AN AGRONOMIC EVALUATION OF SUBTERRANEAN CLOVER CULTIVARS

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CHAPTER I

INTRODUCTION

The permanent pasture based on a grass-clover association and utilised *in situ* by grazing stock is the basis of New Zealand's chief primary industries. Although white clover is the main legume species used for this purpose its production and persistence in the drier eastern areas often leaves much to be desired (O'Connor and Vartha, 1968). In such situations subterranean clover may provide a useful alternative. Subterranean clover has been a very useful species in the past and will probably continue to play an important role in the future, provided the most climatically adapted cultivars are grown. In the light of present knowledge Maiden's (1896) now classical observation, "It is not an introduction which need render us uncomfortable," tends to be rather inadequate.

CHAPTER II

REVIEW OF LITERATURE

I. INTRODUCTION

Subterranean clover (*Trifolium subterraneum* L.) is a winter growing, self-fertilizing, annual legume that is naturally distributed around the Mediterranean region in areas having predominantly wet winters and dry summers. The seed germinates with the advent of autumn rains, the plant growing under favourable conditions until seed is set in the late spring or early summer. The plant therefore survives the dry summer months as seed.

Morley (1961) has compiled a comprehensive review of subterranean clover while Donald (1960), has reviewed the effects of climatic factors on the distribution of the plant. A bibliography of subterranean clover up to mid-1960 has been assembled by Symon (1961).

II. GERMINATION

Under field conditions the peak of germination usually occurs in the late summer and autumn coinciding with the autumn rains (Donald, 1959). On twelve types of sandy soil Roberts (1966) found that highest emergence was achieved when a water content of 10 per cent by weight (-10 cm water potential) was maintained for at least four days. Very little emergence occurred when the water content was maintained at two per cent by weight (-120 cm water potential). However, often when subterranean clover seeds are placed under conditions believed to be optimum for germination they fail to do so. This is due to the phenomena of seed dormancy and hardseededness, both of which greatly assist seed conservation in a Mediterranean type of environment.

Seed dormancy has been defined as the inhibition of germination in viable, fully imbibed seeds (Morley, 1961). It may last one week or a few months (Loftus Hills, 1942) and has evolved as a mechanism to guard against a false break in germination if very early autumn rains arrive before growing conditions are favourable and prolonged. Germination promoters or inhibitors are probably involved but as yet the exact metabolic pathways have not been determined (Ballard and Grant Lipp, 1969). Taylor and Rossiter (1967a) have suggested that these chemical substances are water soluble because the leaching of dormant seeds with water gives greatly increased germination. High temperatures have been shown to inhibit germination in subterranean clover and this is probably one of the key factors operating in the field during the summer. Seed dormancy can be relieved by low temperatures, low oxygen concentrations, carbon dioxide, activated carbon, hydrogen peroxide and removal of the testa (Ballard, 1958, 1961; Ballard and Grant Lipp, 1969; Grant Lipp and Ballard, 1959; Loftus Hills, 1944; Millington, 1956).

Large differences in the degree of seed dormancy exist between cultivars and between plants of the same cultivar, the latter presumed to be environmentally determined (Loftus Hills, 1944; Morley, 1958a).

Hard seeds fail to germinate because the seed coat is impermeable to water, and the seeds may remain hard for many years depending on the seasons (Loftus Hills, 1944). The phenomenon of hardseededness ensures that in a year of total flowering failure due to an early and prolonged spring drought, there is still some seed available for the following years. Aitken (1939) showed that hardseededness depends on the continuity of an impermeable suberized thickening of the testa, the development of which largely depends on favourable growing conditions during and after flowering. Both Aitken (1939) and Loftus Hills (1944) showed that the degree of hardseededness was not consistently related to the cultivar i.e. there was an interaction of cultivar and environment. About four weeks after the commencement of flowering, the earliest produced seeds are mature if they are allowed to dry out. If however there is plenty of soil moisture, the mature seed, and particularly its seed coat continues to grow. The seed coat becomes thick and when the seed dries out it becomes a hard seed. If the spring is favourable and prolonged, a very large proportion of the seed produced is hard. On the other hand, if little rain falls after flowering commences, little or no hard seed will be produced (Higgs, 1958).

→ However, within one flowering group some cultivars appear to have an inherently high capacity for hard seed production. For example, in the lower rainfall areas where seasonal conditions are often variable, the superiority of the cultivars Geraldton and Northam A over Dwalganup and Carnamah has been attributed partly to the higher hard seed contents of the former cultivars (Rossiter, 1966; Taylor and Rossiter, 1967b).

Fluctuating temperatures, as they occur naturally in the field on the soil surface lead to a rapid rate of seed softening (Aitken, 1939; Quinlivan, 1961, 1965; Quinlivan and Millington, 1962). The main factor determining the rate of softening appears to be the maximum temperature of the fluctuation, provided that the temperature changes by some 15°C (Quinlivan, 1966).

At Canberra, Donald (1959) showed that on average 92 per cent of the seed crop germinated in the year following its production with 6.3 per cent in the second year and with falling values to 0.07 per cent in the fifth year. Although both seed dormancy and hardseededness influence this pattern of germination, the relative contribution of each is difficult to assess.

III. VEGETATIVE GROWTH

1. The Effects of Seed Size and Sowing Rate

The seed weight of subterranean clover varies both within and between cultivars, but the average may be from less than 5 mg for a small-seeded cultivar such as Geraldton to more than 8 mg for a large-seeded cultivar such as Woogenellup (Morley, 1961). It is interesting to note that the mean seed weight of subterranean clover is higher than that of most perennial clovers. Presumably the requirement for this high "initial capital" is not as great in a perennial as an annual, since establishment does not have to take place every year.

The effects of seed size and sowing rate on the growth of single plants and swards of subterranean clover have been the subject of several papers by Black (1955a, 1956, 1957a, 1957b, 1958, 1961), Lawson (1959), Lawson and Rossiter (1958) and of a review by Black (1959). These studies have shown that seed size largely governs the early growth rate of the plant (but not the relative growth rate) and this influences the time at which competition becomes operative in swards of a given density. In other words, for two swards sown at the same plant density, the sward with the larger seed size will produce more initially, although differences will become less with time as competition begins to operate, starting in the sward sown with the larger seed. In mixed stands of subterranean clover plants obtained from seed of two contrasting sizes, Black (1958) found that during the first three months' growth there was no change in the number of plants obtained from large seeds in the mixture but that the number of plants obtained from small seed declined markedly. Black contends that these differences come about largely as a result of the cotyledonary area at emergence and its effect on light utilisation. However, as Morley (1961) has pointed out, this contention is not yet wholly proved. It is possible that growth rate could equally depend on meristem size, which is perhaps also a function of seed size.

2. Light Intensity and Temperature Effects

For spaced plants several workers have shown positive responses to increasing light energy. Ozanne (1955), in a study of the effect of daylength and light intensity on the response to zinc by subterranean clover showed that increasing the light intensity from 750 f.c. to 1400 f.c. gave a large increase in the yield of tops in both long and short days but further increases in light intensity gave little or no increase in yield. Greenwood (1950), Millikan (1957) and Mitchell (1956a, 1956b) have also demonstrated clear responses by subterranean clover to increasing light energy.

On the basis of multiple regressions over a period of 52 weeks, Black (1955b) found no effect of temperature on the relative growth rate of subterranean clover (cv. Bacchus Marsh). The plants were of comparable morphological age and were grown outdoors within a range of mean weekly temperatures from 8.2 to 25.2°C. He concluded that the growth rate of this species in the early vegetative stage was mainly determined by the amount of radiant energy received and that temperature was of minor significance, except perhaps in extreme conditions. This finding is at variance with those of a number of other workers who have demonstrated clear temperature responses. In the cultivars Yarloop, Bacchus Marsh, Clare, Wenigup and Tallarook, Morley (1958b) found considerable differences in their relative growth rates at different temperatures. The plants were grown in comparable glasshouses, kept at three temperatures with means of 16.2, 18.6 and 24.2°C, the day temperature being 5°C higher than the night temperature. The optimal temperatures for growth were higher for Clare and Wenigup than Yarloop and Tallarook. Bacchus Marsh showed little response to temperature over the range studied indicating that the choice of this cultivar by Black may have been rather restrictive. Recently, Bouma and Dowling (1969) have shown that even moderately low temperatures of 15°C day/10°C night can cause marked growth reductions of the Mount Barker (Mt. Barker) cultivar. Mitchell (1956b) has also shown clear temperature responses in this cultivar.

Once established, subterranean clover appears to be quite tolerant of very low temperatures. In Central Otago Beggs (1938) found that the cultivars Dwalganup and Mt. Barker could tolerate frosts of up to 30°F once established but frosts were injurious to small seedlings. In the same area Smetham (1968) found that frosts did not cause any appreciable loss of plants or topgrowth except in the year of establishment but this only occurred where the plant density was low. Of the commercial cultivars, Clare seems to be the most susceptible to damage by frosts (Morley, 1961; Walker and Neal-Smith, 1959).

It seems therefore that, contrary to Black's (1955b) conclusions, both light energy and temperature may exert a big influence on the growth of subterranean clover.

Seasonal variations in sward productivity may be influenced by light energy and temperature, the relative contribution of each depending on the plant density and leaf area index (L.A.I.) of the sward. Shortly after germination, growth rate will probably depend largely on the cultivar and its responses to light energy and temperature but, as the leaf canopy forms, mutual shading will cause light intensity to become increasingly limiting for the lower leaves of the canopy. Light energy will then become the main factor determining sward production (Morley, 1961), although the time at which this occurs will probably vary in cultivars due to differences in growth habit.

The differences which exist between cultivars in growth habit may also influence the degree of competition they are capable of offering to associated subterranean clover cultivars, grasses or invading weeds. Yarloop, a cultivar with very long petioles has been shown to restrict severely the growth of the prostrately growing Tallarook when both are grown together and in the absence of defoliation (Black, 1960). The competitive advantage of Yarloop was attributed largely to more efficient interception of light. More efficient light interception by the tall growing Yarloop and Clare is probably the main reason why these cultivars are recommended for sowing in areas where tall growing weeds may be a problem, provided of course, climatic conditions are satisfactory for seed production. In weedy situations the short dense cultivars Dwalganup and Tallarook may be shaded out by taller growing weeds (Higgs, 1958).

The concepts of leaf area and its relationships to pasture production investigated by Davidson and Donald (1958) and reviewed by Donald and Black (1958) suggest that a subterranean clover sward will produce at or near maximum when defoliation maintains the L.A.I. at around 4-5. Davidson and Donald (1958) were working with the cultivar Bacchus Marsh and it seems highly probable that the optimum L.A.I., besides varying with different climatic conditions will also vary between cultivars due to differances in leaf number, size and arrangement. Black (1963) investigated the recovery from one severe defoliation (removal of all leaves at the base of the petiole) for six commercial cultivars of subterranean clover growing in swards. The cultivars sorted themselves out into three distinct groups:

1. Yarloop and Clare were tall, high-yielding with few large leaves and recovered slowly from defoliation.
2. Tallarook and Dwalganup were prostrate, lower yielding, with many small leaves, and recovered rapidly after defoliation.
3. Bacchus Marsh and Mt. Barker were intermediate in all aspects.

It is apparent that production from swards will vary not only according to the cultivar and its responses to the prevailing climatic conditions, but also according to the cutting or grazing management imposed. These aspects obviously require closer study especially under New Zealand conditions.

IV. REPRODUCTIVE GROWTH

Being an annual, the persistence and production of subterranean clover depends to a large extent on a good seed set. A broad spectrum of genotypes has evolved varying widely in time of flowering to ensure that seed setting occurs before the onset of prolonged dry conditions. The ecological significance of flowering time in subterranean clover has been discussed by Aitken (1955b). At one extreme there are the very early flowering cultivars such as Carnamah and Geraldton adapted to growing in areas where the growing season is short, while at the other extreme are the late flowering cultivars such as Tallarook and Wenigup which can take advantage of long growing seasons. Numerous other cultivars cater for the intermediate situations.

1. Physiology of Flowering

Subterranean clover is a long-day plant, in that flower initiation is promoted by increased daylength (Aitken, 1955a; Aitken and Drake, 1941). As with many other long-day plants it also has a requirement for vernalisation (low temperatures during the vegetative growth phase), although the vernalisation requirement can be greatly modified by daylength (Aitken, 1955a). Under laboratory conditions (Evans, 1959), and in the field (Morley and Evans, 1959), it has also been shown that low temperatures may retard floral initiation, even although the requirements for vernalisation and photoperiod have been met.

Flowering time in the field therefore depends on the interaction of vernalisation with daylength and temperature. As the vernalisation process continues, the requirement for long days decreases until the critical daylength corresponds to the prevailing daylength. Provided temperatures are high enough initiation then takes place (Morley, 1961).

Early flowering cultivars have a small demand for both vernalisation and long days plus the capacity to initiate flowers at low temperatures, or some combination of these. Conversely, late flowering cultivars may require extended vernalisation, long days and high temperatures for initiation or some combination of these (Aitken, 1955a; Aitken and Drake, 1941; Evans, 1959; Morley, 1961; Morley and Evans, 1959).

Owing to these three interacting processes, the time interval between floral initiation of early cultivars and late cultivars is short in cold environments but extended in warm environments (Morley and Davern, 1956). The postinitiation phase or the time interval from the initiation of the first flower to the appearance of the first open flower may vary from 20 - 60 days depending largely on the temperature (Aitken and Drake, 1941).

2. Time of Flowering and Potential Inflorescence Production

In a study at Adelaide with spaced plants, Donald and Neal-Smith (1937) showed that the later the cultivar the greater is its number of inflorescences and hence the greater its potential seed production. Rossiter (1959) described a similar trend for the seed yield of spaced plants. Where environmental conditions are favourable during the flowering period, the same trend is evident in swards, provided the plant density is not extremely high (Donald, 1954). For example at Merredin, Yates (1961) found that inflorescence production in swards increased with increasing lateness of flowering, while Morley (1961) described a similar trend for swards at Canberra.

Increasing inflorescence production with increasing lateness of flowering is attributable to late cultivars flowering at a higher node of first flower (N.F.) and therefore producing more runners which are also more branched than early cultivars (Aitken, 1955a; Aitken and Drake, 1941). Within one cultivar, variations in the N.F. caused by different environmental conditions should cause differences in runner production with subsequent differences in inflorescence production. This was one of the aspects investigated in the present study.

Rossiter (1961) found that defoliation up to the commencement of flowering gave increased inflorescence production in swards of Dwalganup and Yarloop probably due to an increase in light intensity at the runner level. The beneficial effects of cutting on inflorescence production in white clover were attributed by Zaleski (1961) to an increase in light intensity at the stolon level giving rise to longer runners which were also more branched.

3. Flower Development and Seed Setting

The outer part of a subterranean clover inflorescence is formed of 3 - 7, usually four, perfect papillionate flowers. The inner part is developed after fertilization as a cluster of barbed projections, which are the calyxes of many abortive flowers. These processes form a burr enveloping the seeds (Morley, 1961). After pollination the florets reflex so that they lie back along the peduncle, which bends down and elongates towards the ground. At an early stage of development the young seeds tend to be pushed below the ground where the protective burr develops and seed maturation takes place (Yates, 1957).

The efficiency of seed set may be defined as the percentage of florets which develop into viable seed, although it is also a function of the individual seed weight. The time taken from anthesis to the production of viable seed is approximately 14 days (Aitken and Drake, 1941), although there are differences in the rate of seed development between cultivars (Millington, 1960; Tennant, 1965). Within one cultivar the rate of seed development is more rapid in buried burrs than above-ground burrs (Tennant, 1965), but the rate may decline with increasing plant density (Taylor and Rossiter, 1969).

A number of workers have demonstrated the adverse effects which a water stress during the flowering period may exert on the efficiency of seed set. For the cultivars Dwalganup, Yarloop and Bacchus Marsh, Aitken and Davidson (1954) found that a water stress artificially imposed during the flowering period reduced the number of burrs and number of seeds/burr compared with adequate moisture. With spaced plants Donald and Neal-Smith (1939) found a strong negative correlation between the mean number of seeds per inflorescence and evaporation (E_o) during the 8th - 28th day after the commencement of flowering. Tallarook was the exception in that it seemed to be less affected by adverse environmental conditions. Seed yields declined rapidly when E_o during full flowering was greater than 0.15 ins./day and were negligible at 0.17 ins.

/day. However, at Kojonup where E_o values were great than 0.15 ins./day Rossiter (1959) still obtained hig seed yields from spaced plants, although in swards seed yields declined with increasing lateness of flowering which, Rossiter suggested, was due to an increasing soil moisture stress. In some later work by the same author (Taylor and Rossiter, 1969) the effect of the available soil water level on flower abortion was also stressed.

Both E_o and the available soil water level will influence plant water stress, but to emphasize the effect of one factor alone may be quite erroneous. As Kramer (1963) has pointed out, the plant water balance is affected by the complex combination of soil, plant and atmospheric conditions which control the rate of water absorption and loss. To correlate seed production with water stress, the water stress of the plants themselves would have to be measured.

For subterranean clover there is evidence to show that the water balance of the individual burr is of considerable significance in affecting the efficiency of seed set. For spaced plants of Red-leaf subterranean clover grown in the field, Yates (1957) showed that seed setting was better in burrs below than above the soil, and artificial shielding of above-ground burrs with rubber appreciably improved seed setting. Yates suggested that burr burial is a protective mechanism against adverse atmospheric conditions.

In any one environment early flowering cultivars tend to bury more burrs than late flowering cultivars, but harsh environmental conditions at flowering seem to stimulate burr burial in all cultivars (Yates, 1958). This potential for burr burial may not in fact be fully realized if very dense topgrowth is present or if the soil surface becomes dry and hard (Yates, 1958; 1961; Taylor and Rossiter, 1969). For the cultivars Dwalganup and Yarloop, Rossiter (1961) has shown that defoliation before and during the flowering period results in a decrease in the mean number of seeds/burr. This decrease is greater in above ground than buried burrs, presumably due to the harsher micro-environmental conditions above ground following removal of the protective leaf cover.

