

Harvest 2

	DF	SS	MS	VR
Blocks	3	0.189	0.063	2.86
Rates	3	0.553	0.184	8.36 **
Error	9	0.203	0.022	
Total	15	0.945		

10. 7. 6. L distribution

(a) Harvest 1
(i) 15 lbs/acre (R1)

	A	B	C	D	E	Total
24-27	-	-	-	-	-	-
21-24	-	-	-	-	-	-
18-21	-	0.02	0.04	0.03	0.01	0.10
15-18	-	0.07	0.18	0.06	-	0.31
12-15	0.01	0.11	0.29	0.09	-	0.50
9-12	-	0.09	0.40	0.08	-	0.57
6-9	-	0.07	0.38	0.07	-	0.52
3-6	0.01	0.05	0.28	0.01	-	0.35
0-3	0.01	0.08	0.10	0.02	-	0.21
Total	0.03	0.49	1.67	0.36	0.01	2.56

(ii) 30 lbs/acre (R2)

	A	B	C	D	E	Total
24-27	-	-	0.01	-	-	0.01
21-24	-	0.01	0.04	0.01	-	0.06
18-21	-	0.05	0.24	0.09	-	0.38
15-18	-	0.16	0.45	0.14	-	0.75
12-15	-	0.17	0.63	0.19	0.02	1.01
9-12	-	0.13	0.67	0.15	0.01	0.96
6-9	-	0.07	0.54	0.13	-	0.74
3-6	-	0.04	0.39	0.07	-	0.50
0-3	-	0.03	0.18	0.05	-	0.26
Total		0.66	3.15	0.83	0.03	4.67

(iii) 45 lbs/acre (R3)

	A	B	C	D	E	Total
24-27	-	-	-	-	-	-
21-24	-	-	0.04	0.01	-	0.05
18-21	-	0.04	0.27	0.06	-	0.37
15-18	-	0.09	0.63	0.12	-	0.84
12-15	-	0.18	0.82	0.16	-	1.16
9-12	-	0.14	0.87	0.17	-	1.18
6-9	-	0.09	0.74	0.09	-	0.92
3-6	0.01	0.05	0.50	0.06	-	0.62
0-3	0.01	0.05	0.21	0.05	-	0.32
Total	0.02	0.64	4.08	0.72	-	5.46

(iv) 60 lbs/acre (R4)

	A	B	C	D	E	Total
24-27	-	0.01	0.06	0.03	-	0.10
21-24	-	0.04	0.19	0.07	-	0.30
18-21	0.01	0.13	0.57	0.20	-	0.91
15-18	0.02	0.21	0.92	0.29	0.02	1.46
12-15	-	0.20	1.04	0.19	-	1.45
9-12	-	0.20	1.03	0.16	0.02	1.41
6-9	-	0.12	0.90	0.09	-	1.11
3-6	0.01	0.15	0.66	0.08	-	0.90
0-3	0.01	0.04	0.30	0.05	-	0.40
Total	0.05	1.10	5.67	1.16	0.04	8.02

(b) Harvest 2
(i) 15 lbs/acre (R1)

	A	B	C	D	E	Total
30-33	-	-	-	-	-	-
27-30	-	-	0.08	0.02	-	0.10
24-27	-	0.01	0.14	0.04	0.01	0.20
21-24	-	0.01	0.13	0.10	-	0.24
18-21	-	0.05	0.13	0.05	-	0.23
15-18	-	0.01	0.22	0.05	-	0.28
12-15	-	0.02	0.18	0.05	0.01	0.26
9-12	-	-	0.24	0.03	-	0.27
6-9	-	-	0.17	0.01	-	0.18
3-6	-	-	0.07	0.02	-	0.09
0-3	-	-	0.02	0.01	-	0.03
Total	-	0.10	1.38	0.38	0.01	1.88

(ii) 30 lbs/acre (R2)

	A	B	C	D	E	Total
30-33	-	-	-	0.01	-	0.01
27-30	-	-	0.02	0.02	-	0.04
24-27	-	0.02	0.14	0.09	0.01	0.26
21-24	-	0.02	0.15	0.07	0.02	0.26
18-21	-	0.02	0.16	0.17	0.03	0.38
15-18	0.01	0.05	0.22	0.12	-	0.39
12-15	-	0.04	0.33	0.10	0.02	0.50
9-12	-	0.02	0.27	0.14	0.01	0.44
6-9	-	0.01	0.21	0.08	-	0.30
3-6	-	0.01	0.13	0.01	-	0.15
0-3	-	-	0.03	-	-	0.03
Total	0.01	0.19	1.66	0.81	0.09	2.76

(iii) 45 lbs/acre (R3)

	A	B	C	D	E	Total
30-33	-	-	-	0.01	-	0.01
27-30	-	0.04	0.07	0.04	0.03	0.18
24-27	-	0.04	0.15	0.06	0.01	0.26
21-24	-	0.07	0.25	0.12	0.02	0.46
18-21	-	0.07	0.30	0.17	0.01	0.55
15-18	0.01	0.10	0.34	0.11	-	0.56
12-15	0.02	0.04	0.38	0.08	0.01	0.53
9-12	-	0.01	0.30	0.05	-	0.36
6-9	-	0.01	0.27	0.02	-	0.30
3-6	-	-	0.24	-	-	0.24
0-3	-	-	0.05	-	-	0.5
Total	0.03	0.38	2.35	0.66	0.08	3.50

(iv) 60 lbs/acre (R4)

	A	B	C	D	E	Total
30-33	-	0.01	0.03	0.02	-	0.06
27-30	-	0.04	0.22	0.07	0.01	0.34
24-27	-	0.04	0.28	0.10	-	0.42
21-24	0.01	0.07	0.30	0.06	0.01	0.45
18-21	-	0.09	0.43	0.09	-	0.61
15-18	-	0.13	0.46	0.08	-	0.67
12-15	-	0.08	0.31	0.14	-	0.53
9-12	-	0.05	0.29	0.06	-	0.40
6-9	-	0.02	0.19	0.01	-	0.22
3-6	-	0.02	0.04	0.01	-	0.07
0-3	-	-	-	-	-	-
Total	0.01	0.55	2.55	0.64	0.02	3.77

10. 7. 7. Dry matter yield of clover g/quadrat (10" x 28")

	WO	W15	W30	W45	W60	L. S. D 5%	1%	1%
Harvest 1	34.78	28.44	28.42	25.22	20.67	5.92	8.16	11.22
Harvest 2	116.29	64.48	57.57	53.25	39.69	7.84	10.84	14.85

Harvest 1

	DF	SS	MS	VR
Blocks	4	163.22	40.80	5.99 ***
Rates	4	532.78	133.19	19.55 ***
Error	16	108.99	6.81	
Total	24	804.99		

Harvest 2

	DF	SS	MS	VR
Blocks	4	537.99	134.49	1.06
Rates	4	17284.88	4321.22	34.23 ***
Error	16	2019.53	126.22	
Total	24	19842.40		

10. 7. 8 Seed yield of clover g/quadrat

WO	W15	W30	W45	W60
19.19	13.50	10.95	8.12	5.55

	DF	SS	MS	VR
Blocks	4	490.25	122.56	6.95 **
Rates	4	551.31	137.82	7.81 **
Error	16	281.94	17.62	
Total	24	1323.50		

10. 7. 9 Dry matter yield of clover at various positions. g/strip (10" x 3½")

(a) Harvest 1

	P0	P3½	P7	P10½	Mean
R1	5.86	6.45	7.78	8.34	7.11
R2	5.53	7.71	7.77	7.40	7.10
R3	4.86	6.96	6.92	6.47	6.30
R4	3.97	6.08	5.36	5.25	5.16
Mean	5.05	6.80	6.96	6.86	

	DF	SS	MS	VR
Blocks	4	31.04	7.76	4.61 *
Rates	3	50.60	16.86	10.03 **
Error (i)	12	20.26	1.68	
Positions	3	49.97	16.65	6.90 **
R x P	9	12.92	1.43	N.S
Error (ii)	48	115.98	2.41	
Total	79	280.77		

		Rates	Positions
L.S.D.	5%	1.26	1.40
	1%	1.77	1.88
	1%	2.50	2.46

(b) Harvest 2

	P0	P3½	P7	P10½	Mean
R1	13.36	16.30	19.27	15.55	16.12
R2	9.87	14.78	19.27	13.65	14.39
R3	9.41	11.70	20.00	12.13	13.31
R4	6.62	10.31	12.19	10.56	9.92
Mean	9.81	13.27	17.63	12.97	