Besides water stress, it has been suggested that frosts during the flowering period may also influence the degree of flower abortion. At an elevation of 2040 feet on the southern tablelands of New South Wales, Donald (1959) suggested that frosts during the flowering period were the principal factor governing seed production in swards. The aggregate deficit of the daily minimum temperature below 40°F in the 21 days from the commencement of flowering showed a high correlation with seed production in four successive seasons. Tallarook appeared to be more susceptible to frosts than Dwalganup, Bacchus Marsh and Mt. Barker. Morley (1961) has pointed out that other climatic factors could have operated, so that one may not unreservedly accept this interpretation. Apart from the work of Donald (1959) there is a distinct lack of quantitative information concerning the effects of frosts on seed production in subterranean clover.

With the exception of the effect of frosts and perhaps competition for substrates (Donald, 1954) all other factors influencing the efficiency of seed setting in subterranean clover therefore appear to be associated with one factor - water stress.

The components of seed yield in subterranean clover may be expressed by the following formula:

Seed Yield = Number of Inflorescences x Number of Seeds/ Inflorescence x Weight of Each Seed.

From the foregoing discussion it will be obvious that under field conditions each of these yield components will have a potential as determined largely by the cultivar but this will be modified by the climatic conditions.

V. DRY MATTER PRODUCTION

1. Vegetative Growth Phase

Shortly after germination Dry Matter (D.M.) production is influenced largely by seed size and/or sowing rate (Black, 1955a, 1956, 1957a, 1957b, 1958, 1959, 1961; Lawson, 1959; Lawson and Rossiter, 1958) as well as the cultivar and its responses to light energy (Black, 1955b, Greenwood, 1950; Millikan, 1957; Mitchell, 1956a, 1956b; Ozanne, 1955) and temperature (Black, 1955b; Bouma and Dowling, 1969; Mitchell, 1956b; Morley, 1958b). Dry Matter production probably reaches its maximum rate at a L.A.I. around 4 - 5 (Davidson and Donald, 1958) although this probably varies between cultivars due to differences in growth habit and responses to defoliation (Black, 1963).

During the vegetative growth phase most of the above ground D.M. production is in the form of leaves because at this stage the runners are short and compressed with very short internodes (Aitken and Drake, 1941). The potential for D.M. production during the vegetative growth phase tends to increase with increasing lateness of flowering due to the longer vegetative growth phase of the late flowering cultivars (Aitken, 1955a; Aitken and Drake, 1941).

2. Reproductive Growth Phase

Following flower initiation there is marked internode elongation as flowering and seed production commence. Compared with early flowering cultivars, late flowering cultivars have a higher potential for dry matter production during the reproductive growth phase due to a greater capacity for runner and seed production (Aitken and Drake, 1941). The same authors also found that in terms of quality, the leaf/stem ratio tends to increase with increasing lateness of flowering firstly because of the extended vegetative growth period of the late flowering cultivars and secondly because the length of internodes tends to decrease with increasing lateness of flowering.

However, as with seed yield, the final yield of dry matter is determined by how closely actual production determined by the climatic conditions approaches the potential production determined by the cultivar. Where the growing season is short highest dry matter yields are produced by the early flowering cultivars but as the length of the growing season is increased highest yields are given by mid-season and finally late flowering cultivars (Donald, 1960; Donald and Neal-Smith, 1937; Levy and Gorman, 1936; Rossiter, 1959, 1966; Yates, 1961).

VI. CULTIVAR EVALUATION IN NEW ZEALAND

The history of subterranean clover in New Zealand (N.Z.) has been reviewed by Saxby (1956). The first comprehensive cultivar evaluations carried out in N.Z. were those of Levy and Gorman (1936). They found that the early mid-season cultivars Bumerang, Nangeela and Bacchus

Marsh were the highest producing over the autumn-winter-spring period but were outproduced by the mid-season and late flowering cultivars Mt. Barker and Tallarook over the summer. Production was based on green weights or computed from figures allotted by eye estimation, a method of questionable accuracy.

Although the Department of Agriculture has been looking at cultivars of subterranean clover throughout N.Z. for the last 30 years (Smetham, 1968), very little information has been published on the subject. In Mid-Canterbury McPherson (1941) compared Mt. Barker, Tallarook, Dwalganup and Burnerang. It was concluded that Mt. Barker and Tallarook were the most successful because they were more leafy and produced more burrs than the other cultivars although there was no quantitative evidence presented to substantiate these claims. In cutting trials near Timaru, McLeod (1966) found that Woogenellup consistently outproduced Mt. Barker and Tallarook by up to 1000 lb D.M./acre/year. Recently, Smetham (1968) compared 18 cultivars of subterranean clover at three sites in Central Otago. On the basis of qualitative evidence he concluded that as many as six cultivars including Woogenellup, Nangella and Bacchus Marsh outproduced Mt. Barker by 20 per cent or more and recommended the sowing of these three cultivars.

Quantitative evidence on the performance of subterranean clover cultivars in N.Z. is therefore lacking. Mt. Barker and Tallarook are the only cultivars used extensively probably because seed is readily available (Saxby, 1956). The aim of the present study was to provide some quantitative information on the performance in Canterbury of several commercial cultivars including Mt. Barker and Tallarook.

CHAPTER III

FIELD TRIALS

I. AIMS

The aim of the field trials was to evaluate the productive performance of several subterranean clover cultivars in Canterbury. Because of the big influence of seed yield on subsequent production and persistence in annuals, this aspect was also investigated.

II. MATERIALS AND TRIAL SITES

In order to give a wide range in flowering times, the following six commercially available cultivars of subterranean clover were selected for evaluation: Geraldton, Yarloop, Woogenellup, Clare, Mt. Barker and Tallarook. Geraldton and Yarloop are early flowering, Woogenellup and Clare are early mid-season, Mt. Barker is mid-season and Tallarook is late flowering (Aitken and Drake, 1941). All seed used was of Australian origin and Government certified.

The two sites chosen for the field trials differed widely in regard to their climatic and soil conditions:

1. Waikari. The trial area was situated on the

"Cowley" property of Mr B. H. Palmer approximately four miles north-east of Waikari at an altitude of 900 ft. A.S.L. This area has a reasonably well distributed mean annual rainfall of 30 in. (Table 1). However, marked summer drought often occurs due to the variability of the summer rainfall and the high evaporation which is prevalent over the summer months as a result of the prevailing north-east and north-west winds (Garnier, 1958).

The soil type of the area has been classified as a Tipapa Hill Soil with a pH 5.6, being deficient in sulphur, phosphorus and sometimes molybdenum (N.Z. Soil Bureau, 1968). The unimproved vegetation is dominated by danthonia (Notodanthonia spp.) along with hard tussock (Festuca novae-zealandiae) and silver tussock (Poa laevis). Minor species include Matagouri (Discaria toumatau), Hair grass (Vulpia bromoides), sorrel (Rumex acetosella) and striated clover (Trifolium striatum).

The trial area was established on a slope of about 10° facing northwards. A general view of the trial area at Waikari can be seen in Plate 1.

2. Pukaki. The trial area was situated at the D.S.I.R. "Kennedy Pond" Experimental Area approximately half a mile south-east of Pukaki township at an elevation of 1700 ft. A.S.L. The climate of this area is characterized by very cold winters with about 120 ground frosts of

Table 1. Monthly and Annual Rainfall (in.) for Field Trial Sites.

Month	Waikari Mean	Waikari 1968	Pukaki Mean	Pukaki 1968
January	N.A.*	N.A.*	2.3	4.69
February	2.32	1.74	1.8	1.83
March	2.37	1.15	1.7	3.80
April	2.64	4.93	1.9	2.12
May	2.36	1.55	1.8	1.40
June	2.25	3.93	1.6	1.20
July	2.54	2.78	1.7	3.46
August	2.94	.36	1.7	3.33
September	2.44	1.38	2.0	3.45
October	2.55	3.81	2.2	3.65
November	2.20	.94	1.8	.52
December	3.05	3.35	2.3	1.16
Annual	30.66	28.92	22.8	30.61
	Mean 1937-58 at Trial Site	Taken at Trial Site	N.Z. Met. Service Pukaki	Taken at Trial Site

* N.A.: Not Available;
Assumed = 3 in. for calculation of annual rainfall.

up to 40°F each year, and very hot dry summers due to north-west winds and a high level of solar radiation. Although the mean annual precipitation at Pukaki is 22.8 in. with a summer maximum (Table 1), there is more variability

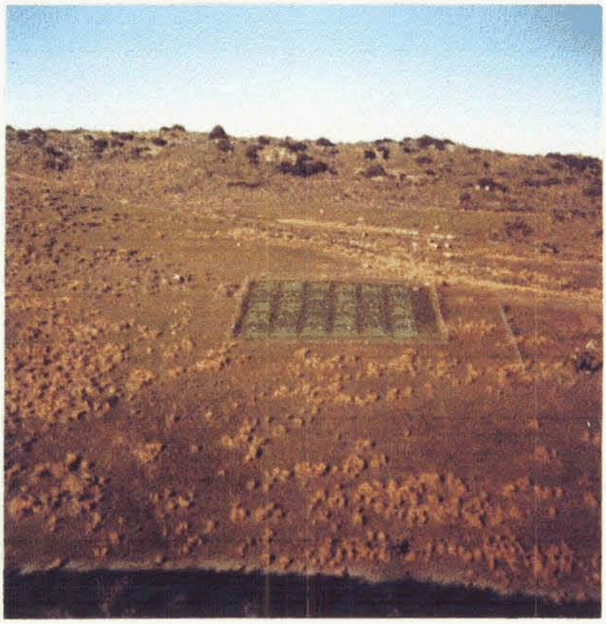


Plate 1. A general view of the Trial Area at Waikari - 31/7/68.

in spring and summer than at other times of the year. This factor, together with the high summer temperatures, accentuates the dryness of the area, for much of the rain comes during periods of high temperature when evaporation is high (Garnier, 1958).

The soil type of the trial area has been classified as an Acheron which is a shallow, infertile, excessively drained soil formed on outwash terraces. The topsoil has a pH 5.5 (N.Z. Soil Bureau, 1968). The low water holding capacity of this soil type probably accentuates the summer drought problem. Unimproved vegetation of the area consists of short tussock grassland dominated by hard tussock (Festuca novae-zealandiae) with intertussock species of sweet vernal (Anthoxanthum odoratum), silvery hair grass (Aira caryophyllea) and sorrell (Rumex acetosella).

The trial area was laid down on a slop of 2 - 3° facing towards the south-east. A general view of the trial area at Pukaki can be seen in Plate 2.

III. EXPERIMENTAL DESIGN AND TECHNIQUES

The experimental techniques were similar for both sites.

1. Establishment. For each soil type the lime requirement was determined by the Buffer Curve Method. This was found to be 32 cwt. lime/acre for the Tipapa soil

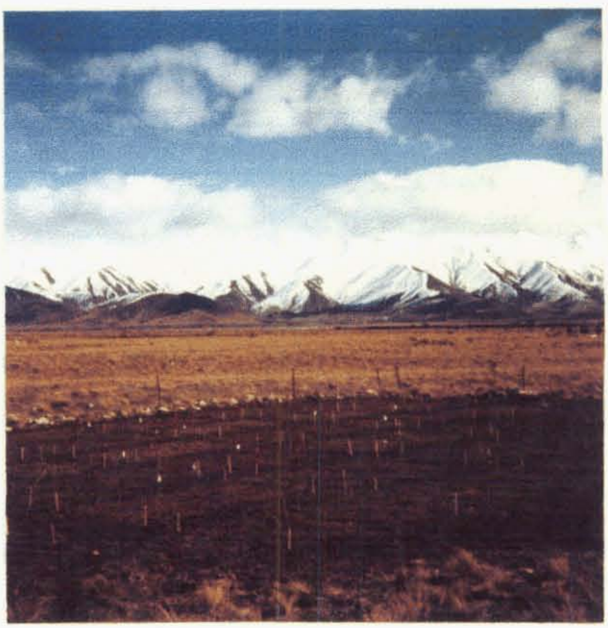


Plate 2. A general view of the Trial Area at Pukaki - 5/8/68.

and 42 cwt./acre for the Acheron. Both trial areas were cultivated over the 1967-68 summer and the requisite amount of lime worked into the topsoil.

The trials were arranged as a randomised block with five replications of the six cultivars, each plot measuring 6 ft. x 9 ft. with 18 in. between plots. All cultivars were sown at the rate of 45 viable seeds/ft.^{2}, a density similar to that used by Donald (1959). The importance of heavy sowing rates in trials of this nature has been discussed by Morley (1961). Superphosphate at 4 cwt./acre and Lindane prills at 2 lb./a.i./acre were applied to all plots following sowing. Ammonium molybdate was sprayed on all plots at the rate of 2 oz of solute/acre. At Pukaki, Borax at the rate of 10 lb./acre was included in the fertiliser (Clifford, pers. comm.). Following broadcasting of the seeds all plots were lightly raked.

All seed was inoculated prior to sowing. Apart from Woogenellup the seed of all cultivars was inoculated with the T.A.I. strain of rhizobia. Woogenellup seed was inoculated with W.A. 67 strain of rhizobia (Date, pers. comm.). Rhizobia counts were carried out for all cultivars to check on the rate of inoculation.

The sowing dates were 1/3/68 at Waikari and 2/3/68 at Pukaki. Following germination seedling counts were carried out at Waikari on 15/3/68 and on 16/3/68 at Pukaki.

To achieve this, a 6 in. square wire quadrat was thrown randomly eight times in each plot and the number of seedlings present inside the quadrat recorded. It was apparent (Table 2) that the rate of establishment varied between cultivars and also that within each plot there was variation in density (Appendices A, B). Because of the big influence of plant density on seed yield (Donald, 1954; Yates, 1961; Taylor and Rossiter, 1969), and to facilitate subsequent sampling for seed yield, it was decided to thin by hand two separate areas of 1 $ft.^2$ in each plot to a constant density of 24 $plants/ft.^2$, a density around the optimum for seed production (Donald, 1954). To eliminate "edge" effects around these areas, a border 6" wide was thinned to the same plant density and the area marked permanently with lengths of wire. A summary of the sowing data is presented in Table 2.

2. Dry Matter Yields. At Pukaki there was very little autumn and winter growth and only one cut was taken on 4/1/69. At Waikari autumn and winter growth was more vigorous and a total of three cuts was taken. The first cut (April cut) was taken on 30/4/68 and the aim here was to investigate the effect of seed size on D.M. yield so that cutting was carried out before much interplant competition became apparent. The second cut (July cut) taken on 30/7/68 measured the regrowth following the April

Table 2. Field Trials Sowing and Establishment Data.

Cultivar	1000 Seed Wt. g.	Laboratory Germination %	Sowing Rate g./plot	No. Rhizobia / Seed	No. Plants/ft.^{2}* Waikari	No. Plants/ft.^{2}* Pukaki
Geraldton	4.85	97	122	1160	46 a	48 a
Yarloop	8.86	90	239	2880	25 c	26 b
Woogenellup	10.74	95	275	3940	33 b	44 a
Clare	9.96	94	258	8950	41 a	43 a
Mt. Barker	8.32	75	269	3510	40 ab	46 a
Tallarook	5.69	88	157	1500	33 b	32 b
				S.E. Mean	$\pm$2.47	$\pm$2.67
				C.V. %	15	15

* Duncan's Multiple Range Test. Common letters indicate non significance at 5% level.

cut over the late autumn-winter period. The final cut (November cut) taken on 13/11/68 measured the spring production following the July cut, and at the time of cutting all cultivars had begun to senesce.

Due to the sparseness of herbage on some of the plots at Waikari when the April cut was taken, 24 ft.^{2} was cut from each plot although for each subsequent cut at both sites the sampling area was 16 ft.^{2}/plot. Following cutting of the sample area the whole plot except for the areas marked for seed production was trimmed to the same height as the sample area and the herbage discarded. A "Tarpen" mower was used to cut the plots to about 1 in. during the vegetative growth phase but for the final cuts at both sites the sample area was cut to ground level with hand shears. All herbage from the sample area including above ground burrs was collected and weighed green. Where the bulk of material allowed it, a 500 g. sub-sample of green material was removed, dried to constant weight and weighed for determination of total D.M. For the April cut at Waikari a smaller sub-sample had to be taken.

Another sub-sample representing about 5 per cent of the total green weight was removed for botanical analysis. For the Waikari site this was separated into subterranean clover, weed clover, weeds and litter. At Pukaki the sample was separated into subterranean clover and weeds.

Following separation all samples were dried to constant weight and weighed from a desiccator.

3. Seed Yields. The commencement of flowering of each cultivar at each site was determined by recording the time when there were at least four open flowers/$ft.^2$ quadrat present. Flowering times are approximate only as the trial sites were inspected weekly at Waikari but fortnightly at Pukaki over the spring period. At this time a count was also made of the number of florets per inflorescence for each cultivar by randomly selecting 10 inflorescences/quadrat.

At Waikari seed yields were determined both for the uncut areas and the areas cut on 30/7/68 by sampling the $ft.^2$ quadrats thinned to a constant plant density as described previously. Because of the poor autumn and winter growth at Pukaki seed yields were determined only from uncut areas. However, due to the variable plant density within the quadrats brought about by frost "heave" following hand thinning, two separate $ft.^2$ quadrats were harvested from each plot.

Within each quadrat all above-ground burrs were harvested by cutting with hand shears and removing the remainder manually. Any burrs not adhering to the soil surface were classified as above ground. Buried burrs were recovered by removing the top 2 in. of soil and separating out the burrs manually. At the same time, the total number of subterranean plant crowns within the sample area was recorded, and at Pukaki the total number of primary runners per plant was also noted to investigate the influence of runner density on seed yield.

The burrs were then counted, threshed by gently rubbing them between rubber pads and the seed cleaned by rotating it in a sieve over a small fan. Any inert material not removed by this process was removed manually. The seeds were then counted and weighed.