	DF	SS	MS	VR
Blocks	4	66.48	16.20	1.61
Rates	3	409.71	136.57	13.60 *
Error (i)	12	129.64	10.04	
Positions	3	628.25	209.41	40.27 ***
R x P	9	89.51	9.94	1.91
Error (ii)	48	249.93	5.20	
Total	79	1573.52		

		Rates	Positions
L.S.D.	5%	9.74	6.52
	1%	13.65	8.72
	1%	N.S	11.45

10. 7.10 Light intensity at ground level (% daylight)

(a) 15 lbs/acre (R1)

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$
28/7	81.1	100.0	100.0	92.8
11/8	71.0	91.2	95.8	89.5
25/8	52.2	70.8	88.3	79.2
8/9	7.7	66.6	99.3	56.6
22/9	4.0	29.6	92.7	33.0
6/10	7.1	21.9	91.7	82.7
20/10	8.3	58.7	93.5	87.0
3/11	18.7	82.6	96.4	81.2
17/11	27.7	48.1	55.5	58.3

(b) 30 lbs/acre (R2)

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$
28/7	74.7	90.9	95.8	86.7
11/8	65.5	80.0	96.1	75.8
25/8	21.6	44.2	83.7	73.6
8/9	3.5	40.4	88.9	47.2
22/9	6.9	39.4	89.8	37.5
6/10	5.2	51.0	97.4	36.7
25/10	3.7	52.7	97.1	89.7
3/4	9.3	74.1	99.0	95.4
17/11	37.6	47.7	66.9	46.5

(c) 45 lbs/acre (R3)

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{10\frac{1}{2}}$
28/7	92.1	91.4	100.0	74.8
11/8	29.0	81.2	91.9	75.3
25/8	13.1	39.4	84.3	70.6
8/9	2.5	24.5	92.5	93.6
22/9	2.8	33.2	91.1	34.4
6/10	4.5	35.6	95.9	79.0
25/10	3.7	69.4	100.0	56.4
3/11	5.2	81.2	96.7	95.8
17/11	34.0	39.1	48.7	41.3

(d) 60 lbs/acre (R4)

Date	P_0	$P_{3\frac{1}{2}}$	P_7	$P_{6\frac{1}{2}}$
28/7	68.9	76.1	98.0	80.7
11/8	52.2	76.0	84.9	60.3
25/8	15.6	32.7	77.5	37.9
8/9	1.4	34.2	96.0	32.7
22/9	1.7	27.2	94.2	26.4
6/10	1.7	67.8	89.7	46.8
25/10	4.7	34.3	99.0	74.2
3/11	12.2	89.0	97.1	81.8
17/11	38.8	39.1	50.7	38.6

10. 8. 0. Climatic records during the growing seasons of 1960 & 1961.

1960

Date		Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
April	1	66.9	57.2	245	.03	.21
	2	68.9	51.0	430	.03	.13
	3	73.0	49.7	461		.17
	4	68.8	58.3	454		.15
	5	72.9	54.4	469		.23
	6	81.1	59.0	457		.20
	7	89.2	69.7	384		.20
	8	72.6	64.6	127		.20
	9	69.8	54.0	336	.07	.07
	10	72.8	50.8	283		.14
	11	67.5	53.9	217		.15
	12	74.6	54.9	298		.09
	13	78.3	51.3	348		.11
	14	70.0	58.9	114		.09
	15	61.9	52.8	327	.20	.13
	16	62.3	50.9	121	.02	.15
	17	64.8	54.2	189	.07	.08
	18	66.3	55.7	250	.10	.09
	19	67.9	53.9	223		.09
	20	62.1	53.1	96	.01	.07
	21	59.1	43.7	345	.52	.12
	22	57.8	45.8	247		.14
	23	58.5	49.7	147		.11
	24	62.1	45.5	141		.06
	25	60.7	51.3	59	.14	.13
	26	57.2	49.7	162	.61	
	27	59.3	47.4	182	.48	.07
	28	62.9	51.0	198	.41	.03
	29	68.7	54.7	281	.04	.04
	30	62.2	57.2	165		.10