Some difficulties in seed harvesting were experienced at Waikari due to the rather unseasonal weather conditions. There was some premature germination of seed in plots of Woogenellup and Mt. Barker. Although this only occurred on the cut areas of these cultivars, some disintegration of burrs occurred on both the cut and uncut areas so that a small loss of seed may have occurred. Any seeds which had germinated were counted, and discarded, their 1000 seed weight and distribution in relation to the soil surface assumed to be the same as the mean of all other seeds in that quadrat.

All seed for each cultivar at each site was then bulked, mixed and three samples each of 100 seeds removed for a germination test. In order to remove all hard seeds the samples were gently rubbed between two layers of fine sandpaper and placed on moist blotting paper in petri dishes. This procedure was continued until all seeds showed visible evidence of imbibition. The petri dishes were then placed in a refrigerator for 48 hours to break seed dormancy, removed and allowed to germinate at approximately 32°C. After seven days all normal seedlings were counted.

Following the autumn rains a seedling count was made at each site to measure re-establishment. The technique used was the same as that described previously for the determination of seedling establishment. Where the seedling density within the quadrat was greater than 30, the seedlings were not counted but given a score of >30.

IV. RESULTS

1. Dry Matter Yields

Analysis of Variance was conducted on dry weights as g./plot but for presentation in the text the means have been converted to lb./acre and the standard errors adjusted accordingly. When F tests showed significant differences, Duncan's Multiple Range Tests were conducted. In all Tables common letters indicate non significance at the 5 per cent level.

(a) Waikari

Treatment means and analysis of the April cut are presented in Table 3.

Table 3. Mean D.M. Yields (lb./acre) April Cut - Waikari.

Cultivar	Sub. Clover	Weed Clover	Weeds	Total Weeds	Total D.M.	% Weeds*
Geraldton	219 b	11 a	66 ab	77 ab	296 b	27 a(23)
Yarloop	282 b	18 a	30 b	48 b	330 b	20 a(13)
Woogenellup	529 a	25 a	83 a	108 a	647 a	24 a(18)
Clare	476 a	22 a	39 ab	61 ab	637 a	19 a(11)
Mt. Barker	497 a	24 a	34 b	58 ab	555 a	19 a(11)
Tallarook	239 b	21 a	38 ab	59 ab	298 b	25 a(18)
S.E. Mean	±42	±4	±15	±17	±42	±3
C.V. %	25	50	69	54	21	29

* Angular transformed values. Actual percentages shown in brackets.

Woogenellup, Clare and Mt. Barker produced significantly more subterranean clover and total D.M. than the other cultivars. The high C.V. values for both weed clover and weeds suggest that these weeds were spread unevenly throughout the plots and that at this stage there was very little difference between cultivars in the amount of competition they were offering weeds. Although Woogenellup plots contained significantly more total weeds than Yarloop there were no significant differences between cultivars in the percentage weeds. The weed clover fraction consisted of striated clover (*Trifolium striatum*) while other weeds were mainly hairgrass (*Vulpia bromoides*) and sorrel (*Rumex acetosella*).

It appeared that most of the differences in subterranean clover production for this first cut were due to differences in seed weight and there was in fact a significant positive correlation ($r = +0.835$, $p < 0.05$) between subterranean clover yield and 1000 seed weight (Figure 1). From this graph it can be seen that Yarloop produced considerably less D.M. than expected from its seed weight. This may have been due to the fact that Yarloop established at a significantly lower plant density than all other cultivars (Table 2). However, an analysis of covariance to correct for plant density proved insignificant indicating that seed weight was the main factor operating in this particular case.

Treatment means and analysis of the July cut are presented in Table 4.

There was no significant difference between the three highest yielding cultivars namely Clare, Woogenellup and Mt. Barker. Of these only Clare was significantly higher yielding than Yarloop, the next highest yielding cultivar. Tallarook produced significantly less subterranean clover than all other cultivars except Geraldton.

Yarloop and Clare stood out as the most weed-free

FIGURE 1. The Relationship between D.M.Yield and Seed Weight.

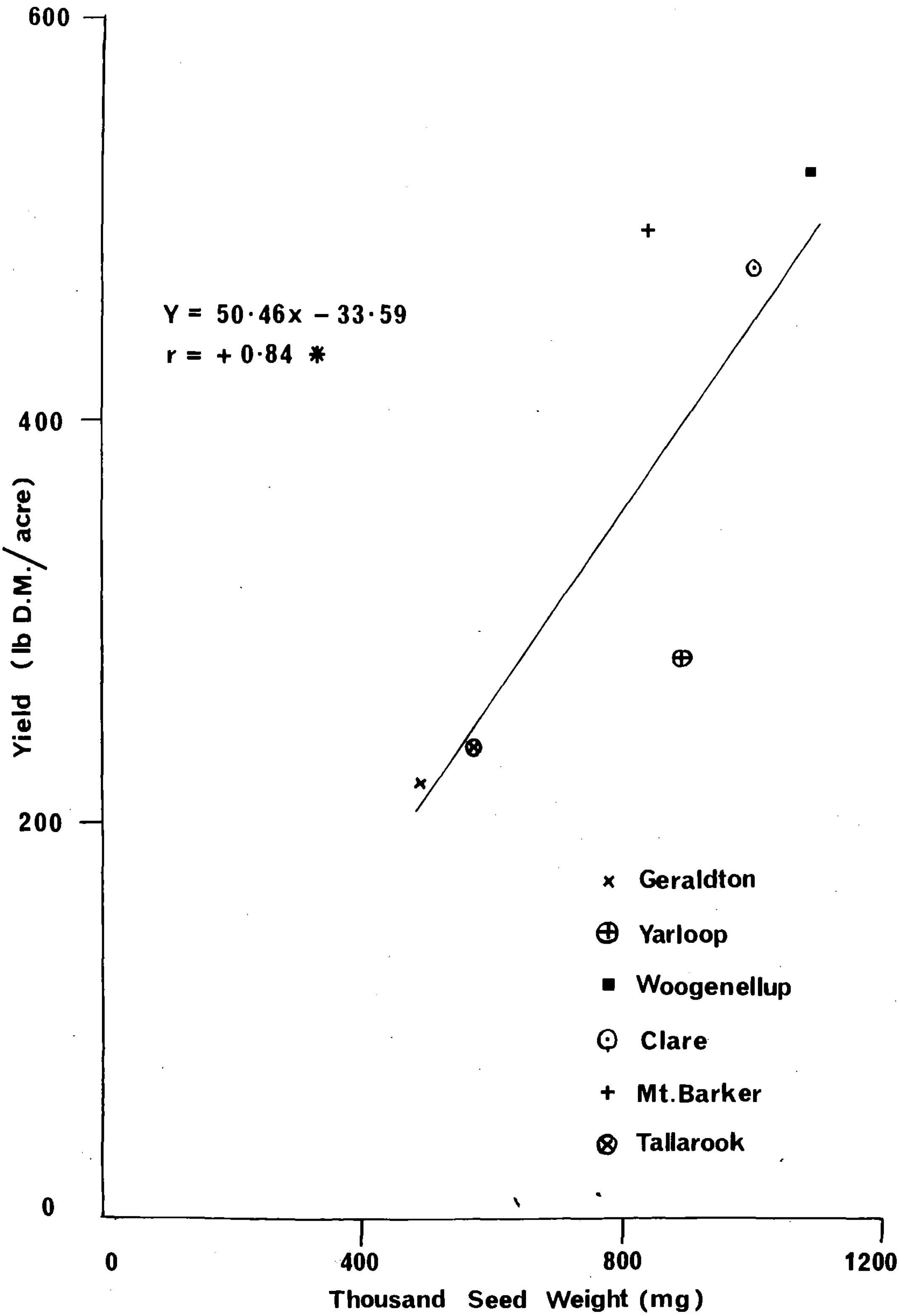


Table 4. Mean D.M. Yields (lb./acre) July Cut - Waikari.

Cultivar	Sub. Clover	Weed Clover	Weeds	Total Weeds	Total D.M.	% Weeds*
Geraldton	1010 cd	126 a	266 a	392 a	1402 ab	32 a(28)
Yarloop	1218 bc	51 c	73 b	124 b	1342 ab	17 d(9)
Woogenellup	1417 ab	67 bc	196 a	263 a	1680 a	23 c(15)
Clare	1536 a	40 c	93 b	133 b	1669 a	16 d(8)
Mt. Barker	1284 abc	106 ab	218 a	324 a	1608 a	26 bc(20)
Tallarook	893 d	106 ab	217 a	323 a	1216 b	30 ab(25)
S.E.	±93	±13	±35	±42	±105	±2
C.V. %	17	36	44	37	16	16

* Angular transformed values. Actual percentages shown in brackets.

cultivars while Geraldton, Mt. Barker and Tallarook all contained a high proportion of weeds. Woogenellup was in an intermediate position. Because of the high yield of weeds in the low producing cultivars, there was little difference between cultivars in the yield of total D.M. except for Tallarook which produced significantly less than Woogenellup, Clare and Mt. Barker. The weed species present were the same as those for the April cut.

Treatment means and analysis of the November cut are presented in Table 5.

Woogenellup and Clare produced significantly more

Table 5. Mean D.M. Yields (lb./acre) November Cut - Waikari.

Cultivar	Sub. Clover	Weed Clover	Weeds	Total Weeds	Total D.M.	% Weeds
Geraldton	1462 c	1684 a	960 a	2644 a	4106 d	53 a(64)
Yarloop	3191 b	1213 b	365 c	1578 b	4769 bcd	36 b(33)
Woogenellup	5154 a	155 c	251 c	406 c	5560 b	16 c(7)
Clare	5938 a	304 c	328 c	632 c	6570 a	17 c(8)
Mt. Barker	3689 b	400 c	474 bc	874 c	4563 cd	23 c(16)
Tallarook	3348 b	1155 b	630 a	1785 b	5133 bc	34 b(32)
S.E.	±318	±132	±80	±191	±266	±3
C.V. %	19	35	36	32	12	19

subterranean clover than all other cultivars while Geraldton was lowest yielding. Yarloop, Mt. Barker and Tallarook were in an intermediate position. The yield of weeds was low in Woogenellup, Clare and Mt. Barker plots but very high in Geraldton, Yarloop and Tallarook. Most of this weed content consisted of striated clover (*Trifolium striatum*). Clare produced significantly more total D.M. than all other cultivars.

Treatment totals and analysis of the three cuts combined are presented in Table 6.

Since most of the D.M. production occurred during the

Table 6. Mean D.M. Yields (lb./acre) Total Three Cuts - Waikari.

Cultivar	Sub. Clover	Weed Clover	Weeds	Total Weeds	Total D.M.	% Weeds*
Geraldton	2691 c	1821 a	1292 a	3113 a	5804 b	45 a(53)
Yarloop	4691 b	1282 b	468 c	1750 bc	6441 b	31 b(27)
Woogenellup	7100 a	247 c	530 c	777 d	7877 a	18 c(10)
Clare	7950 a	366 c	460 c	826 d	8776 a	17 c(9)
Mt. Barker	5470 b	530 c	726 bc	1256 cd	6726 b	24 b(17)
Tallarook	4480 b	1282 b	885 b	2167 b	6647 b	33 ab(30)
S.E.	±348	±135	±101	±213	±314	±4
C.V. %	14	33	31	29	10	29

* Angular transformed values. Actual percentages shown in brackets.

spring, it is not surprising that the total production for all three cuts was largely a reflection of the spring cuts. Woogenellup and Clare produced significantly more subterranean clover and total D.M. than all other cultivars. These two cultivars also contained a significantly lower percentage of weeds.

(b) Pukaki

Treatment means and analysis of the D.M. yields from Pukaki are presented in Table 7.

Mt. Barker and Tallarook produced significantly more

Table 7. Mean D.M. Yields (lb./acre) Pukaki - 4/1/69.

Cultivar	Sub. Clover	Weeds	Total D.M.	% Weeds
Woogenellup	2792 b	1028 a	3820 b	31 a(27)
Clare	3034 b	1242 a	4276 b	34 a(32)
Mt. Barker	4750 a	1602 a	6352 a	30 a(25)
Tallarook	4448 a	1185 a	5633 a	28 a(22)
S.E. -	±457	±182	±366	±3
C.V. %	27	32	16	22

* Angular transformed values. Actual percentages shown in brackets.

subterranean clover and total D.M. than Woogenellup and Clare. There was no significant difference between cultivars for total weed production or for the percentage weeds. At this site Geraldton and Yarloop performed very poorly and the amount of herbage present did not warrant cutting.

The weed fraction at Pukaki was composed mainly of silvery hair grass (*Aira caryophyllea*) with a little sorrel (*Rumex acetosella*).

2. Flowering and Seed Production

(a) Waikari

The approximate time of the commencement of flowering for each cultivar together with the daily rainfall over the flowering and seed setting period is presented in Figure 2.

Approximately two months separated the time of flowering of Geraldton, the earliest flowering cultivar used and Tallarook the latest flowering. Cutting at the end of July had no effect on the time of flowering of Geraldton, Yarloop and Clare but advanced it about two weeks in Woogenellup and about one week in Mt. Barker and Tallarook. Very little rain fell over the flowering period.

The seed yields and components of seed yield from Waikari were statistically analysed as a split plot design with cultivars as the main plot treatments and cutting as the sub-plot treatments. Analysis of variance for seed yields was conducted on air-dry weights as g./ft.^{2} but for presentation in the text the means have been converted to lb./acre. When F tests showed significant differences, L.S.D. tests were conducted.

Treatment means and Analysis of Total Seed Yields, Total Number of Seeds and Mean 1000 Seed Weight are presented in Tables 8, 9 and 10.

With the exception of Yarloop, there was a tendency for both seed yield and seed numbers to decline with increasing lateness of flowering. Although it appeared that cutting had increased the seed yield and seed number

FIGURE 2. Time of Flowering and Rainfall - Waikari

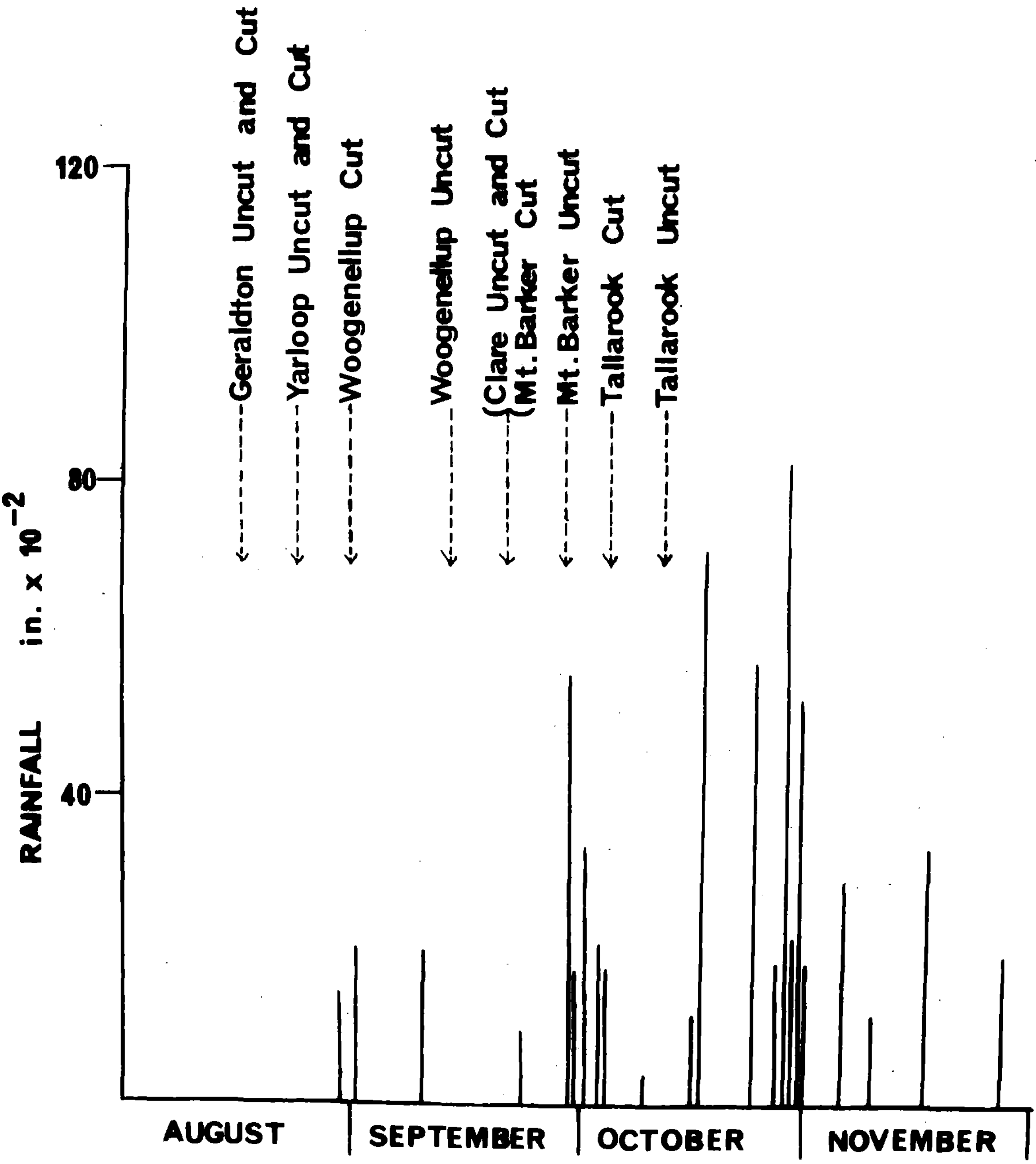


Table 8. Mean Total Seed Yields lb./acre Waikari.

Cultivar	Seed Yield lb./acre			Effect of Cutting
	Uncut	Cut	Mean	
Geraldton	659	1075	867	Cut > Uncut**
Yarloop	86	240	163	N.S.
Woogenellup	445	492	469	N.S.
Clare	754	511	633	Cut < Uncut*
Mt. Barker	213	323	268	N.S.
Tallarook	62	122	92	N.S.
S.E. Mean	±72		±47	±77
L.S.D. 5%	210		137	224

Main Effect of Cutting: N.S.
Cultivars x Cutting **
* = Significant at 5% level
** = Significant at 1% level

Table 9. Mean Total Seed Numbers/ft.^{2} Waikari.

Cultivar	Number of Seeds/ft.^{2} Uncut	Cut	Mean	Effect of Cutting
Geraldton	1369	2119	1774	Cut>Uncut**
Yarloop	167	379	273	N.S.
Woogenellup	836	889	863	N.S.
Clare	874	623	749	N.S.
Mt. Barker	439	707	573	N.S.
Tallarook	187	357	272	N.S.
S.E. Mean	±98		±69	±98
L.S.D. 5%	286		203	286

Main Effect of Cutting: Cut >Uncut**
Cultivars x Cutting **
* = Significant at 5% level
** = Significant at 1% level

Table 10. Mean Thousand Seed Weight (g.) Waikari.

Cultivar	Mean 1000 Seed Wt. g. Uncut	Cut	Mean	Effect of Cutting
Geraldton	4.99	5.28	5.13	N.S.
Yarloop	4.73	5.94	5.33	Cut > Uncut*
Woogenellup	5.45	5.81	5.63	N.S.
Clare	8.83	8.36	8.59	N.S.
Mt. Barker	4.94	4.75	4.85	N.S.
Tallarook	3.41	3.55	3.48	N.S.
S.E. Mean	±0.31		±0.25	±0.27
L.S.D. 5%	0.91		0.73	0.78

Main Effect of Cutting: N.S.
Cultivars x Cutting: N.S.
* = Significant at 5% level
** = Significant at 1% level

of all cultivars except Clare, this increase only reached significance in Geraldton. Cutting gave a significant reduction in the seed yield of Clare by reducing both the number of seeds and the 1000 seed weight although the reduction of these yield components alone failed to reach significance.

Apart from Geraldton, all cultivars produced seed of a lower 1000 seed weight than the seed which was sown (Table 2), probably due to the very dry conditions.

Yarloop was the only cultivar in which cutting gave a significant increase in mean thousand seed weight.

Treatment means and analysis of total burr numbers are presented in Table 11.

Table 11. Mean Total Number of Burrs/ft.^{2} Waikari.

Cultivar	Number of Burrs/ft.^{2} Uncut	Cut	Mean	Effect of Cutting
Geraldton	490	648	569	Cut > Uncut**
Yarloop	97	181	139	N.S.
Woogenellup	342	333	338	N.S.
Clare	346	238	292	Uncut > Cut*
Mt. Barker	173	277	225	Cut > Uncut*
Tallarook	84	132	108	N.S.
S.E. Mean	±34		±25	±32
L.S.D. 5%	99		74	92

Main Effect of Cutting: Cut > Uncut*
Cultivars x Cutting**
* = Significant at 5% level
** = Significant at 1% level

With the exception of Yarloop, there was a decline in burr numbers with increasing lateness of flowering. Cutting gave a significant increase in burr numbers for Geraldton and Mt. Barker but a significant decrease for

Clare. For Yarloop and Tallarook the apparent increase in burr numbers following cutting was not significant.

Treatment Means and analysis of the number of florets per inflorescence are presented in Table 12.

Table 12. Mean Number of Florets/Inflorescence Waikari.

Cultivar	No. Florets/Inflorescence Uncut	Cut	Mean	Effect of Cutting
Geraldton	3.92	3.99	3.95	N.S.
Yarloop	3.34	3.38	3.35	N.S.
Woogenellup	3.96	3.98	3.96	N.S.
Clare	3.95	3.98	3.97	N.S.
Mt. Barker	3.92	3.95	3.94	N.S.
Tallarook	4.00	4.00	4.00	N.S.
S.E. Mean	±0.05		±0.04	±.04
L.S.D. 5%	0.14		0.11	0.11

Main Effect of Cutting: N.S.
Cultivars x Cutting: N.S.

There was very little difference between cultivars with regard to the number of florets/inflorescence produced except for Yarloop which produced significantly less than all other cultivars. Cutting had no significant effect on the number of florets/inflorescence for any cultivar.

The number of florets/inflorescence sets the upper limit to number of seeds/burr which can be produced. Treatment means and analysis of the mean number of seeds/burr are presented in Table 13.

Table 13. Mean Number of Seeds/Burr Waikari.

Cultivar	No. seeds/burr Uncut	Cut	Mean	Effect of Cutting
Geraldton	2.78	3.26	3.02	Cut > Uncut*
Yarloop	1.74	2.09	1.91	N.S.
Woogenellup	2.46	2.67	2.56	N.S.
Clare	2.48	2.56	2.52	N.S.
Mt. Barker	2.53	2.54	2.53	N.S.
Tallarook	2.22	2.65	2.44	Cut > Uncut*
S.E. Mean	±0.14		±0.10	±0.13
L.S.D. 5%	0.41		0.31	0.39

Main Effect of Cutting: Cut > Uncut**
Cultivars x Cutting: N.S.
* = Significant at 5% level
** = Significant at 1% level

From the cultivar means it can be seen that Geraldton produced significantly more and Yarloop significantly less seeds/burr than the other cultivars. Yarloop produced significantly less seeds/burr in both cut and uncut plots but in uncut plots there were no significant differences between the other cultivars. However in cut plots Geraldton was significantly better than all other cultivars.

Cutting gave a significant increase in the mean number of seeds/burr of both Geraldton and Tallarook. The increase in the number of seeds/burr of Yarloop following cutting just failed to reach significance.

Besides cutting (Rossiter, 1961), the number of seeds/burr is also influenced by burr burial (Yates, 1957, 1958, 1961). Treatment means and analysis of the percentage of buried burrs are presented in Table 14.

Table 14. Mean Percentage Buried Burrs (Angular Transformed Values) - Waikari.

Cultivar	Buried Burrs %*			Effect of Cutting
	Uncut	Cut	Mean	
Geraldton	60 (75)	65 (83)	63 (79)	N.S.
Yarloop	45 (49)	45 (51)	45 (50)	N.S.
Woogenellup	22 (15)	27 (22)	25 (18)	N.S.
Clare	40 (41)	45 (50)	42 (46)	N.S.
Mt. Barker	17 (8)	28 (22)	22 (15)	Cut > Uncut**
Tallarook	16 (7)	21 (12)	18 (11)	N.S.
S.E. Mean	±2		±2	±2
L.S.D. 5%	7		5	7

Main Effect of Cutting: Cut > Uncut**
Cultivars x Cutting: N.S.
** = Significant at 1% level
* Analysis was carried out after angular transformation of the data. The figures in brackets represent actual percentages.

In general the percentage of buried burrs declined with increasing lateness of flowering although Woogenellup only buried a small fraction of its burrs. Cutting caused a small increase in burr burial in all cultivars, although this increase only reached significance in Mt. Barker.

To investigate further the factors involved in seed setting, the analysis of the effect of cutting and burr burial on the number of seeds/burr and the 1000 seed weight was carried out separately for each cultivar. The treatment means shown in Tables 15-26 do not quite correlate with those in Tables 10 and 13 due to the different numbers of seeds and burrs involved in the calculations of the arithmetic means.

Table 15. The Effect of Burr Burial and Cutting on the Mean Number of Seeds/Burr - Geraldton.

Burr Position	Cutting Treatments Uncut	Cut	Burr Position Mean
Above Ground	2.86	2.78	2.02
Buried	2.76	3.37	3.06
Cutting Treatment Mean	2.81	3.07	Burr Burial x Cutting**

L.S.D's 5%: Between Burr Position Means = 0.27
Between Cutting Treatment Means = 0.15
Between cutting treatments at same Burr Position = 0.21
Between burr positions at same or different cutting treatments = 0.30
** = Significant at 1% level

Table 16. The Effect of Burr Burial and Cutting on the Mean Number of Seeds/Burr - Yarloop.

Burr Position	Cutting Treatments Uncut	Cut	Burr Position Mean
Above Ground	1.69	2.00	1.85
Buried	1.74	2.14	1.94
Cutting Treatment Mean	1.72	2.07	Burr Burial x Cutting:N.S.

L.S.D.'s 5%: Between Burr Position Means = 0.46
Between Cutting Treatment Means = 0.34
Between cutting treatments at same Burr Position = 0.48
Between burr positions at same or different cutting treatments = 0.57
N.S. = Not Significant

Table 17. The Effect of Burr Burial and Cutting on the Mean Number of Seeds/Burr - Woogenellup.

Burr Position	Cutting Treatments Uncut	Cut	Burr Position Mean
Above Ground	2.68	2.87	2.78
Buried	2.08	1.98	2.03
Cutting Treatment Mean	2.43	2.38	Burr Burial x Cutting:N.S.

L.S.D.'s 5%: Between Burr Position Means = 0.36
Between Cutting Treatment Means = 0.42
Between cutting treatments at same Burr Position = 0.59
Between burr positions at same or different cutting treatment = 0.55
N.S. = Not Significant

Table 18. The Effect of Burr Burial and Cutting on the Mean Number of Seeds/Burr - Clare.

Burr Position	Cutting Treatments Uncut	Cut	Burr Position Mean
Above Ground	2.47	2.47	2.47
Buried	2.48	2.62	2.55
Cutting Treatment Mean	2.47	2.54	Burr Burial x Cutting: N.S.

L.S.D.'s 5%: Between Burr Position Means = 0.39
Between Cutting Treatment Means = 0.39
Between cutting treatments at Same Burr Position = 0.55
Between burr positions at same or different cutting treatments = 0.55
N.S. = Not Significant

Table 19. The Effect of Burr Burial and Cutting on the Mean Number of Seeds/Burr - Mt. Barker.

Burr Position	Cutting Treatments Uncut	Cut	Burr Position Mean
Above Ground	2.57	2.54	2.55
Buried	1.98	2.61	2.29
Cutting Treatment Mean	2.28	2.57	Burr Burial x Cutting: N.S.

L.S.D.'s 5% : Between Burr Position Means = 0.31
Between Cutting Treatment Means = 0.36
Between Cutting treatments at same Burr Position = 0.51
Between Burr Positions at same or different cutting treatments = 0.47
N.S. = Not Significant

Table 20. The Effect of Burr Burial and Cutting on the Mean Number of Seeds/Burr - Tallarook.

Burr Position	Cutting Treatments Uncut	Cut	Burr Position Mean
Above ground	2.12	2.66	2.39
Buried	2.21	2.48	2.34
Cutting Treatment Mean	2.17	2.57	Burr Burial x Cutting: N.S.

L.S.D's 5%: Between Burr Position Means = 0.26
Between Cutting Treatment Means = 0.64
Between cutting treatments at same Burr Position = 0.91
Between burr positions at same or different cutting treatments = 0.69
N.S. = Not Significant

For both Clare and Tallarook neither burr burial nor cutting had any significant effect on the mean number of seeds/burr. Burr burial had no significant effect on the number of seeds/burr of Yarloop, but caused a significant decrease in uncut plots of Mt. Barker and in both cut and uncut plots of Woogenellup.

In Geraldton there was a highly significant burr burial x cutting interaction (Table 15). Although burr burial had no significant effect in uncut plots of this cultivar, in cut plots burr burial gave a significant increase in the mean number of seeds/burr. Cutting had no significant effect on above ground burrs but gave a significant increase in the number of seeds/burr of buried burrs.

Treatment means and analysis of the effect of burr burial and cutting on the mean 1000 seed weight for each of the six cultivars are presented in Table 21 - 26 inclusive.

Table 21. The Effect of Burr Burial and Cutting on the Mean 1000 Seed Weight (g.) - Geraldton.

Burr Position	Cutting Treatments Uncut	Cut	Burr Position Mean
Above Ground	5.07	4.71	4.89
Buried	4.96	5.36	5.16
Cutting Treatment Mean	5.02	5.04	Burr Burial x Cutting:**

L.S.D.'s 5%: Between Burr Position Means = 0.39
Between Cutting Treatment Means = 0.25
Between cutting treatments at same Burr Position = 0.36
Between burr positions at same or different cutting treatments = 0.46
** = Significant at 1% level

For Geraldton burr burial had no significant effect in uncut plots but gave a significant increase in mean 1000 seed weight in cut plots. Although cutting gave a significant decrease in the mean 1000 seed weight of above ground burrs, for buried burrs it had the opposite effect in that here cutting gave a significant increase in mean 1000 seed weight. Because of the opposite effect of cutting for the two burr positions, the main effect of cutting was not significant, and there was a highly significant interaction between burr burial and cutting.

Table 22. The Effect of Burr Burial and Cutting on the Mean 1000 Seed Weight (g.) - Yarloop.

Burr Position	Cutting Treatments Uncut	Cut	Burr Position Mean
Above Ground	3.99	5.64	4.81
Buried	5.50	6.14	5.82
Cutting Treatment Mean	4.74	5.89	Burr Burial x Cutting:N.S.

L.S.D.'s 5%: Between Burr Position Means = 0.64
Between Cutting Treatment Means = 0.96
Between cutting treatments at same Burr Position = 1.36
Between burr positions at same or different cutting treatments = 1.15
N.S. = Not Significant

For Yarloop burr burial had no significant effect in cut plots but gave a significant increase in the mean 1000 seed weight of uncut plots. Cutting increased the mean 1000 seed weight of both above ground and buried burrs although the increase which occurred in buried burrs failed to reach significance.

Table 23. The Effect of Burr Burial and Cutting on the Mean 1000 Seed Weight (g.) - Woogenellup.

Burr Position	Cutting Treatments Uncut	Cut	Burr Position Mean
Above Ground	5.33	5.46	5.39
Buried	6.60	7.36	6.98
Cutting Treatment Mean	5.97	6.41	Burr Burial x Cutting:N.S.

L.S.D's 5%: Between Burr Position Means = 0.80
Between Cutting Treatment Means = 0.79
Between cutting treatments at same burr position = 1.11
Between burr positions at same or different cutting treatments = 1.12
N.S. = Not Significant

For Woogenellup burr burial gave a significant increase in the mean thousand seed weight in both uncut and cut plots. Cutting had no significant effect on the mean 1000 seed weight.

The results for Clare were very similar to those of Woogenellup. Although burr burial gave a significant increase in the mean 1000 seed weight in both uncut and cut plots, cutting had no significant effect.

Table 24. The Effect of Burr Burial and Cutting on the Mean 1000 Seed Weight (g.) - Clare.

Burr Position	Cutting Treatments Uncut	Cut	Burr Position Mean
Above Ground	8.25	7.59	7.92
Buried	9.65	9.02	9.33
Cutting Treatment Mean	8.95	8.30	Burr Burial x Cutting:N.S.

L.S.D's 5%: Between Burr Position Means = 0.28
Between Cutting Treatment Means = 0.95
Between Cutting Treatments at same burr position = 1.35
Between burr positions at same or different cutting treatments = 0.99
N.S. = Not Significant

Table 25. The Effect of Burr Burial and Cutting on the Mean 1000 Seed Weight (g.) - Mt. Barker.

Burr Position	Cutting Treatments Uncut	Cut	Burr Position Mean
Above Ground	4.86	4.53	4.70
Buried	6.06	5.39	5.73
Cutting Treatment Mean	5.46	4.96	Burr Burial x Cutting:N.S.

L.S.D's 5%: Between Burr Position Means = 0.82
Between Cutting Treatment Means = 0.68
Between Cutting Treatments at same burr position = 0.96
Between Burr Positions at same or different cutting treatments = 1.07
N.S. = Not Significant

For Mt. Barker burr burial gave a significant increase in the mean 1000 seed weight in uncut plots but in cut plots the increase failed to reach significance. Cutting had no significant effect on the mean 1000 seed weight.

Table 26. The Effect of Burr Burial and Cutting on the Mean 1000 Seed Weight (g.) - Tallarook.

Burr Position	Cutting Treatments Uncut	Cut	Burr Position Mean
Above Ground	3.39	3.33	3.36
Buried	3.77	5.02	4.39
Cutting Treatment Mean	3.58	4.17	Burr Burial x Cutting:**

L.S.D's 5%: Between Burr Position Means = 0.97
Between Cutting Treatment Means = 0.44
Between Cutting Treatments at same Burr Position = 0.62
Between Burr Positions at same or Different Cutting Treatment = 0.58
** = Significant at 1% level

For Tallarook there was a highly significant interaction between burr burial and cutting. Although burr burial had no significant effect in uncut plots, in cut plots burr burial gave a significant increase in mean 1000 seed weight. Cutting had no significant effect on the 1000 seed weight of above ground burrs but gave a significant increase in the 1000 seed weight of buried burrs.

The cultivar means for the percentage germination of the seed from Waikari are presented in Table 27.

Table 27. Mean Percentage Seed Germination - Waikari.

Cultivar	% Germination*
Geraldton	90.3 a
Yarloop	57.0 c
Woogenellup	55.0 c
Clare	80.6 b
Mt. Barker	54.6 c
Tallarook	56.0 c
S.E. Mean	±1.5
C.V. %	4

* Duncan's Multiple Range Test - Common letters indicate non significance at the 5% level.

With the exception of Geraldton and Clare all cultivars produced seed of very low viability. This was not unexpected because the seed appeared very pinched and shrivelled (Plates 3, 4).

Table 28 lists the mean seedling densities of the different cultivars following the autumn rains. No statistical analysis was carried out on these values because some of the denser quadrats were scored only. As with seed yield, the plant density tended to decline with increasing lateness of flowering.

Table 28. Seedling Re-establishment - Waikari.

Cultivar	No. Seedlings/ft.^{2}
Geraldton	>95
Yarloop	46
Woogenellup	30
Clare	53
Mt. Barker	29
Tallarook	10

(b) Pukaki

The approximate time of the commencement of flowering for each cultivar together with the daily rainfall over the flowering and seed setting period are presented in Figure 3. The daily grass minimum temperatures recorded at the Pukaki Meteorological Station for the same period are shown in Table 29.