1960

Date	Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
May 1	60.5	51.9	203	.24	.07
2	57.9	50.1	121	.08	.09
3	64.3	51.7	171		.08
4	58.8	47.0	114	.46	.12
5	55.8	43.6	203	.40	.08
6	58.8	47.4	158	.33	.08
7	61.0	52.2	191	.12	.06
8	57.3	50.2	191	.11	.06
9	57.2	43.9	189		.08
10	65.6	45.0	260		.07
11	53.7	51.6	46	.02	.11
12	54.0	41.9	153	.71	.03
13	59.4	44.9	198	.86	.02
14	55.1	47.7	207	.11	.05
15	55.7	47.7	87	.18	.06
16	57.7	48.1	236	.16	.03
17	58.2	44.3	232		.07
18	57.1	41.1	283		.08
19	60.9	41.8	227		.09
20	54.7	44.3	79		.03
21	55.8	42.2	103	.01	.03
22	52.8	44.3	84	.01	.05
23	59.4	42.7	259		.04
24	65.7	43.9	275		.07
25	68.8	52.1	256		.09
26	66.1	59.3	85	.14	.08
27	61.9	53.2	266	1.55	.01
28	64.6	51.4	227	.01	.13
29	58.4	50.0	127	.37	.07
30	56.7	48.8	171	.71	.03
31	56.7	51.0	65	.30	.03

1960

Date	Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
June 1	57.4	50.6	62		.02
2	57.2	50.8	80	.06	.04
3	59.3	49.0	204	.13	.04
4	62.4	51.2	233		.09
5	57.3	52.9	53		.11
6	59.8	48.5	217	.23	.03
7	60.6	45.6	177	.01	.06
8	58.2	50.3	84	.06	.05
9	57.6	47.1	117	.07	.01
10	55.5	48.8	150	.15	.03
11	55.1	45.4	138	.14	.09
12	56.9	47.4	133	.01	.04
13	58.3	45.0	259		.05
14	55.6	49.2	41		.13
15	52.1	44.5	105	1.22	.02
16	56.6	44.8	147	.14	.02
17	57.1	44.8	168	.06	.04
18	57.7	42.4	189	.01	.05
19	54.0	45.8	97		.04
20	53.4	40.4	171		.05
21	57.4	46.5	259		.07
22	59.7	43.9	226		.06
23	54.1	41.8	251		.07
24	52.1	37.8	167		.06
25	54.9	39.5	201	.01	.04
26	55.0	40.3	204	.01	.04
27	58.1	42.8	245	.01	.04
28	57.3	39.1	266	.01	.07
29	59.3	46.7	242		.07
30	62.8	42.1	262		.09

1960

Date		Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
July	1	61.2	47.9	171		.10
	2	57.3	52.3	65		.11
	3	54.9	46.7	123		.03
	4	52.1	39.2	203	.21	.06
	5	54.6	41.6	130	.07	.05
	6	51.2	41.7	87	.03	.04
	7	54.8	45.0	242		.04
	8	58.5	48.2	100		.11
	9	57.1	46.7	214	.17	.07
	10	53.1	44.1	210	.24	.05
	11	53.4	37.9	223	.03	.08
	12	55.2	37.8	214	.04	.06
	13	53.6	40.6	129		.05
	14	53.2	45.9	34	.03	.04
	15	54.6	46.4	93	.06	
	16	58.2	44.8	200		.02
	17	51.9	44.6	97	.20	.04
	18	53.6	38.9	201	.26	.06
	19	52.2	43.5	64	.04	.05
	20	53.9	41.9	115	.20	.04
	21	56.8	44.6	26		.07
	22	55.7	50.0	120	.11	.03
	23	51.8	40.4	123	.03	.05
	24	56.9	42.5	121		.05
	25	61.3	48.7	113		.11
	26	63.4	50.4	286		.09
	27	64.9	49.5	26		.09
	28	59.3	48.8	136	.04	.03
	29	63.4	49.1	138		.04
	30	62.6	49.7	165		.04
	31	57.9	46.1	300	.05	.08

1960

Date	Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
Aug 1	55.3	45.3	176	.10	.06
2	54.5	42.0	265	.19	.06
3	55.2	45.4	286	.92	.09
4	55.0	43.0	214	.02	.06
5	57.7	44.2	288		.08
6	57.0	40.1	257		.11
7	56.6	36.2	318		.07
8	52.1	44.3	162	.18	.08
9	54.3	40.7	236	.11	.03
10	54.8	43.2	168		.04
11	47.2	40.7	100	.27	.09
12	50.1	39.1	67	.41	.06
13	54.9	45.6	185	.23	
14	57.1	47.8	212	.05	.01
15	61.7	48.0	351	.01	.06
16	65.1	50.2	354		.14
17	57.2	49.3	257	.03	.12
18	53.3	40.1	197	.01	.08
19	54.9	43.9	300	.02	.07
20	55.1	38.4	333		.07
21	59.0	42.8	280		.10
22	58.6	45.9	227		.04
23	57.7	48.6	224		.06
24	61.0	39.6	415	.05	.07
25	67.2	49.0	362		.15
26	60.0	52.1	206		.18
27	50.2	46.1	99	.03	.07
28	51.0	41.0	145	.03	.05
29	54.7	40.7	339	.21	.02
30	59.0	43.8	341		.09
31	65.0	50.3	275		.10