At Pukaki less than one month separated the time of flowering of Geraldton and Tallarook. Although rainfall was adequate over most of the flowering and seed setting period there was a total of 19 ground frosts in October, 12 in November and 3 in December.

Data are presented in the same way as Waikari except

FIGURE 3. Time of Flowering and Rainfall – Pukaki.

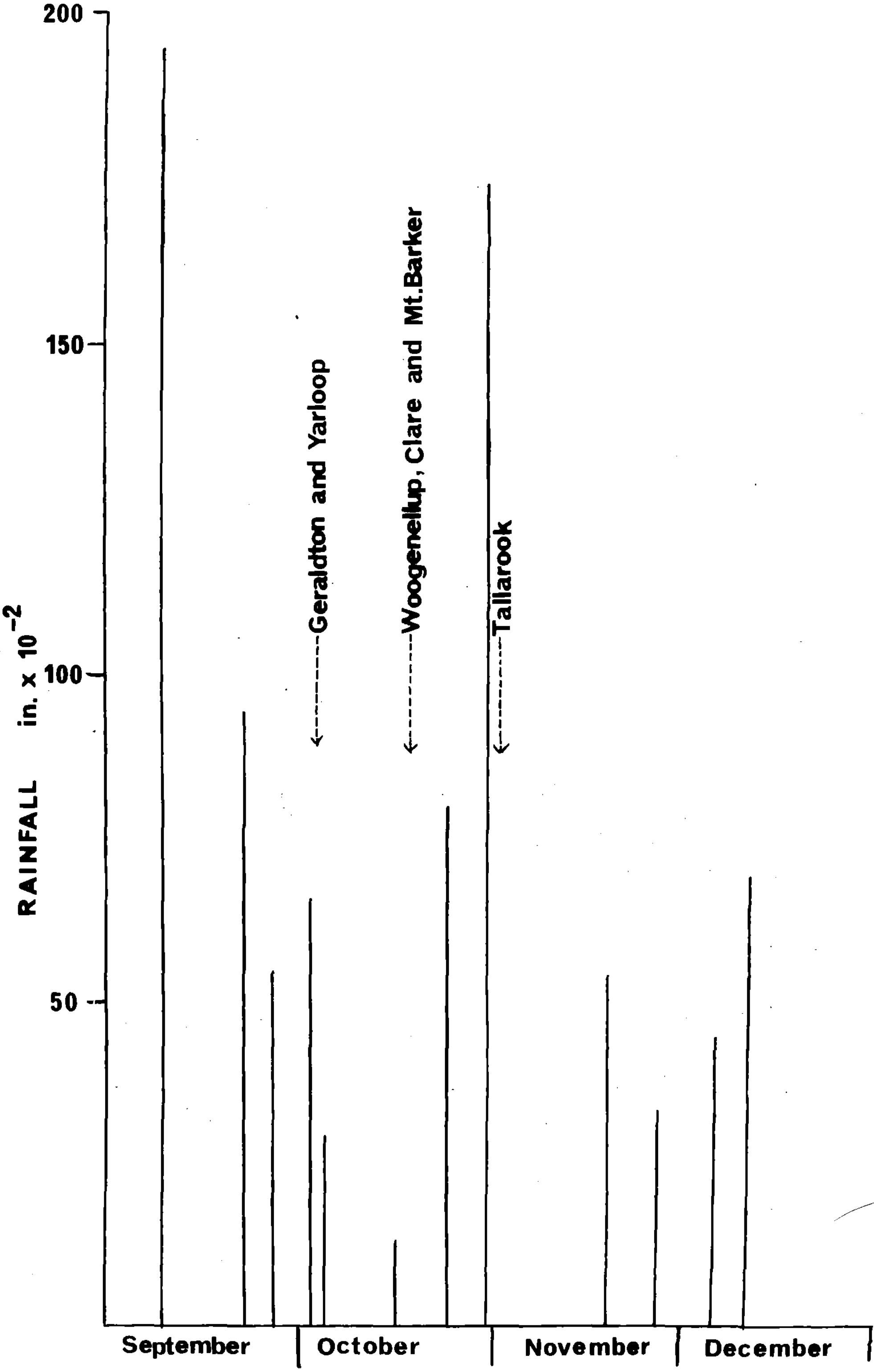


Table 29. Pukaki Grass Minimum Temperatures °F.

	VIII Aug.	IX Sept.	X Oct.	XI Nov.	XII Dec.
Date 1	15.0	22.5	31.0	34.0	28.0
2	19.0	24.0	38.1	29.0	34.0
3	25.0	36.2	34.0	31.5	34.0
4	26.0	31.0	40.5	34.0	46.0
5	28.0	28.5	28.0	34.0	43.0
6	23.0	23.0	23.1	29.0	47.3
7	32.0	25.2	21.8	32.0	45.0
8	28.0	32.0	36.3	45.1	35.0
9	24.0	22.5	28.4	33.0	25.5
10	24.0	22.0	31.5	41.3	29.0
11	35.0	25.3	29.0	34.0	40.5
12	33.3	30.0	22.5	31.0	42.6
13	32.0	35.5	24.0	45.0	40.0
14	23.2	28.8	26.5	33.5	37.5
15	19.0	32.0	27.0	41.0	36.5
16	20.5	23.0	20.0	42.5	49.0
17	25.5	27.5	24.5	35.5	36.0
18	22.0	29.7	40.5	27.5	41.3
19	26.2	27.0	30.6	31.0	43.0
20	27.3	28.0	29.1	27.5	42.0
21	18.5	28.6	36.3	28.0	42.2
22	21.0	39.5	46.0	29.3	42.5
23	27.0	37.5	42.4	29.5	42.5
24	30.5	27.0	28.5	44.0	39.0
25	24.5	35.5	36.7	33.0	42.3
26	26.0	33.0	42.0	36.6	42.3
27	26.0	20.0	39.2	31.5	54.0
28	24.0	26.0	30.0	34.0	46.0
29	28.0	25.0	42.5	44.0	48.1
30	30.8	20.6	31.5	49.1	51.0
31	22.0		27.0		51.0
Ground Frosts	29	24	19	12	3

Duncan's Multiple Range Tests were carried out.

Treatment means and analysis of Total Seed Yields and components of seed yield from Pukaki are presented in Table 30.

With the exception of Clare there was a tendency for both seed yield and seed numbers to increase with increasing lateness of flowering. Mt. Barker and Tallarook produced significantly more seeds than the other cultivars. The total number of burrs followed a similar trend. Although there was little difference between cultivars with regard to their mean 1000 seed weight, there were large differences between cultivars in the mean number of seeds/burr. Yarloop produced significantly less seeds/burr and florets/inflorescence than all other cultivars. Clare also produced a relatively low number of seeds/burr.

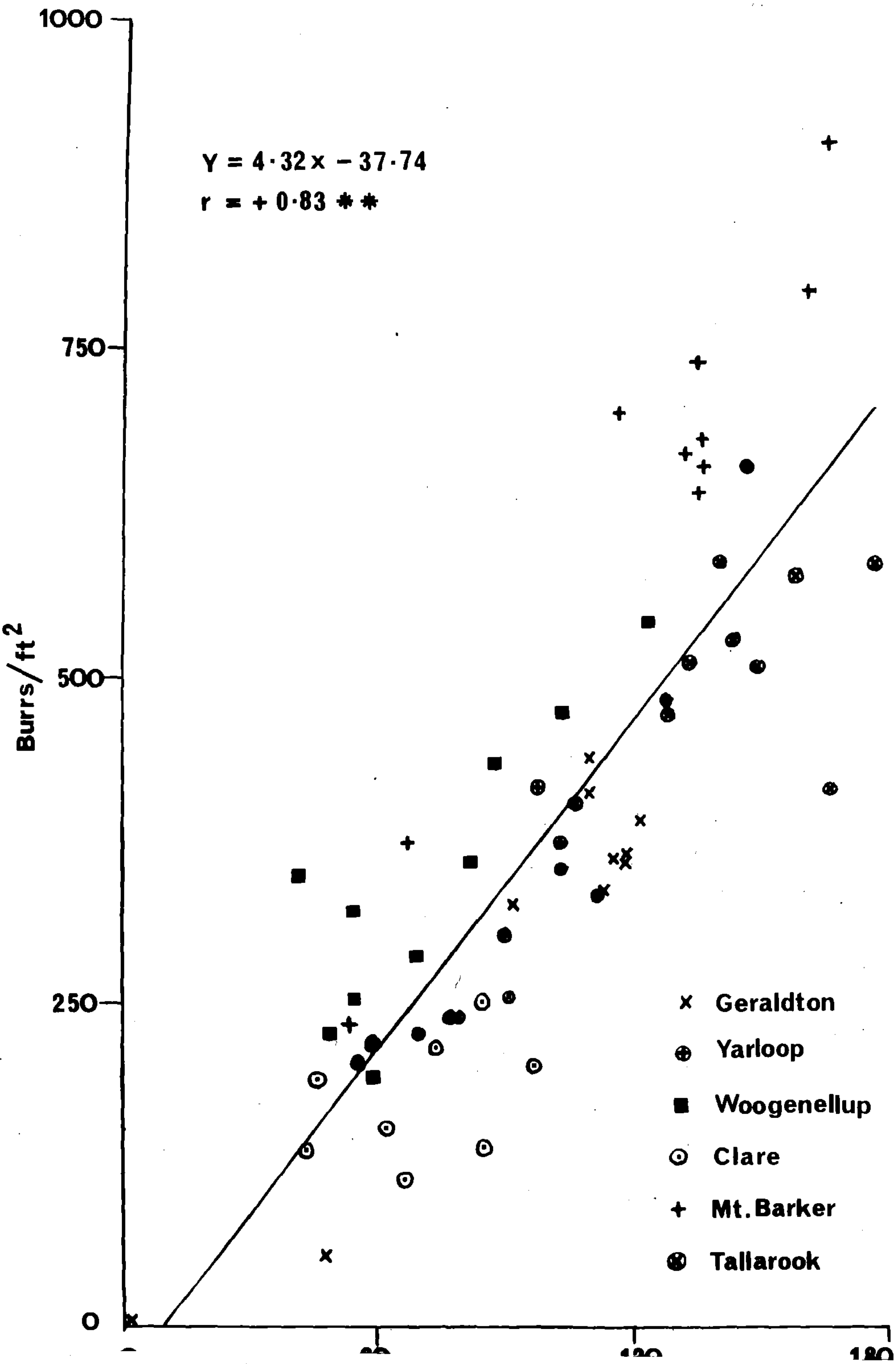
There was a highly significant positive correlation ($r = +0.83$, $p = 0.01$) between burr numbers and runner numbers at Pukaki (Figure 4). It is apparent from Table 30 that within each cultivar there was considerable variation in total seed yield, number of seeds and number of burrs. Some of this variation can be explained by variations in runner density (Figure 4). Although there was not much variation in the mean number of runners/plant within each cultivar, there was considerable variation in plant density due to frost "heave" over the winter

Table 30. Pukaki Seed Yields and Components of Seed Yield.

Cultivar	Seed Yield lb./acre	1000 Seed Wt. (g.)	No. Seeds /ft.^{2}	No. Burrs /ft.^{2}	% Buried* Burrs	No. Seeds /Burr	No. Florets /Inflorescence	No. Primary Runners/ ft.^{2}	No. Primary Runners/ Plant	Plant Density Plants/ft.^{2}
Geraldton	549 c	6.19 b	919 bc	296 bc	90 a(100)	3.10 a	3.90 a	94 bc	4.65 bc	19.7 a
Yarloop	499 c	8.18 a	622 bc	315 bc	72 c(90)	1.96 d	3.44 b	89 bc	4.39 c	19.9 a
Woogenellup	741 bc	7.26 ab	1012 b	346 b	60 d(75)	2.85 b	3.94 a	72 c	3.91 c	18.3 a
Clare	376 c	7.85 a	496 c	191 c	78 b(96)	2.59 c	4.00 a	73 c	3.96 c	18.0 a
Mt. Barker	1256 a	6.55 b	1950 a	644 a	50 e(58)	3.06 ab	3.92 a	122 ab	5.54 ab	21.5 a
Tallarook	1021 ab	6.43 b	1657 a	534 a	46 e(51)	3.11 a	3.98 a	143 a	6.27 a	22.7 a
S.E. Mean	±119	±0.35	±138	±48	±2	±0.07	±0.04	±12	±0.30	±1.7
C.V. %	36	11	28	28	7	6	2	27	14	19

* Angular transformed values. Actual percentages shown in brackets.

FIGURE 4 . The Relationship between the number of Burrs and Runners in Swards from Pukaki.



(Appendix C). However, plant density did not differ significantly between cultivars.

With the exception of Clare the percentage of buried burrs tended to decline with increasing lateness of flowering. Whereas the early flowering cultivar Geraldton buried all burrs, the late flowering Tallarook only buried about half its burrs. Treatment means and analysis of the effect of burr burial on the mean number of seeds/burr and mean 1000 seed weight of each cultivar are presented in Table 31.

Burr burial gave a significant increase in the mean number of seeds/burr of Yarloop and Woogenellup. For Clare, an increase of similar magnitude as that of Yarloop and Woogenellup failed to reach significance owing to the high variability of the number of seeds/burr in this cultivar.

Burr burial gave a significant increase in the mean 1000 seed weight of all cultivars. It was not possible to investigate the effect of burr burial on the seed yield components of Geraldton because this cultivar buried all its burrs.

The cultivar means for the percentage germination of the seed from Pukaki are presented in Table 32.

All cultivars produced seed of very high viability. This was expected from the general appearance of the seed (Plates 3, 4).

Table 31. The Effect of Burr Burial on the Mean Number of Seeds/Burr and 1000 Seed Weight - Pukaki.

Burr Position \ Cultivar	Geraldton	Yarloop	Woogenellup	Clare	Mt. Barker	Tallarook
A. Mean Number of Seeds/Burr						
Above Ground	-	1.85 b	2.63 b	2.30 a	2.97 a	3.11 a
Buried	3.10	1.97 a	2.92 a	2.61 a	3.11 a	3.11 a
S.E. Mean	-	±0.01	±0.05	±0.22	±0.05	±0.05
C.V. %	-	1.3	4	20	4	3
B. Mean 1000 Seed Weight (g.)						
Above Ground	-	6.23 b	6.39 b	5.86 b	5.59 b	5.92 b
Buried	6.19	8.36 a	7.48 a	7.90 a	7.17 a	6.91 a
S.E. Mean	-	±0.24	±0.19	±0.32	±0.25	±0.13
C.V. %	-	7	6	10	9	5

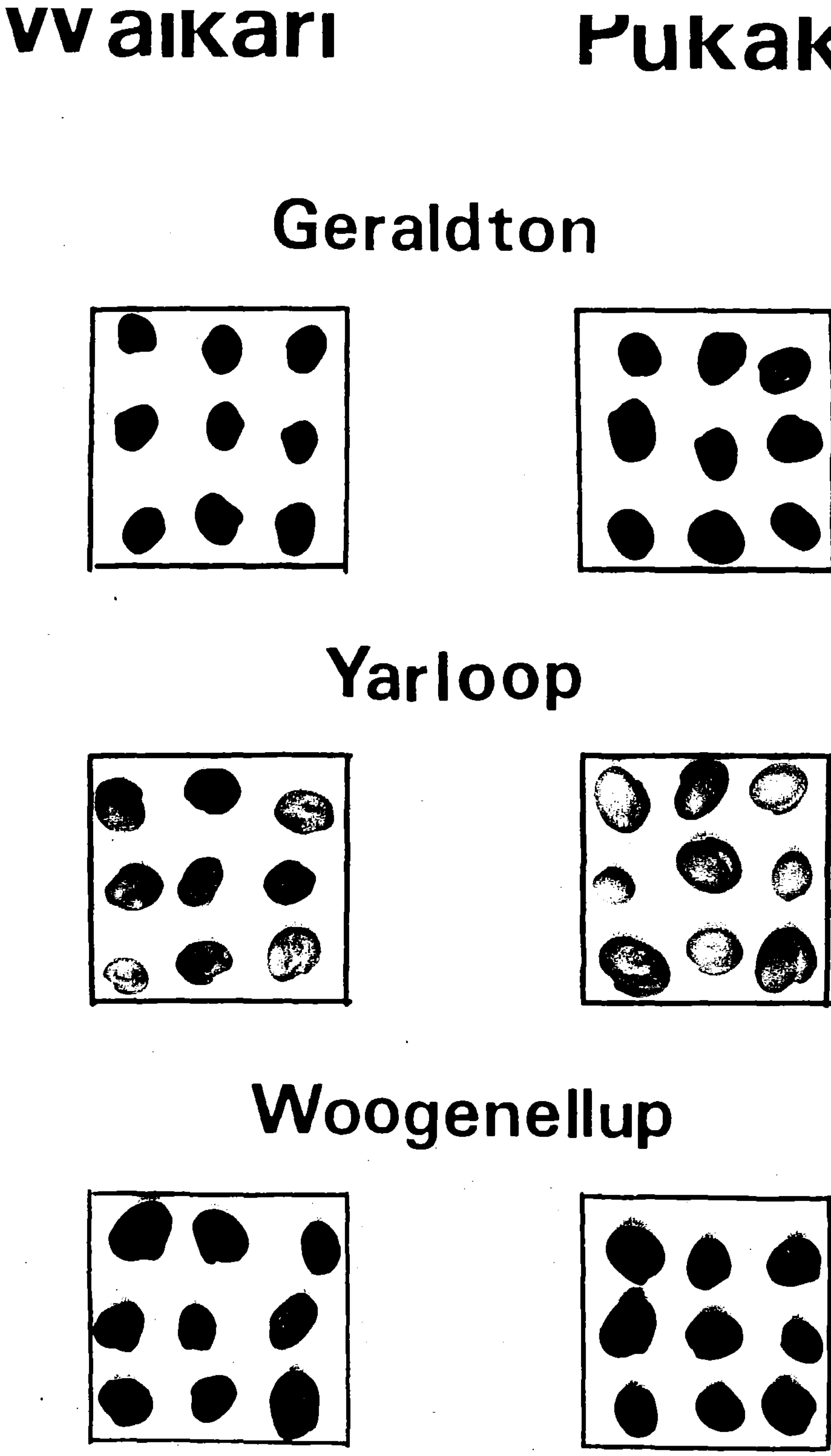


Plate 3. A comparison of seed samples from the field trial sites. I. Geraldton, Yarloop and Woogenellup.