1960

Date	Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
Sep 1	56.6	47.6	167		.08
2	56.9	46.1	285	.04	.07
3	55.1	45.5	325	.42	.10
4	54.3	43.3	230	.17	.08
5	59.9	43.9	348		.06
6	59.3	50.1	40		.15
7	54.1	47.1	307	1.36	.05
8	53.5	44.9	250	.06	.07
9	55.9	43.5	115	.02	.08
10	62.2	46.7	389		.01
11	69.6	51.9	390		.09
12	69.7	59.8	117		.13
13	60.6	55.9	68	.59	.07
14	58.4	50.8	73	.30	.02
15	58.8	52.0	136	.02	.04
16	59.7	51.0	224	.23	.04
17	57.2	48.2	236	.50	.05
18	56.9	44.9	266	.05	.08
19	58.4	45.0	375		.07
20	62.9	42.5	440		.10
21	65.2	45.4	513		.10
22	71.8	50.7	407		.14
23	72.0	54.7	424		.16
24	54.7	48.8	204	.30	.16
25	56.9	45.8	360	.21	.15
26	58.2	48.2	310	.10	.08
27	56.2	49.1	247	.01	.07
28	68.8	43.1	531		.06
29	60.7	55.5	212		.18
30	60.2	48.4	410	.02	.09

1960

Date	Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
Oct 1	67.1	44.3	519	.03	.10
2	74.7	55.1	337		.11
3	78.3	59.7	480		.15
4	57.9	49.0	428		.19
5	59.6	49.5	285	.03	.17
6	56.6	51.0	135	.04	.07
7	60.0	47.3	309	.13	.03
8	66.2	49.4	445	.19	.11
9	80.1	48.3	487		.09
10	58.2	49.5	419		.22
11	59.4	48.4	460	.15	.13
12	59.6	50.1	353		.14
13	71.1	44.1	501		.09
14	80.2	58.1	614		.15
15	86.6	64.8	478		.21
16	85.9	75.2	316		.32
17	59.6	50.8	425	.48	.12
18	58.8	47.7	321	.01	.17
19	59.2	44.5	324		.12
20	65.9	48.1	582		.11
21	74.1	50.8	545		.18
22	78.2	56.2	620		.10
23	86.4	64.8	649		.19
24	67.5	53.3	685		.26
25	78.4	47.3	659		.23
26	82.7	61.1	655		.22
27	78.6	51.5	672		.21
28	79.7	49.9	608		.27
29	88.1	64.0	327		.31
30	60.6	50.9	536	.06	.25
31	58.8	47.2	504	.08	.22

1960

Date	Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
Nov 1	58.7	47.1	341	.01	.16
2	69.8	42.4	599		.11
3	61.0	48.4	555	.08	.21
4	67.8	44.2	711		.17
5	64.4	47.8	691		.19
6	73.3	43.9	718		.19
7	84.9	57.8	516		.30
8	59.2	52.1	443	.43	.23
9	65.7	44.7	610	.03	.15
10	74.6	51.9	393		.24
11	74.7	63.3	55		.21
12	58.0	51.9	156	2.33	.07
13	61.3	49.8	718	.05	.09
14	69.5	44.0	585		.16
15	81.0	56.8	602		.25
16	76.1	63.8	596		.36
17	66.2	55.3	511	.16	.17
18	63.4	50.1	537	.07	.15
19	77.3	50.8	635		.16
20	67.8	61.9	233		.28
21	62.2	48.9	492	.02	.13
22	62.9	51.8	341	.01	.24
23	63.8	52.9	445	.08	.08
24	66.9	50.5	617	.03	.08
25	66.6	50.0	656		.15
26	65.2	49.7	694		.19
27	74.1	45.1	770		.19
28	88.4	53.2	602		.21
29	64.7	56.3	402		.26
30	69.1	49.1	369		.26