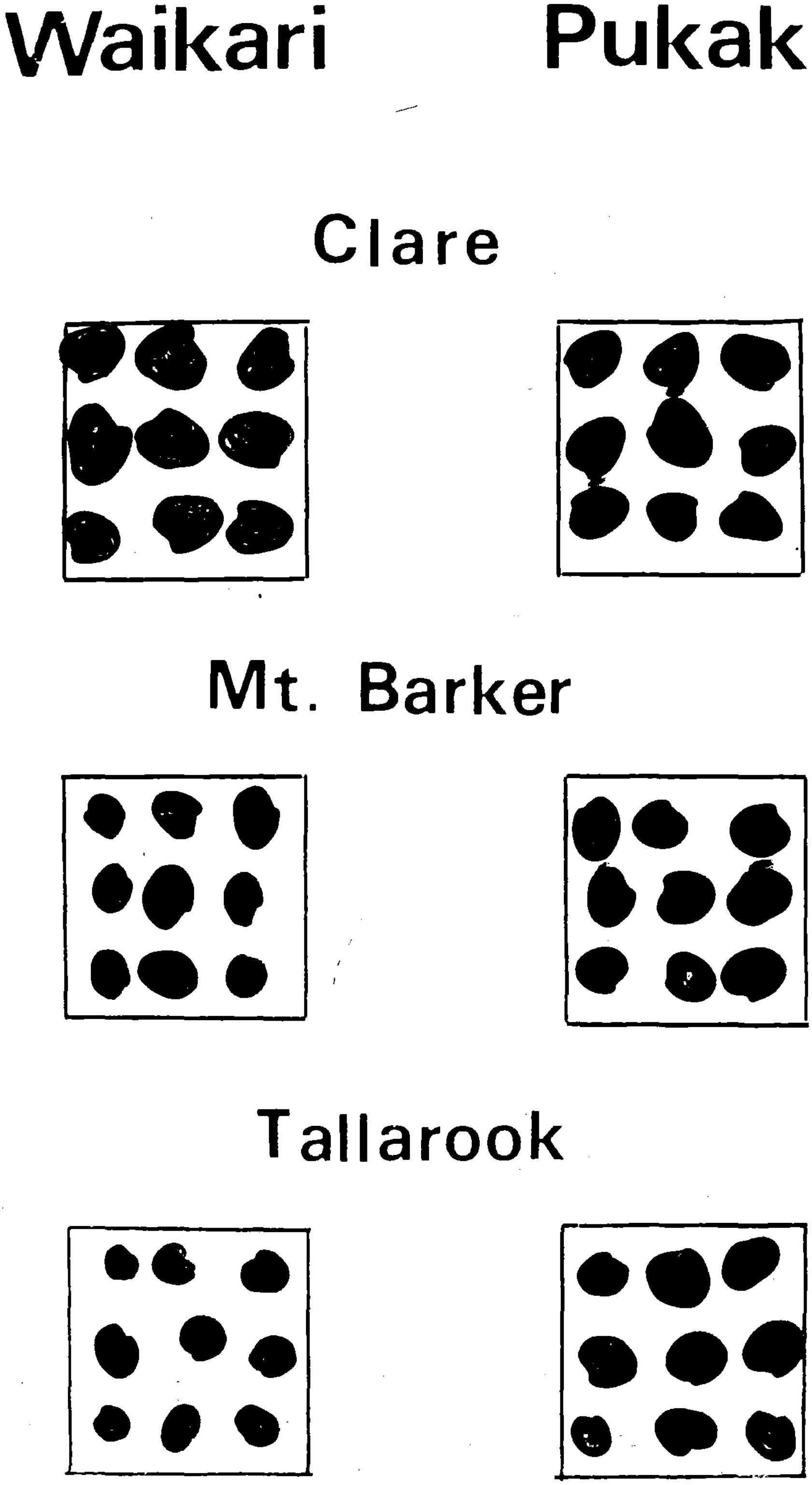


Plate 4. A comparison of seed samples from the field trial sites. II. Clare, Mt. Barker and Tallarook.

Table 32. Mean Percentage Seed Germination - Pukaki.

Cultivar	Germination % *
Geraldton	79.2 bc (96.3)
Yarloop	77.6 c (96.5)
Woogenellup	86.2 a (99.3)
Clare	88.1 a (99.7)
Mt. Barker	84.8 ab (98.7)
Tallarook	85.4 ab (99.0)
S.E. Mean	±1.9
C.V. %	4

* Angular Transformed Values. Actual percentages shown in brackets.

Table 33 lists the mean seed seedling densities of the different cultivars at Pukaki following the autumn rains. No statistical analysis was carried out on these values because the dense quadrats were scored only. Seedling density tended to increase with increasing lateness of flowering and was very high in the Mt. Barker and Tallarook plots. The values recorded for all cultivars did however tend to overrate the success of establishment as many seedlings were dying at the time of sampling due to frost damage.

Table 33. Seedling Re-establishment - Pukaki.

Cultivar	No. Seedlings/ft.^{2}
Geraldton	28
Yarloop	30
Woogenellup	31
Clare	22
Mt. Barker	>75
Tallarook	>87

V. DISCUSSION

1. Dry Matter Yields

Despite the very dry spring conditions, the total yields of D.M. produced by Woogenellup and Clare at Waikari were quite high by Canterbury standards even allowing for the fact that the plots were cut to ground level in the spring. This probably added an extra 500 lb. D.M./acre to the yields compared with conventional cutting heights (Brougham, 1956). At Winchmore Rickard (1968) found that non-irrigated ryegrass-subterranean clover (cv. Mt. Barker) pastures averaged 5520 lb. D.M./acre/yr. over a period of seven years, while at Ashley Dene Calder and Iversen (1957) found that the same pasture mixture averaged only 2992 lb. D.M./acre/yr. over an eight year period although this varied from 900 - 7000 lb. D.M. depending on the season. At Waikari, Mt. Barker produced a total of 6726 lb. D.M./acre of which 5470 lb. consisted of subterranean clover. This production is therefore very similar to that quoted by Rickard (loc. cit.) but higher than that recorded by Calder and Iversen (loc. cit.).

Tallarook, the other cultivar commonly sown in N.Z. was also comparatively low producing at Waikari and yielded a total of 6647 lb. D.D./acre of which 4480 lb. consisted of subterranean clover. This production was very similar to that of Yarloop.

However, both Woogenellup and Clare produced about 8,000 lb. D.M./acre at Waikari of which more than 7000 lb. consisted of subterranean clover. They were therefore clearly superior to all other cultivars at this site.

The situation at Pukaki was somewhat the reverse in that here Mt. Barker and Tallarook were the highest yielding cultivars. At both sites more than 70 per cent of the total D.M. production occurred during the spring period so that total D.M. yields were largely a reflection of the spring production. With increasing lateness of flowering there is an increasing potential for D.M. production owing to the longer period of active growth shown by the late flowering cultivars and their greater capacity for runner and seed production (Aitken and Drake, 1941). The final yield of D.M. will be determined by how closely actual production determined by climatic conditions approaches the potential production determined by the cultivar. At Waikari where growing conditions during the early spring were abnormally dry, only the early and early mid-season cultivars Geraldton, Yarloop, Woogenellup and Clare were able to realize most of their potential for D.M. production. Although growing conditions became favourable again during October and November the mid-season and late flowering Mt. Barker and Tallarook were not able to capitalize on these favourable conditions because by this time many of the plants had died.

The highest D.M. yields were therefore produced by the early mid-season cultivars Woogenellup and Clare. The yields of Geraldton and Yarloop were comparatively low because of their low potential for D.M. production. Mt. Barker and Tallarook were low producing because dry spring conditions prevented these later flowering cultivars from realizing their higher potential production.

At Pukaki where spring conditions were much more favourable and prolonged the potential relationship for D.M. production was almost fully expressed, as there was increasing D.M. production with increasing lateness of flowering, although the growth of Tallarook may have been slightly restricted by water stress.

The significant positive correlation found between seed size and D.M. yield for the April cut at Waikari confirms the findings of Black (1957a, 1957b), Lawson (1959) and Lawson and Rossiter (1958). In the present study more than 80 per cent of the differences in yield between cultivars for the April cut could be explained by differences in seed weight. Woogenellup, Clare and Mt. Barker with 1000 seed weights of 8 - 10 g. all produced about twice as much subterranean clover as Geraldton and Tallarook with 1000 seed weights of 4 - 5 g. Yarloop produced less than would be expected from its seed weight, possibly because this cultivar established at a significantly lower plant density than the other cultivars. However an analysis of covariance to correct for plant density did not alter the situation.

Woogenellup, Clare and Mt. Barker were also the three highest producing cultivars over the May-June-July period and grew at the rate of 15 lb. D.M./acre/day. At Winchmore Rickard (1968) found that ryegrass-subterranean clover (cv. Mt. Barker) pastures produced at the rate of 8.4, 5.0 and 4.2 lb. D.M./acre/day for May, June, July respectively. The winter production at Waikari was therefore comparatively high, possibly because the trial area was situated on a sunny face which would have a better temperature and light regime than the Canterbury Plains. Very little frost damage was apparent on the hérbage (Plate 5). Stewart and Taylor (1965), in discussing the management and utilisation of lucerne on light land stated that August was a critical month for feed supply because of the demand for high quality pre-lambing and lambing greenfeed. Subterranean clover, particularly the cultivars Woogenellup and Clare, could play a major role in the provision of this greenfeed on North Canterbury Hill Country although the winter production of these cultivars on the Canterbury Plains has yet to be evaluated.

Although the weed content was very variable both between and within cultivars for the April cut at Waikari, by the end of July the situation had changed quite dramatically. The two tallest growing cultivars, Yarloop and Clare, contained significantly less weeds than the prostrately growing cultivars Geraldton, Mt. Barker and Tallarook. Woogenellup appeared to be intermediate in growth habit and weed content. Black (1960) showed that Yarloop is very efficient in competing for light by virtue of its long petioles. Presumably Clare also is very efficient in competing for light as it has very large leaves held on long petioles. Higgs (1958) recommended that Yarloop and Clare should be sown on areas where tall growing weeds may be a problem, and the results of the present study confirm that both these cultivars are

Plate 5. Waikari 31/7/68. Front to Rear - Woogenellup, Geraldton, Mt. Barker, Clare, Tallarook, Yarloop.

very efficient in suppressing weeds during the vegetative growth phase.

By November the relative proportions of weeds in the different cultivars had changed again. At this time the weed content appeared to be not only a reflection of growth habit but also of the time at which senescence commenced. Weeds, particularly striated clover, made up more than half the total D.M. yield of Geraldton. Because of its very prostrate growth habit this cultivar had become badly invaded by weeds during the vegetative growth phase. Geraldton began flowering in mid-August and had begun to senesce by the end of September allowing the weeds to make vigorous growth unhampered by competition from the subterranean clover when the rains came in October. Yarloop behaved similarly, although the weed content of this cultivar was significantly lower than Geraldton, probably because Yarloop had very successfully suppressed weeds during the vegetative growth phase.

Although both Tallarook and Mt. Barker were relativel late flowering cultivars, they both suffered severely from the dry spring conditions and many plants had died by the end of September. Tallarook appeared to be worse hit than Mt. Barker. Neither of these two cultivars had been very successful at suppressing weeds during the vegetative growth phase, so that following the death of many of the subterranean clover plants the weeds grew vigorously particularly in the Tallarook plots.

Woogenellup and Clare appeared to be the least affected by the drought conditions and did not begin to senesce until the end of October. This factor, together with the erect growth habit of these cultivars which had suppressed the weed growth during the vegetative growth phase, was responsible for their low weed content.

It is perhaps interesting to speculate on how the very high weed contents of the early flowering cultivars may be used to advantage through the use of lucerne-subterranean clover mixtures. Calder and Iversen (1957) carried out trials with lucerne-subterranean clover mixtures and Smetham (1968) suggested that the use of such a mixture might prove useful. In trials at Ashley Dene, Iversen (1965) found that mixtures of Mt. Barker with Wairau or Glutinosa lucerne outyielded conventional subterranean clover-ryegrass pastures but were out-produced by lucerne alone. Wairau and Glutinosa lucerne both commence growth early in the spring (early August) although Glutinosa is about 1 - 2 weeks later than Wairau (White, pers. comm.). These two lucerne cultivars also continue growth late into the autumn. Being a mid-season cultivar, Mt. Barker continues to grow well into November in favourable years.

It seems obvious that by combining Mt. Barker with Wairau or Glutinosa lucerne, neither species will be able to display its best points due to the effects of competition. By growing late into the autumn the lucerne suppresses severely the establishment of the subterranean clover. Although this suppression could be overcome to some extent by grazing, this may have very deleterious effects on the subsequent spring production and persistence of the lucerne (Smith, 1964). During the spring the subterranean clover not only competes severely with the lucerne but the lucerne also depresses the seed yield of the subterranean clover. The beneficial effects of a high seed yield of subterranean clover on subsequent production and persistence have been clearly demonstrated by Black (1957a, 1957b), Donald (1951), Rossiter (1966) and Taylor and Rossiter (1969).

It is suggested that the use of a "falcata" type of lucerne (Iversen and Meijer, 1968), which commences growth late in the spring and goes into dormancy early in the autumn together with an early flowering subterranean clover cultivar which senesces early in the spring, may overcome some of the difficulties discussed above. Such a combination would provide two plants with almost reciprocal growth patterns giving a sward with more even seasonal production than pure lucerne. Further work is obviously required on the use of lucerne-subterranean clover mixtures.

The cutting regime which was imposed at Waikari could be described as severe and infrequent. Black (1963) showed that the tall growing Yarloop and Clare were slow to recover from one severe defoliation while Tallarook and Dwalganup with prostrate growth habits recovered rapidly after defoliation. Mt. Barker was intermediate in growth habit and in its rate of recovery. It would seem from Black's work that the cutting regime imposed at Waikari would tend to favour Geraldton, Mt. Barker and Tallarook even although these were low producing cultivars.

2. Seed Yields

(a) Waikari

The flowering times of the different cultivars at Waikari were very similar to those recorded at Burnley Gardens, Melbourne by Aitken and Drake (1941). Nearly two months separated the time of flowering of Geraldton, the earliest flowering cultivar used, and Tallarook, the latest flowering cultivar. A rather strange phenomenon was observed in Clare. Although this cultivar did not commence flowering until late September some internode elongation was evident in late July, and by the end of August the internode length had increased to about three inches. At this time many closed flowers were present but these did not open until the end of September. Aitken and Drake (1941) found that in general, conspicuous lengthening of internodes did not begin until one to two weeks before flowering although in the two late cultivars Rostock and Wenigup conspicuous elongation occurred more than a month before flowering. It seems therefore that Clare also is an exception to the general rule and commences internode elongation more than one month before flowering.

As far as the author is aware, the effect of cutting in advancing the time of flowering has not been recorded previously. This phenomenon was very evident in Woogenellup where cutting advanced the time of flowering by about two weeks although it also occurred in Mt. Barker and Tallarook (Figure 2). Cutting would give increased light intensity and possibly also increased temperature at the runner level. In white clover Zaleski (1961) found that cutting gave increased inflorescence production which was attributed to an increase in light intensity at the stolon level. Following vernalisation the promotive effects of high temperatures on flower initiation and development in subterranean clover have been described by Aitken (1955a), Aitken and Drake (1941), Evans (1959) and Morley and Evans (1959). However, from the data available from the present trial it is not possible to state whether the promotive effect of cutting on time of flowering was due to a temperature effect or, if it was due to increased temperature whether this influenced flower initiation or development. Both light intensity and temperature were probably involved. A third possible explanation is that cutting so decreased the level of plant water stress that flower development occurred faster in cut plots. In all cultivars uncut areas began wilting about two weeks earlier than cut areas probably due to the reduced leaf area and transpiration following cutting. Rossiter (1961) also found that cutting delayed the time of senescence. The beneficial effects of cutting in reducing the extent of wilting in Yarloop can be seen in Plate 6.

Although the highest D.M. yields were produced by the early mid-season cultivars Woogenellup and Clare, highest seed yields were given by the earliest flowering cultivar Geraldton. At Waikari it appeared that seed production was more adversely affected by water stress than was D.M. production. There was a trend for both seed yield and seed numbers to decline with increasing lateness of flowering. Similar trends for the seed yield of swards have been described by Rossiter (1959, 1966). Rossiter (1966) emphasized that the positive correlation

Plate 6. A plot of Yarloop at Waikari - 29/8/68. The severely wilted uncut area in the centre contrasts sharply with the unwilted cut area in the right foreground and background.

which he found between earliness of flowering and seed yield was almost certainly a function of the Mediterranean climate.

Yarloop was the exception at Waikari in that it produced less seed than expected from its flowering time. This cultivar is adapted to growing on waterlogged soils and is known to wilt very quickly at the onset of dry conditions (Elliot and Gardiner, 1947). It was the first cultivar to wilt at Waikari and was probably well out of its ecological niche at this site.

The main component affecting seed yield appeared to be the number of burrs and this declined with increasing lateness of flowering. The percentage of buried burrs also declined with increasing lateness of flowering. Although there is a natural tendency for early flowering cultivars to bury a higher proportion of their burrs than late flowering cultivars, harsh environmental conditions tend to stimulate burr burial in all cultivars (Yates, 1958). However, as the same author has pointed out, burr burial may be prevented if the soil surface becomes hard due to dry conditions. Observations suggested that this occurred at Waikari.

The number of florets/inflorescence obviously sets the upper limit to the number of seeds/burr which can be produced. In this regard there was very little difference between cultivars except for Yarloop which produced significantly fewer florets/inflorescence than the other cultivars. There are very few published data available on the number of florets/inflorescence for different cultivars. Aitken and Drake (1941) found that there were normally 3 - 4 florets/inflorescence produced by the 40 cultivars studied but in Reigart's White-seeded (Yarloop) normally only three florets were formed. In describing the Yarloop cultivar, Elliot and Gardiner (1947) stated that it usually produced only 2 - 3 florets/inflorescence. The present study tends to bear out these observations. Because Yarloop produced significantly fewer florets/inflorescence it is not surprising that this cultivar also produced significantly fewer seeds/burr than the other cultivars. Geraldton produced significantly more seeds/burr than the other cultivars, presumably because it was setting seed under more favourable environmental conditions. The fact that Geraldton was setting seed under the most favourable conditions is also reflected in the mean 1000 seed weights of the different cultivars (Table 10). Geraldton was the only cultivar which produced seed with a higher 1000 seed weight than that of the seed which was sown (Table 2). In other cultivars the seed appeared to be very pinched and shrivelled (Plates 3, 4) and had a low percentage germination.

This was particularly so for Yarloop, Woogenellup, Mt. Barker and Tallarook. Although the seed of Clare was slightly pinched it still had a reasonably high percentage germination. Walker and Neal-Smith (1959) observed that the seeds of Clare are often depressed in the centre when conditions have been unfavourable during maturation.

The interpretation of the effects of cutting and burr burial on the components of seed yield is complicated by two factors. Firstly, all cultivars were cut at the end of July so that the time of cutting relative to time of flowering varied between cultivars. Secondly there was some premature germination and loss of seed in Woogenellup and Mt. Barker plots. Donald (1954) encountered a similar problem. There are however several points worth mentioning.

The beneficial effects of early defoliation on the seed yield of subterranean clover found by Rossiter (1961) were confirmed, although the increase in seed yield following cutting only reached significance in Geraldton. Clare was the exception in that cutting significantly reduced the seed yield of this cultivar. The increase in yield following cutting was largely the result of an increase in the number of burrs probably due to increased inflorescence production (Rossiter, 1961). Cutting caused a significant reduction in the number of burrs produced by Clare. As discussed previously, Clare was showing internode elongation at the time of cutting in July and some stem apices were removed. This probably reduced the extent of runner formation and inflorescence production in this cultivar.

Cutting gave a significant increase in the mean number of seeds/burr which appeared to be due in part to an increase in the percentage of buried burrs, although the effect of burr burial on the mean number of seeds/burr varied between cultivars. Burr burial gave a significant increase in the mean number of seeds/burr of Geraldton and a slight but non significant one in Yarloop and Clare. The significant depression in the mean number of seeds/burr of Woogenellup and Mt. Barker caused by burr burial was probably due to the loss of seed which occurred in these cultivars as the values recorded were abnormally low.

Cutting had very little effect on the mean 1000 seed weight except for Yarloop where it gave a significant increase. There was a tendency for cutting to decrease the 1000 seed weight of burrs formed above ground but increase the 1000 seed weight of buried burrs so that the two effects tended to cancel each other out. Cutting probably created harsher environmental conditions for the above ground burrs (Yates, 1958). The Burr Position x Cutting interaction reached significance in Geraldton and Tallarook.

With the exception of Clare and Mt. Barker, the heaviest seeds were produced by buried burrs in cut plots. Cutting was therefore adding to the beneficial effects of burr burial probably by reducing the level of plant water stress as discussed previously.

The effect of cutting on mean 1000 seed weight found in this study therefore agrees with the results of Rossiter (1961) who found that within one cultivar progressively later defoliation gave a marked decline in the 1000 seed weight of above ground burrs. Rossiter (loc. cit.) observed a similar trend in the mean number of seeds/burr but such a trend was not so evident in this study.

Although the premature germination of seed which occurred in Woogenellup and Mt. Barker plots did rather complicate the interpretation of the data, it did indicate that these two cultivars possessed very little seed dormancy. A lack of dormancy could be a distinct disadvantage in Canterbury where heavy summer rains followed by dry conditions could cause catastrophic seedling mortality. Surprisingly enough, Clare did not show any premature germination even although this cultivar is reputed to have no seed dormancy below 30°C (Walker and Neal-Smith, 1959).

On the basis of data obtained from five field experiments, three of which extended over a nine year period, Rossiter (1966) postulated that a subterranean clover cultivar is only really successful in a Mediterranean environment when it can produce about 60 g./m^2 (535 lb./acre) of seed in pure swards. At Waikari the only cultivars to achieve this "threshold" seed yield were Geraldton and Clare. This was reflected in the subsequent re-establishment of these cultivars (Table 28). Although Woogenellup produced an average of 469 lb./acre of seed and a higher number of seeds than Clare, it established at a lower plant density probably because of poor seed quality and loss of seed through premature germination. The low seed yield of poor quality seed produced by Tallarook resulted in very poor re-establishment of this cultivar. Rather surprisingly, Yarloop which produced seed in similar quantity and viability as that of Tallarook established at a much higher plant density.

It is obvious that only a small fraction of the seed produced by all cultivars germinated following the autumn rains. The phenomenon of hardseededness may have been operating although the germination tests suggested that, with the exception of Geraldton, only a small fraction of the seed produced (about 10 per cent) by the other cultivars was hard. The production of hard seed would not be expected under the very dry spring conditions anyway (Aitken, 1939; Higgs, 1958). The late autumn rains which did not arrive until early May and some seed loss through field mice may have been other factors contributing to the low proportion of seed which germinated in the field at Waikari.

(b) Pukaki

At Pukaki the interval between the flowering time of Geraldton, the earliest flowering cultivar used, and Tallarook the latest flowering, was less than four weeks compared with eight weeks at Waikari. Mean flowering times were also about four weeks later at Pukaki. From the work of Evans (1959) and Morley and Evans (1959) it seems that flower initiation at Pukaki was retarded by low spring temperatures (Table 29). Similar trends in flowering intervals between cold and warm environments have been described in Australia. The interval between the inception of flowering in Dwalganup, which flowers within a few days of Geraldton (Millington, 1960), and Tallarook, varies from three weeks at Launceston, Tasmania (Aitken and Drake, 1941) to more than four months at Lismore, New South Wales (Morley and Davern, 1956).

The seed yields at Pukaki followed a reverse trend to those recorded at Waikari in that here seed yields increased with increasing lateness of flowering. In other words the potential relationship for seed yield described by Aitken and Drake (1941) and Donald and Neal-Smith (1937) was almost fully expressed. Similar trends in the seed yields from swards have occurred at Canberra (Morley, 1961). Clare was the exception in that it produced much less seed than expected from its flowering time.

The view that this potential relationship for seed yield was almost fully expressed was reinforced by the highly significant positive correlation found between burr numbers and runner numbers (Figure 4). The later flowering cultivars which flower at a higher node of first flower initiated more primary runners (Aitken, 1955a; Aitken and Drake, 1941) and therefore produced more sites for inflorescence formation. The favourable moisture regime which prevailed during the flowering period appeared to allow maximum development of these inflorescences as exemplified by the seed yield data and general appearance of the seeds.

All cultivars produced an average of about four florets/inflorescence except for Yarloop which produced only 3.4 and was significantly inferior to the other cultivars in this regard. However, as discussed previously, the comparatively low floret production of Yarloop seemed to be due to genetic rather than environmental factors.

In general the percentage buried burrs declined with increasing lateness of flowering, a trend which has also been observed by Yates (1958). The coarse textured Acheron soil type did not become dry and caked even when dry and probably allowed the potential for burr burial to be fully realized. The beneficial effects of burr burial on the mean number of seeds/burr and 1000 seed weight were very apparent (Table 31). Burr burial gave a significant increase in the mean 1000 seed weight of all cultivars. An interesting trend was evident in the effect of burr burial on the mean number of seeds/burr. Whereas burr burial gave a significant increase in this component for Yarloop and Woogenellup, it had no effect in the later flowering cultivars Mt. Barker and Tallarook. Presumably these cultivars developed a denser leaf cover to protect the above ground burrs from harsh atmospheric conditions.

Total seed yields at Pukaki were quite high despite the fact that a total of 34 ground frosts occurred during the flowering and seed setting period (Table 29). This tends to cast some doubt on Donald's (1959) conclusion that frosts during the flowering period may drastically reduce seed yields. Without the data on primary runner production for the different cultivars, the trend for seed yields to increase with increasing lateness of flowering could be misinterpreted to mean that frosts were causing flower abortion in the early flowering cultivars. However the comparatively low seed yields of the early flowering cultivars appeared to be due to their low capacity for runner production rather than flower abortion. Although total inflorescences were not counted, very little flower abortion was evident at Pukaki in any of the cultivars apart from Clare. It did appear that the seed yield of Clare may have been adversely affected by frosts because this cultivar produced much less seed than expected from its time of flowering. The mean number of seeds/burr of Clare was significantly lower than that of all other cultivars except Yarloop but in contrast to Yarloop this appeared to be due to partial abortion of florets rather than an inherently low number of florets/ inflorescence.

At the time of harvesting many totally aborted inflorescences were present in the Clare plots, and although this cultivar had the same primary runner density as Woogenellup, it produced significantly fewer burrs. Morley (1961) and Walker and Neal-Smith (1959) both noted that Clare was very susceptible to frost damage.

Donald (1959) suggested that Tallarook was more susceptible to frosts than Dwalganup, Bacchus Marsh, and Mt. Barker. In the present study Tallarook produced more than 1000 lb./acre of seed in spite of the fact that 15 ground frosts occurred during the flowering and seed setting period, but the data do suggest that Tallarook produced slightly fewer burrs and seed than expected from its primary runner production. Whether this was due to frosts or a moisture stress during December cannot be determined from the data available. The need for further research into the effects of frosts on seed production in subterranean clover is clearly indicated.

With the exception of Yarloop and Clare, all other cultivars at Pukaki exceeded Rossiter's (1966) threshold seed yield of 535 lb./acre. The subsequent re-establishment and growth left much to be desired. Germinating rains did not occur until May and, although many seeds germinated (Table 33), most of these were soon killed by frosts. It seems highly likely that one of the main factors limiting subterranean clover persistence in inland high country areas is poor autumn establishment and not poor seed production as is frequently suggested. The "Continental" nature of the climate (Garnier, 1958) is probably the main factor responsible, as there is often a rapid transition from the extremely hot dry summer conditions to extremely cold conditions of winter. This is because the autumn rains usually bring snow to the "tops" resulting in severe frosts quite inimical to subterranean clover establishment.

It remains to be seen whether the plants resulting from the spring germination have sufficient time to set seed before dry conditions prevail.

CHAPTER IV

SPACED PLANT TRIAL

I. INTRODUCTION

The phenomenon of increasing inflorescence production with increasing lateness of flowering is due to the fact that late flowering cultivars flower at a higher node of first flower (N.F.) and produce more runners which are also more branched than those of early flowering cultivars (Aitken, 1955a; Aitken and Drake, 1941). The same authors also showed that after the commencement of flowering at the top of the main axis further runner initiation is prevented. It follows therefore that within one cultivar the number of runners produced will be influenced by the degree of vegetative growth prior to the commencement of flowering.

The aim of the spaced plant trial was to investigate the effects which a varying degree of vegetative growth prior to the commencement of flowering has on subsequent runner and inflorescence production.

II. EXPERIMENTAL METHODS

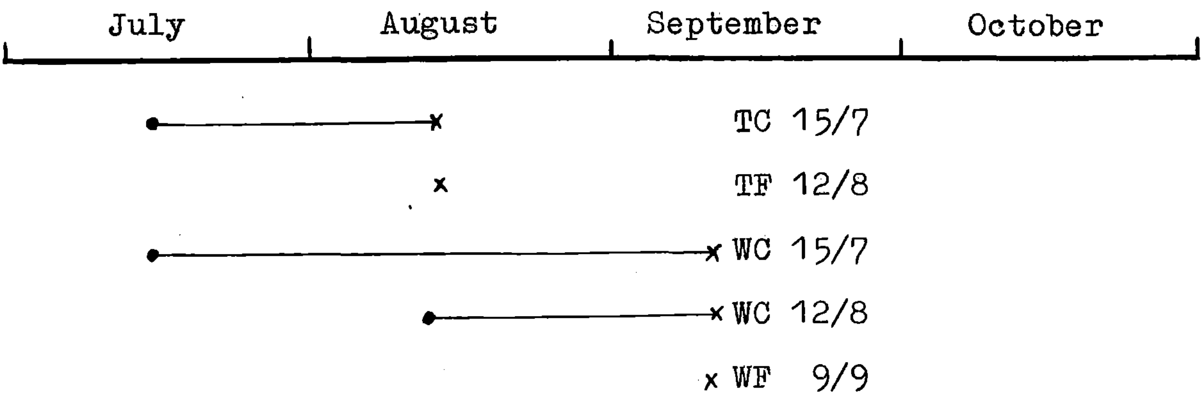
The two cultivars chosen for the study were Woogenellup and Tallarook. It was necessary to design a trial to make these two cultivars flower at approximately the same time and also to vary the degree of vegetative development within each cultivar prior to the commencement of flowering. Subsequent differences in runner and inflorescence formation could then be attributed directly to the pretreatments if they all commenced flowering under identical environmental conditions.

From the work of Aitken (1955a) a calculated guess was made of the time when each of the cultivars would have to be planted out in the field in spring to receive sufficient vernalisation for flowering to commence at approximately the same time. All Woogenellup plants were planted out in the field on 9th September and Tallarook plants on the 12th August.

To achieve varying amounts of vegetative growth within each cultivar prior to the commencement of flowering without altering the time of flowering, staggered sowings at four weekly intervals were made and the plants grown in the growth cabinet at a constant 70°F temperature and an eight hour photoperiod to keep them vegetative (Aitken, 1955a). For both cultivars sowings commenced on 15th July and were continued at four weekly intervals until the plants were removed to the field. At the time of moving the plants into the field, a sowing directly in the field was also carried out. There were therefore two treatments for Tallarook and three for Woogenellup. A diagramatic representation of the sowing times is presented in Figure 5.

All plants were grown in three inch peat "Jiffy" pots containing a fertile potting soil. To eliminate the effects of seed size on the growth of spaced plants (Black, 1957b), the seed used was graded to weigh 7 ± 0.5 mg. Following their removal from the growth cabinet all plants were retained in a shade house for three days prior to planting out in the field to harden the plants off and prevent frost damage. At the same time two apical meristems from each of three plants from each treatment were dissected and examined under a microscope to check that they had remained vegetative.

The field site was paddock R.2 of the Lincoln College Research farm on a Templeton silt loam. The area was topdressed with superphosphate at four cwt./acre, hand weeded as required and spray irrigated to maintain the soil near field capacity. The trial was arranged as a randomised block with five plants for each of the five treatments and seven replications, a total of 245 plants. The plants were grown at four ft. centres.



• Time of Sowing in Growth Cabinet

x Time of Sowing in Field

TC 15/7 - Tallarook sown in cabinet 15th July, field 12th August

TF 12/8 - Tallarook sown directly in field 12th August

WC 15/7 - Woogenellup sown in cabinet 15th July, field 9th September

WC 12/8 - Woogenellup sown in cabinet 12th August, field 9th September

WF 9/9 - Woogenellup sown directly in field 9th September

<u>Figure 5</u>. Spaced Plant Trial Sowing Times.

The flowering date for each treatment was taken when two plants in each replicate had produced open flowers. To obtain an accurate count of all runners and inflorescences produced, harvesting commenced on 20th February when all treatments had just started to senesce but could be handled easily without disintegrating. The plants were removed by severing the taproot just below ground level and, starting at the base of the main axis all primary runners were removed. For each primary runner the total number of secondary, tertiary and quaternary runners was recorded together with the total number of inflorescences produced.

III. RESULTS

Following an analysis of variance, Duncan's Multiple Range Tests were carried out on the results. Treatment means and analysis of the number of inflorescences and runners together with the time of commencement of flowering for the different treatments are presented in Table 34.

There was very little difference between treatments in flowering time and only 10 days separated the time of flowering of WC 15/7, the earliest flowering treatment and TC 15/7 the latest flowering.

With each cultivar, increasing the amount of vegetative growth prior to the commencement of flowering

Table 34. Mean Flowering Date. Number of Runners and Inflorescences - Spaced Plant Trial.

Treatment	Time of Flowering	Mean No. Runners/Plant					No. Inflorescences / Plant
		Primary	Secondary	Tertiary	Quaternary	Total	
WF 9/9	20/11	11.5 d	25.8 d	18.9 d	0 c	56.2	415 e
WC 12/8	20/11	16.3 b	74.6 b	60.3 b	8.6 b	159.8	1296 c
WC 15/7	17/11	20.8 a	82.6 a	65.5 b	6.8 b	175.6	1436 b
TF 12/8	23/11	14.4 c	35.5 c	33.8 c	6.2 b	89.9	830 d
TC 15/7	27/11	15.6 b	81.1 a	110.8 a	37.8 a	245.3	1713 a
S.E. Mean	-	±0.3	±1.7	±2.0	±0.9	±3.6	±33
C.V. %	-	5	8	9	19	7	8

gave rise to large and significant increases in subsequent runner and inflorescence production. This increase occurred in all components of the total runner production except for the quaternary runner fraction of Woogenellup where there was no significant difference between the WC 12/8 and WC 15/7 treatments.