1960

Date	Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
Dec 1	79.9	57.7	480	.01	.26
2	81.8	63.7	601		.29
3	60.2	56.6	124		.23
4	64.7	53.4	409	.02	.11
5	71.3	53.9	641		.11
6	73.1	52.6	749		.19
7	72.0	51.8	774		.22
8	88.7	52.6	765		.20
9	97.7	71.3	759		.34
10	100.8	81.8	628		.43
11	66.9	56.9	797		.41
12	73.2	47.3	799		.27
13	76.3	51.4	747		.27
14	70.2	50.7	502		.25
15	63.0	52.0	513	.01	.30
16	68.7	51.4	631	.01	.10
17	78.2	53.0	776		.17
18	84.9	53.6	773		.22
19	92.5	67.9	681		.28
20	96.2	78.9	425		.36
21	96.2	77.0	775		.28
22	86.8	63.5	799		.32
23	86.3	60.3	794		.43
24	87.0	63.4	817		.28
25	90.9	61.3	789		.26
26	98.9	68.4	706		.32
27	98.9	72.4	789		.26
28	98.2	74.0	694		.31
29	101.0	83.9	771		.46
30	100.2	84.0	433		.49
31	74.8	68.5	312	.04	.24

1961

Date	Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
Apr 1	89.2	55.3	478		.20
2	87.3	67.0	269		.18
3	90.7	74.9	203	.01	.21
4	69.0	64.1	142	.56	.09
5	84.0	60.2	448	.28	.05
6	72.5	67.4	70		.14
7	75.7	63.8	209	.76	.02
8	85.3	64.0	415	.11	.09
9	79.9	74.0	165		.23
10	71.8	62.3	298	.53	.14
11	70.2	57.8	248	.02	.10
12	65.4	57.9	333	.13	.08
13	60.9	55.8	136	.15	.16
14	61.8	54.8	301	1.10	.12
15	63.8	51.8	424	.29	.12
16	64.8	45.6	342	.04	.13
17	63.9	52.1	424		.15
18	67.0	55.9	262		.22
19	67.4	55.1	131	.15	.18
20	74.3	54.6	297	.26	.01
21	75.1	62.1	389		.06
22	67.2	63.9	123	.02	.13
23	66.1	57.1	226	.01	.06
24	66.1	56.3	288	.20	.08
25	67.4	53.2	266	.01	.09
26	63.2	49.1	331		.08
27	64.3	48.3	402		.11
28	70.0	48.2	392		.12
29	66.9	56.1	203		.12
30	73.1	56.0	381		.06

1961

Date	Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
May 1	72.1	53.0	368		.12
2	65.2	55.2	164		.11
3	58.0	46.2	348	.27	.11
4	61.6	45.0	236	.04	.10
5	61.9	47.1	209	.03	.04
6	61.7	50.6	153	.04	.03
7	63.2	47.0	247		.06
8	63.1	50.9	248	.04	.06
9	58.6	45.3	215	.15	.08
10	60.3	42.8	350		.07
11	61.2	43.8	351		.09
12	62.8	51.5	241		.14
13	61.1	51.2	197	.22	.12
14	63.2	51.9	291	.53	.02
15	65.3	52.0	179	.03	.06
16	67.3	54.0	328		.05
17	70.7	54.4	334		.10
18	70.6	53.4	333		.08
19	71.7	52.1	325		.07
20	70.8	53.2	322		.09
21	70.2	58.2	315		.12
22	72.0	60.9	277		.14
23	71.9	60.8	313		.13
24	65.8	52.9	209	.01	.08
25	62.0	53.4	90	.10	.06
26	62.1	53.6	139	.04	.08
27	66.6	53.1	275	.02	.06
28	63.6	53.9	207	.14	.03
29	61.5	50.9	150		.06
30	65.9	48.7	312	.01	.07
31	64.1	54.2	280		.08

1961

Date	Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
June 1	66.7	52.0	285		.10
2	68.4	53.9	226		.09
3	61.2	52.4	206	.18	.10
4	60.3	51.3	173	.34	.04
5	63.4	48.2	256	.10	.01
6	66.4	52.3	245		.08
7	66.3	53.8	188	.10	.12
8	60.3	53.7	105	.13	.04
9	63.0	54.2	269	.21	.01
10	66.0	49.6	292	.01	.09
11	68.5	55.5	283		.08
12	68.2	56.6	280		.08
13	65.9	53.9	283		.12
14	65.5	57.3	186		.14
15	62.6	56.9	80		.15
16	56.2	52.2	176	.17	.09
17	57.9	48.1	150	.17	.09
18	59.9	51.9	176	.27	.02
19	55.5	47.0	227	.17	.05
20	53.3	44.3	150	.04	.08
21	56.5	42.5	253	.15	.04
22	56.9	42.2	221	.02	.08
23	53.5	43.0	136		.07
24	59.8	47.8	212	.63	
25	60.1	49.3	174	.02	.04
26	59.9	50.3	288	.08	.02
27	58.1	46.1	291		.10
28	61.2	47.4	186		.10
29	62.9	49.1	218		.10
30	64.3	53.4	248		.08

1961

Date	Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
July 1	63.1	46.1	259		.09
2	59.8	51.2	182	.18	.06
3	59.0	47.0	198	.34	.06
4	61.8	50.2	167	.14	.01
5	55.9	45.1	206	.73	.04
6	55.5	48.7	156	.04	.13
7	55.9	43.0	223	.37	.03
8	53.8	47.7	145	.05	.05
9	54.9	47.2	114	.04	.07
10	56.6	48.5	193	.11	.03
11	58.2	44.6	227		.05
12	58.5	45.6	173		.05
13	52.7	47.2	112		.04
14	57.0	48.4	195	.21	.02
15	57.2	44.0	235	.01	.05
16	55.6	43.0	203	.02	.06
17	56.1	44.2	170	.02	.04
18	54.1	42.2	247		.05
19	58.8	42.5	322		.06
20	56.4	40.8	325		.08
21	57.7	40.6	244		.08
22	53.8	41.8	99		.09
23	54.6	44.9	132	.27	.03
24	59.3	46.4	292	.16	.01
25	60.7	48.8	337	.02	.08
26	56.4	46.9	192	.08	.05
27	54.2	48.4	194	.10	.03
28	56.7	43.3	109	.06	.03
29	55.8	49.4	127	.05	.05
30	60.5	46.0	251	.11	.02
31	59.4	46.8	229	.02	.04

1961

Date		Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
Aug	1	57.3	46.4	165	.01	.04
	2	57.4	48.6	242	.07	.03
	3	54.6	41.8	242	.02	.08
	4	53.1	40.5	204	.03	.05
	5	55.3	37.5	322		.07
	6	59.3	45.5	369		.10
	7	61.6	45.6	324		.08
	8	67.6	53.1	288		.13
	9	59.2	42.5	257	.20	.11
	10	58.9	45.9	245	.01	.04
	11	59.2	43.3	291	.01	.06
	12	59.3	46.8	189		.05
	13	67.8	49.2	399		.07
	14	69.8	55.8	356		.11
	15	58.9	47.8	372	.11	.11
	16	56.1	46.9	303	.25	.08
	17	57.5	49.3	271	.12	.10
	18	56.1	44.1	238	.03	.06
	19	66.3	45.7	396		.08
	20	55.2	42.6	300	.56	.10
	21	57.0	47.1	250	.15	.06
	22	57.5	48.3	277	.17	.11
	23	55.2	42.0	312	.10	.09
	24	59.6	42.5	325	.07	.08
	25	60.0	43.5	369	.01	.08
	26	61.7	42.1	446		.09
	27	63.9	49.9	300		.11
	28	57.5	47.1	363	.03	.09
	29	55.5	46.7	288	.07	.10
	30	55.8	39.3	158	.01	.08
	31	62.5	48.1	271	.15	.02

1961

Date		Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
Sep	1	57.9	52.6	179	.22	.04
	2	60.1	50.1	389	.07	.03
	3	66.8	45.5	480		.07
	4	65.3	53.5	173		.16
	5	58.8	46.3	433	.19	.10
	6	61.8	48.9	248		.09
	7	64.8	51.7	304		.05
	8	71.3	53.7	480		.11
	9	71.1	60.5	505		.19
	10	68.9	48.2	472		.16
	11	71.1	54.7	504		.19
	12	73.5	60.3	374		.25
	13	59.9	57.8	174	.04	.22
	14	58.1	46.0	212	.41	.04
	15	60.4	46.3	333	.30	.07
	16	58.9	49.3	319	.10	.09
	17	59.3	48.5	344		.07
	18	66.3	45.0	431		.10
	19	71.5	54.5	545		.13
	20	71.5	48.5	514		.12
	21	63.0	44.2	555		.13
	22	64.6	49.4	569		.12
	23	74.0	46.0	572		.12
	24	82.7	57.1	492		.17
	25	62.9	53.0	481		.20
	26	62.8	49.3	543		.12
	27	72.9	46.1	597		.14
	28	81.0	60.1	596		.21
	29	88.5	66.8	591		.27
	30	92.0	71.5	475		.30