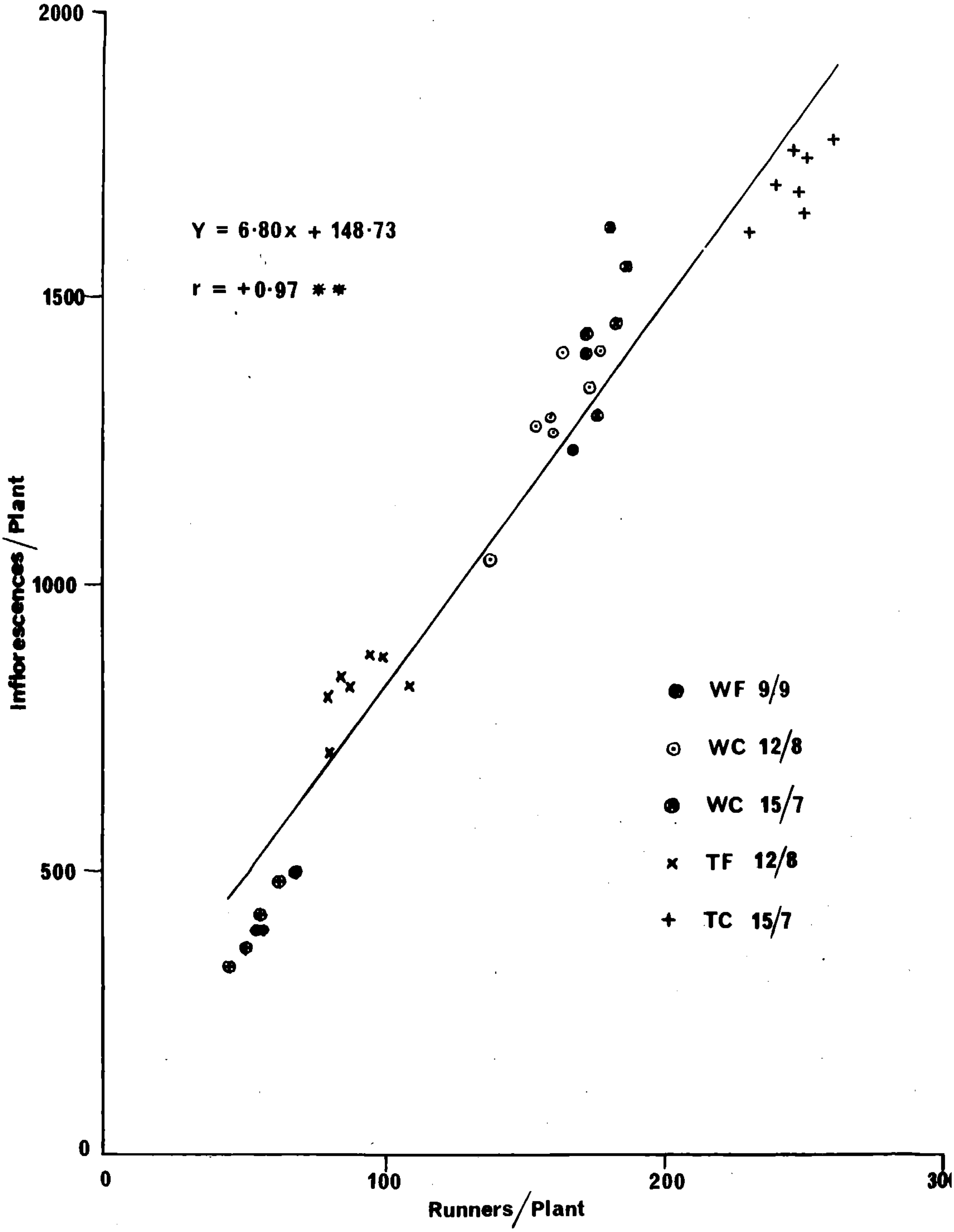
Whereas Woogenellup gave almost linear increases in runner production with increasing vegetative growth, the increase in the number of primary runners of Tallarook was only small, although still significant. However in Tallarook the pretreatment gave very large and significant increases in the number of secondary, tertiary and quaternary runners.

There was a highly significant positive correlation ($r = +0.973$, $p = 0.01$) between the number of inflorescences and the number of runners per plant. Both cultivars appeared to lie on the same regression line (Figure 6).

IV. DISCUSSION

Because there were only minor differences in the flowering times of the different treatments, and all treatments were flowering under identical climatic conditions in the field, it can probably be safely assumed that the differences in runner and inflorescence production were due very largely to differences in the degree

FIGURE 6. The Relationship between the number of Runners and Inflorescences/Plant for Spaced Plants.



of vegetative growth which occurred prior to the commencement of flowering. As expected, increasing the amount of vegetative growth prior to the commencement of flowering gave rise to significant increases in runner and inflorescence production for both cultivars. The similarities in flowering times also suggest that within one cultivar the pretreatments in the growth cabinets at high temperatures and short photoperiods had little or no effect on the physiological responses of the plants to the flowering stimuli received subsequently in the field.

Because the initiation of primary runners is inhibited following flowering of the main axis (Aitken and Drake, 1941), on any laterals produced runner production is probably also inhibited by flowering at the apex of the lateral. Observations at the time of dissecting the plants suggested that this was the case. Total runner production is therefore determined prior to the commencement of flowering and depends on the amount of vegetative growth which occurs at this time.

The practical implications of runner and inflorescence production for seed yields are discussed further in the General Discussion.

CHAPTER V

GENERAL DISCUSSION

From the field trials carried out no general recommendations can be made as to the subterranean clover cultivar most climatically adapted to Canterbury conditions. The opposite trends with time of flowering in both D.M. and seed yields between the two trial sites suggest that the choice of the most suitable cultivar will vary according to the climatic conditions particularly spring rainfall. At Waikari where spring conditions were abnormally dry highest D.M. yields were given by the early mid-season cultivars Woogenellup and Clare, although the highest seed yields were produced by the earliest flowering cultivar Geraldton and seed yields tended to decline with increasing lateness of flowering. At Pukaki where spring conditions were more favourable and prolonged both D.M. and seed yields increased with increasing lateness of flowering so that at this site Mt. Barker and Tallarook produced the highest D.M. and seed yields.

The field trials described are subject to three limitations:

1. The trials were carried out for only one growing season. It seems highly likely that in the evaluation of annuals like subterranean clover where both seed production and subsequent re-establishment are subject to the vagaries of climate, more long-term trials such as those described by Rossiter (1966) are desirable. The most productive cultivar will probably vary not only according to the particular site but also according to the particular season. It may be that a mixture of two or more cultivars should be sown. For example at Waikari, Woogenellup would probably produce well and persist in all seasons although the ability of a later flowering cultivar to continue production later into the growing season in wet years may also be useful.

The apparent poor seed dormancy of Woogenellup and Mt. Barker at Waikari together with the deleterious effects which invasion by danthonia (Notodanthonia spp.) following the buildup of soil nitrogen levels could exert on subsequent nodulation and growth at this site (Janson, pers. comm.) also requires more long term trial work.

2. At Waikari the trial site was located on a sunny face. Although this gave more winter growth than would probably occur on the Canterbury Plains (Rickard, 1968) it also dried out very rapidly in the spring.

3. The trials were carried out under a cutting regime.

For practical purposes cultivar evaluations of this kind should be carried out under grazing. Although the severe infrequent defoliation regime imposed would tend to favour Geraldton and Tallarook (Black, 1963) several questions still remain unanswered. Firstly, it seems highly likely that animal returns of dung and urine should increase winter and early spring growth when the rate of nitrogen fixation is limited by low temperatures. Secondly trampling and close grazing could have some deleterious effects on the more erect growing cultivars Yarloop, Clare and perhaps Woogenellup. In this regard the significant reduction in the seed yield of Clare following cutting (Table 8) obviously requires further study. Because Clare commenced internode elongation much earlier than expected from its flowering time, and cutting gave a significant reduction in seed yield one would hesitate to recommend widespread sowings of this cultivar at present, even although it was the highest producing cultivar at Waikari.

Increasing inflorescence production with increasing lateness of flowering under favourable conditions is attributable to late flowering cultivars flowering at a higher node of first flower and therefore producing more runners which are also more branched than early cultivars (Aitken, 1955a; Aitken and Drake, 1941). It is evident that, within certain limits, the higher the number of runners per unit area of sward (runner density) the higher will be the potential inflorescence and seed production. Although this fact is probably appreciated by overseas workers in this field some of its practical implications do not seem to have been fully explored. Being an annual, the production and persistence of subterranean clover depends on a high seed yield so that the aim in the establishment year of a subterranean clover sward should be to produce a heavy seed crop. For this to be achieved a large number of inflorescences must be produced, and it would appear that for this to occur a high runner density is an essential pre-requisite. There are perhaps two ways of increasing the runner density in the establishment year.

1. Sowing Rate. There is ample evidence to show that increasing sowing rates up to about 40 lb/acre in the establishment year result in increased inflorescence and seed production (Donald, 1954; Yates, 1961; Taylor and Rossiter, 1967b). However, it must be emphasized that this relationship only holds for sowing rates of up to about 40 lb/acre and when reasonably favourable growing conditions prevail during the flowering period. At sowing rates above this level the number of inflorescences formed may actually decline, especially in the late

flowering cultivars (Donald, 1954; Yates, 1961). Donald (1954) suggested that the decline in inflorescence production at very high plant densities was due to intense interplant competition.

It is the author's opinion that this increase in inflorescence production following increases in sowing rate in the establishment year is due primarily to an increase in runner density. The need for further research on this topic together with the effect of defoliation is clearly indicated to show whether sowing rates above the commonly recommended 2 - 4 lb/acre would give worthwhile increases in seed yield. The work already carried out on this topic (Donald, 1954; Taylor and Rossiter, 1967b; Yates, 1961) has not included a wide enough range of sowing rates that are economically feasible.

2. Time of Sowing. In regions with a strictly Mediterranean rainfall pattern, the time of sowing is simple to determine, and coincides with the opening autumn rains (Morley, 1961). The rainfall pattern in those areas of New Zealand where subterranean clover is likely to prove useful is not strictly Mediterranean in distribution (e.g. Table 1). Heavy summer rains may occur and the autumn "flush" of growth may commence as early as late February - early March. Aitken and Drake (1941) have shown that early sowings at such times as compared with late

sowings in early June produce plants that flower at a higher node. Compared with late-sown plants, such plants therefore produce more primary runners and, furthermore, the N.F. on these primary runners is also higher so that they show more lateral branching. The highly significant positive correlation (r = +0.973, p = 0.01) between the number of inflorescences and number of runners found in the spaced plant trial suggests that early-sown plants should also produce more inflorescences. Rossiter (1959) has emphasized the limitations of extrapolating the results of spaced plants to sward conditions. However the highly significant positive correlation (r = +0.833, p = 0.01) found between runner density and burr numbers from the swards at Pukaki indicates that although the effects of competition may considerably reduce the extent of runner formation per plant in swards, the effects of a high N.F. on runner formation should still be present in the establishment year when plant density is low. Early sowings should therefore give an increase in runner density with a consequent increase in inflorescence and seed production provided climatic conditions are favourable.

The effect of time of sowing on inflorescence and seed production in swards of subterranean clover therefore requires more study, particularly under New Zealand conditions. Early sowing may have distinct advantages when subterrranean clover is sown into cultivated seed-beds containing adequate soil moisture from a summer fallow. This practice would tend to make establishment less subject to the vagaries of dry autumn conditions.

The trend on highly improved light land in Canterbury has been away from subterranean clover into an all lucerne system (Stewart, pers. comm.), but subterranean clover will probably continue to play an important role in the pioneer stages of development of light land for lucerne. It is suggested that the use of a "falcata" type lucerne together with an early flowering subterranean clover cultivar may be a more useful sward on light land than pure lucerne. Such a sward containing two plants with almost reciprocal growth patterns should give more even seasonal production than pure lucerne.

Subterranean clover, particularly the Woogenellup cultivar, would appear to be the most suitable legume for sowing on dry sunny faces in Canterbury, Marlborough and the drier eastern areas of the North Island, where steep topography or acid soil conditions limit the feasibility of establishing lucerne or where severe summer droughts limit the persistence of shallow rooted perennial legumes such as white clover.

CHAPTER VI

SUMMARY

The subterranean clover cultivars Geraldton, Yarloop, Woogenellup, Clare, Mt. Barker and Tallarook were evaluated under cutting in swards at two sites in Canterbury. At Waikari where very dry spring conditions were experienced Woogenellup and Clare produced more than 7000 lb. D.M./acre. This exceeded the production of all other cultivars by at least 2000 lb. D.M./acre. Woogenellup and Clare also contained significantly less weeds than the other cultivars at this site. At Pukaki where spring conditions were more favourable and prolonged highest D.M. yields were produced by Mt. Barker and Tallarook.

At Waikari highest seed yields were produced by Geraldton and seed yields tended to decline with increasing lateness of flowering. An opposite trend in seed yields was evident at Pukaki where burr production was highly correlated with runner production. From this correlation and meteorological data it is suggested that the deleterious effects of frosts in reducing the seed yields of subterranean clover may have been overemphasized

in the past. Supplementary data from a spaced plant trial also demonstrated the influence of runner formation on inflorescence production. The practical implications of the findings on runner production for seed yield are discussed.

From the available evidence it is suggested that the Woogenellup cultivar could profitably be used instead of Mt. Barker in many situations although the serious limitations of the trials are emphasized. It is also suggested that the reciprocal growth patterns of an early flowering subterranean clover cultivar and a "falcata" type lucerne could be usefully exploited by combining the two species in a mixture.

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APPENDICES

APPENDIX A

Waikari Plant Density (No. Plants/6 in. square Quadrat)

Geraldton

Block No. / Sample No.	1	2	3	4	5
1	5	21	16	14	6
2	10	14	9	2	5
3	3	20	19	18	14
4	3	11	20	5	3
5	6	24	3	20	8
6	26	2	6	11	10
7	8	12	10	16	19
8	15	2	26	2	18
Plants/ft.^{2}	38	53	54.5	44	41.5

Yarloop

Block No. / Sample No.	1	2	3	4	5
1	13	15	2	3	10
2	5	5	21	10	3
3	1	6	1	10	8
4	3	2	2	4	19
5	6	1	2	5	4
6	2	7	3	3	6
7	8	3	2	6	4
8	5	4	9	11	7
Plants/ft.^{2}	21.5	26.5	21	26	30.5

Woogenellup

Block No. / Sample No.	1	2	3	4	5
1	8	14	5	5	8
2	16	6	2	2	15
3	22	8	10	5	2
4	2	10	8	6	4
5	6	11	8	16	19
6	2	6	11	5	7
7	12	10	6	12	4
8	11	11	8	6	4
Plants/ft.^{2}	39.5	38	29	28.5	31.5

Clare

Block No. / Sample No.	1	2	3	4	5
1	9	13	16	11	6
2	1	6	6	16	5
3	15	6	8	3	26
4	24	13	11	5	8
5	19	8	6	7	6
6	2	2	2	18	16
7	7	14	10	11	20
8	4	16	9	13	9
Plants/ft.^{2}	40.5	39	34	42	48

Mt. Barker

Block No. / Sample No.	1	2	3	4	5
1	5	8	3	6	2
2	6	2	16	6	9
3	4	30	5	17	13
4	24	6	15	20	16
5	4	2	14	32	5
6	14	10	15	9	4
7	4	10	3	2	7
8	8	7	6	7	24
Plants/ft.^{2}	34.5	37.5	38.5	49.5	40

Tallarook

Block No. / Sample No.	1	2	3	4	5
1	11	13	6	10	11
2	9	27	10	9	8
3	7	3	2	12	8
4	5	2	20	8	9
5	7	2	4	6	3
6	7	4	8	7	5
7	16	5	8	2	7
8	16	6	4	16	11
Plants/ft.^{2}	39	31	31	35	31

APPENDIX B

Pukaki Plant Density (No. Plants 6 in. Square Quadrat)

Geraldton

Sample No. \ Block No.	1	2	3	4	5
1	9	12	10	11	14
2	10	23	18	18	21
3	13	10	2	8	5
4	12	14	9	8	14
5	22	6	9	8	23
6	2	4	8	5	11
7	8	29	14	14	19
8	10	18	10	10	10
Plants/ft.^{2}	43	58	40	41	58.5

Yarloop

Sample No. \ Block No.	1	2	3	4	5
1	20	4	8	12	4
2	10	3	4	6	4
3	7	8	8	7	2
4	2	12	2	4	6
5	2	8	7	4	5
6	3	5	3	6	3
7	18	6	13	4	12
8	3	12	3	3	6
Plants/ft.^{2}	32.5	29	24	23	21

Woogenellup

Block No. / Sample No.	1	2	3	4	5
1	15	19	16	7	12
2	6	6	12	15	10
3	12	24	12	8	7
4	3	5	6	14	17
5	8	8	7	13	19
6	12	18	16	4	7
7	10	18	14	6	22
8	2	6	10	14	4
Plants/ft.^{2}	34	52	46.5	40.5	49

Clare

Block No. / Sample No.	1	2	3	4	5
1	14	19	6	7	3
2	11	20	6	5	26
3	6	14	10	18	6
4	12	12	9	20	5
5	4	4	12	7	21
6	9	20	12	7	9
7	10	5	7	10	11
8	4	8	16	13	13
Plants/ft.^{2}	35	51	39	43.5	47

Mt. Barker

Block No. / Sample No.	1	2	3	4	5
1	12	6	6	17	18
2	4	13	9	8	10
3	12	7	12	12	8
4	14	5	11	8	19
5	16	26	20	10	8
6	5	6	9	17	14
7	9	18	7	14	24
8	8	13	7	11	6
Plants/ft.^{2}	40	47	40.5	48.5	53.5

Tallarook

Block No. / Sample No.	1	2	3	4	5
1	6	5	4	4	9
2	6	7	3	6	6
3	10	5	11	5	6
4	3	13	2	12	16
5	7	2	12	9	18
6	17	6	6	13	2
7	7	14	11	4	14
8	8	4	2	9	10
Plants/ft.^{2}	32	33	25.5	31	40.5

APPENDIX C

Plant Survival (No. Plants/ft.^{2}) at Pukaki in Quadrats Thinned to 24 Plants/ft.^{2}

Replicate \ Cultivar	Geraldton	Yarloop	Woogenellup	Clare	Mt. Barker	Tallarook
1	14 1	24 22	18 15	19 19	14 18	20 18
2	24 17	22 19	16 19	21 22	23 20	23 24
3	24 21	16 15	17 19	12 12	24 24	24 24
4	24 24	16 21	15 15	20 18	24 24	24 24
5	22 22	20 24	23 23	18 21	23 21	22 24