1961

Date	Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
Oct 1	61.2	53.0	490	.01	.32
2	63.8	45.9	617	.01	.13
3	71.4	47.5	626		.15
4	73.2	53.5	368		.15
5	72.7	53.6	620		.14
6	82.6	53.1	607		.20
7	83.7	59.1	597		.23
8	80.3	57.5	622		.16
9	87.0	69.0	464		.23
10	64.4	55.8	348	.10	.25
11	63.1	53.5	448	.16	.20
12	80.7	50.1	489	.01	.12
13	74.0	58.9	572		.20
14	65.2	53.5	415		.14
15	69.9	48.3	369		.12
16	70.2	46.4	679		.17
17	81.9	55.4	672		.22
18	92.9	63.7	546		.24
19	81.3	67.3	291		.26
20	64.8	55.4	664	.11	.13
21	63.4	48.9	445		.23
22	63.0	43.0	570		.15
23	66.8	53.5	495		.17
24	62.8	55.1	365	.02	.17
25	63.7	51.1	416	.04	.18
26	66.2	50.2	543		.13
27	70.5	46.9	712		.14
28	83.2	51.4	693		.17
29	90.2	62.8	653		.23
30	88.9	72.2	307		.41
31	66.3	54.9	319	.30	.23

1961

Date	Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
Nov 1	59.3	52.3	168	.41	.10
2	71.0	53.0	549	.09	.03
3	84.1	53.0	679		.11
4	92.7	70.6	593		.24
5	99.0	81.1	672		.30
6	73.9	69.3	499	.01	.30
7	67.7	47.6	584	.02	.19
8	64.8	50.3	531		.20
9	61.7	52.4	365	.01	.34
10	63.6	53.1	487	.06	.15
11	73.8	49.0	780		.18
12	83.1	57.0	785		.24
13	89.3	65.3	767		.33
14	68.1	65.6	466		.36
15	65.9	52.0	535	.02	.18
16	63.8	48.9	121		.31
17	64.9	52.5	451	.18	.09
18	74.5	55.0	737		.09
19	80.1	61.1	705		.18
20	85.0	59.1	762		.20
21	90.2	66.7	505		.25
22	72.2	59.3	619		.22
23	67.3	50.4	591		.29
24	65.9	54.0	638		.18
25	69.0	47.1	759	.01	.21
26	71.2	54.1	416		.28
27	78.6	58.6	740	.01	.19
28	87.6	57.6	498		.22
29	72.4	60.8	409	.04	.26
30	70.0	57.1	742	.01	.14

1961

Date	Max.Temp.	Min.Temp.	Rad.	Rain	Evap.
Dec 1	74.7	49.8	805		.21
2	92.3	55.8	786		.23
3	97.9	64.8	712		.31
4	81.5	59.6	744		.39
5	66.2	53.5	484		.28
6	66.2	49.5	814	.01	.24
7	66.8	46.8	519		.25
8	65.2	53.7	561	.06	.23
9	68.5	53.7	661		.19
10	74.5	52.5	634		.17
11	76.7	54.3	675		.26
12	76.9	61.3	350		.35
13	78.0	61.3	377	.10	.22
14	71.5	60.3	307	.03	.14
15	74.3	59.8	464	.17	.11
16	94.3	61.0	300		.13
17	67.5	59.1	374	.11	.22
18	63.9	50.9	605	.06	.17
19	67.8	48.2	759	.01	.22
20	74.5	50.5	835		.25
21	82.9	60.0	823		.25
22	90.3	67.0	824		.28
23	94.0	66.8	838		.34
24	95.7	75.3	838		.47
25	94.8	69.2	803		.40
26	97.7	67.7	740		.38
27	102.5	72.5	602		.39
28	78.3	60.1	458		.29
29	73.5	56.5	848		.22
30	74.9	51.6	767		.25
31	76.2	57.4	762		.27